

ORIGINAL ACRST-3110

**OFFICIAL TRANSCRIPT OF PROCEEDINGS  
NUCLEAR REGULATORY COMMISSION  
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS**

**Title: MEETING: THERMAL-HYDRAULIC  
PHENOMENA**

**Docket No.:**

TRO4 (ACRS)  
RETURN ORIGINAL  
TO BJWHITE  
M/S T-2E26  
415-7130  
THANKS!

**Work Order No.: ASB-300-1184**

**LOCATION: Rockville, MD**

**DATE: Wednesday, March 15, 2000**

**PAGES: 1 - 268**

**ANN RILEY & ASSOCIATES, LTD.  
1025 Connecticut Ave., NW, Suite 1014  
Washington, D.C. 20036  
(202) 842-0034**

*ACRS Office Copy - Retain  
for the Life of the Committee*

DISCLAIMER

UNITED STATES NUCLEAR REGULATORY COMMISSION'S  
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

MARCH 15, 2000

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards, taken on March 15, 2000, as reported herein, is a record of the discussions recorded at the meeting held on the above date.

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

1 UNITED STATES OF AMERICA  
2 NUCLEAR REGULATORY COMMISSION  
3 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

4 \*\*\*

5 MEETING: THERMAL-HYDRAULIC PHENOMENA  
6

7 USNRC

8 Two White Flint North, Rm. T2-B3

9 11545 Rockville Pike

10 Rockville, Maryland

11 Wednesday, March 15, 2000

12 The subcommittee met pursuant to notice, at 8:30

13 a.m.

14 MEMBERS PRESENT:

15 GRAHAM B. WALLIS, Chairman, ACRS

16 THOMAS S. KRESS, Member, ACRS

17 DANA POWERS, Member, ACRS

18 WILLIAM SHACK, Member, ACRS

19 JOHN SIEBER, Member, ACRS

20 CONSULTANTS PRESENT:

21 VIRGIL SCHROCK

22 NOVAK ZUBER

23 COGNIZANT ACRS STAFF ENGINEER:

24 PAUL BOEHNERT  
25

ANN RILEY & ASSOCIATES, LTD.  
Court Reporters  
1025 Connecticut Avenue, NW, Suite 1014  
Washington, D.C. 20036  
(202) 842-0034

## C O N T E N T S

| PAGE | ITEM                                  |     |
|------|---------------------------------------|-----|
| 3    | Introduction                          | 3   |
| 4    | Status of RETRAN-3D Code Review       | 4   |
| 5    | NRR T/H Code Acceptance Reviews       |     |
| 6    | Siemens Power Co. SRELAP-5            | 63  |
| 7    | GE Nuclear Energy TRACG               | 93  |
| 8    | Pressurized Thermal Shock Rule Review | 126 |
| 9    | Scaling of PTS Experiments            | 202 |
| 10   |                                       |     |
| 11   |                                       |     |
| 12   |                                       |     |
| 13   |                                       |     |
| 14   |                                       |     |
| 15   |                                       |     |
| 16   |                                       |     |
| 17   |                                       |     |
| 18   |                                       |     |
| 19   |                                       |     |
| 20   |                                       |     |
| 21   |                                       |     |
| 22   |                                       |     |
| 23   |                                       |     |
| 24   |                                       |     |
| 25   |                                       |     |

ANN RILEY & ASSOCIATES, LTD.  
Court Reporters  
1025 Connecticut Avenue, NW, Suite 1014  
Washington, D.C. 20036  
(202) 842-0034

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

1  
2 MR. WALLIS: The meeting will now come to order.  
3 Today is the Ides of March, March 15, 2000.

4 MR. POWERS: Is that serious if you're a Roman?

5 MR. BOEHNERT: Yes, Julius Caesar.

6 MR. WALLIS: Well, it's serious for us today. We  
7 have serious business as usual.

8 MR. POWERS: Oh, yes.

9 MR. WALLIS: This is a meeting of the ACRS  
10 subcommittee on thermal-hydraulic phenomena, and I am Graham  
11 Wallis, the chairman of the subcommittee. ACRS members in  
12 attendance are Thomas Kress, Jack Sieber and Dana Powers.  
13 ACRS consultants are Virgil Schrock and Novak Zuber.

14 The purpose of this meeting is to begin review of  
15 the thermal-hydraulic issues associated with the pressurized  
16 thermal shock screening criteria and reevaluation project  
17 being conducted by the NRC Office of Nuclear Regulatory  
18 Research; also, to discuss the status of the NRC staff  
19 acceptance review of the Siemens-S RELAP 5 and GE Nuclear  
20 Energy TRACG Codes; and furthermore to discuss the status of  
21 the NRC staff's review of the EPRI RETRAN-3D code.

22 The subcommittee will gather information, analyze  
23 relevant issues and facts; ask many questions; and formulate  
24 proposed positions and actions as appropriate for  
25 deliberation by the full committee. Paul Boehnert is the

1 cognizant ACRS staff engineer for this meeting. The rules  
2 for participation in today's meeting have been announced as  
3 part of the notice of this meeting, previously published in  
4 the Federal Register on February 25 and March 7, 2000. A  
5 transcript of the meeting is being kept and will be made  
6 available as stated in the Federal Register notice. It is  
7 requested that speakers first identify themselves and speak  
8 with sufficient clarity and volume so that they can be  
9 readily heard.

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

12 We're now ready to begin, and I will call on Sir  
13 Ralph Landry from the Office of Nuclear Reactor Regulation  
14 to begin. Good morning, Ralph.

15 MR. LANDRY: Okay; good morning. I'm Ralph Landry  
16 from NRR, reactor systems branch, and have the lead on the  
17 review of the thermal-hydraulic codes. This morning, we're  
18 going to talk about the codes in the order in which we have  
19 received them for our review; that is, we will talk about  
20 RETRAN 3D for a little while; then, we'll talk about the  
21 Siemens S-RELAP code, and then, we'll talk about TRACG.

22 What I'm going to talk about is the status of the  
23 review of RETRAN-3D and the status of the review of RELAP5,  
24 S-RELAP5 and the status of the TRACG review. The package  
25 which you have been given has all of the slides for this

1 morning. That they will not be gone through in one complete  
2 stream; we'll break after the RETRAN-3D discussion, because  
3 Greg Swindlehurst would like to say a few words on behalf of  
4 the RETRAN maintenance group. Then, we'll take up the topic  
5 of S-RELAP5, stop, and Siemens would like to say some words  
6 about the Siemens S-RELAP5 code. Then, we'll take up TRACG,  
7 and I believe Jens Andersen will be speaking on behalf of  
8 General Electric for TRACG.

9 MR. WALLIS: Ralph, these are very summary  
10 presentations. We have a very short presentation on each  
11 code, I notice, so we don't really have time to go into  
12 details.

13 MR. LANDRY: That is correct. We were not  
14 planning on going into a great deal of detail on these. The  
15 slides which I have prepared for the RETRAN-3D code are  
16 rather extensive, and I don't plan to go through all of  
17 those slides. What I would like to do is just hit some of  
18 the high points.

19 The slides were put together to document really  
20 where all of the problems are that we see with the code as  
21 of last December and to have it on record what we've done,  
22 where we stand. At this point, we've stopped the review  
23 while we've been waiting for material to come from RETRAN  
24 maintenance group. In documentation of RETRAN-3D and the  
25 code itself were submitted for our review. I've prepared a

1 timeline which gives an overview of all of the events which  
2 have gone forth on the review of RETRAN-3D. We're going to  
3 talk a little bit about some of the code problem areas.  
4 Currently, the review, as I said, is on hold because we have  
5 been waiting for material and further guidance from the  
6 RETRAN maintenance group.

7 Additional material was supposed to have been sent  
8 to us on March 6, 2000. That material just arrived last  
9 night, so we haven't had a chance to look at the material  
10 yet to determine its adequacy, its completion of our  
11 concerns with the code.

12 Briefly, the timeline for the RETRAN-3D review:  
13 in September of 1988 -- 1998, RETRAN-3D was submitted for  
14 the staff's review. We've met with the committee a number  
15 of times. We parted out in RAIs, two rounds of RAIs where  
16 there were a number of problems with the code. We've had  
17 continual discussions with the code owner, EPRI; with their  
18 contractor and with the RETRAN maintenance group about these  
19 problems. We've pointed out repeatedly that a real big  
20 problem is in the -- in the assessment of the code, and  
21 we've been very disappointed in the response to our concern  
22 with the code assessment. When we pointed that out last  
23 April, and in phone conversations with the group, the  
24 response was to send in to us documents dated 1986 and 1988  
25 as supposedly supporting the assessment of the code.

ANN RILEY & ASSOCIATES, LTD.  
Court Reporters  
1025 Connecticut Avenue, NW, Suite 1014  
Washington, D.C. 20036  
(202) 842-0034

1           Our response was these are not even pertaining to  
2 the code we're looking at. These are generations old, and  
3 in our opinion, they do not reflect this code at all and are  
4 not at all applicable. We've met with the subcommittee and  
5 pointed out that there is a five-equation flow field model  
6 which is being reformulated. We have gotten that  
7 information. We learned in reviewing some conference papers  
8 that EPRI new about that reformulation prior to even  
9 submitting the code to us, so the code which we received for  
10 review was not the code that was intended for distribution.

11           Dr. Wallis pointed out in the presentation to the  
12 ACRS a year ago or last July, almost a year ago, that there  
13 were severe problems with the momentum equation as  
14 formulated in the documentation. That conversation has  
15 resulted in a great deal of additional documentation which  
16 we are starting to review again. We've taken part in the  
17 RETRAN-3D training course that is offered to the industry.  
18 We've come away from that course with an understanding of  
19 the quality of the training that is offered and quite  
20 satisfied with that quality of training, but again, that  
21 pointed out to us some of our concerns and some of the needs  
22 for user guidelines for this code.

23           We've looked at the 3D kinetics. The 3D part of  
24 the RETRAN title refers to kinetics, not to  
25 thermal-hydraulics. The staff assessed the 3D kinetics part

1 of this code. We instructed EPRI on what to do in the way  
2 of providing us further assessment on their part. We've  
3 even gone so far as to provide the data for that assessment  
4 and to even provide the cross-sections for the use of EPRI  
5 in performing those assessments.

6 As I said, the code version which we had been  
7 reviewing is not the code version which is intended for  
8 distribution. There is additional information on the 3D  
9 kinetics.

10 MR. ZUBER: Pardon me; on your review of that, the  
11 review, was this intended for distribution or not?

12 MR. LANDRY: That's what I'm talking about right  
13 now, Novak, that the version that we were reviewing was not  
14 the version --

15 MR. ZUBER: The reviewers.

16 MR. LANDRY: That's the same version.

17 MR. ZUBER: And that is not for distribution.

18 MR. LANDRY: Correct; the version that's now being  
19 finished for distribution has different 3D kinetics in it  
20 and has a different five-field, five-equation flow field  
21 model.

22 MR. ZUBER: This is unbelievable.

23 MR. LANDRY: This material we have right now, the  
24 kinetics material, I believe, was just submitted last  
25 Monday. We haven't had a chance to look at it yet.

1 MR. SCHROCK: You don't expect any change.

2 MR. LANDRY: I can't say, Professor Schrock. I  
3 haven't even looked at it.

4 Our question at this point has been what are we  
5 reviewing when we write a safety evaluation based on this  
6 experience? We are going to be very specific in our safety  
7 evaluation. We are going to specify the exact version of  
8 the code we reviewed, and the safety evaluation will apply  
9 only to that version. It cannot be extended to any other  
10 version of the code. Any other version is a different code,  
11 as far as we are concerned.

12 MR. WALLIS: Do you also check what's in the  
13 computer version of the code is the same as is described in  
14 the documentation?

15 MR. LANDRY: We haven't been going through the  
16 source code line-by-line to see.

17 MR. WALLIS: Not only in the -- what's submitted  
18 for review being different from what's distributed, but  
19 what's actually distributed as a code may be different from  
20 what's in the documentation.

21 MR. LANDRY: We've been assuming that the source  
22 code which we received is the same as the source code that's  
23 referred to in the documentation. We do not do -- we don't  
24 have the staff to do line-by-line checking of source code.

25 MR. WALLIS: Because I remember when I was looking

1 at the documentation, I couldn't quite figure out what this  
2 meant, as you might recall. For some reason, I couldn't  
3 figure out what they meant. The only way I could figure out  
4 what they meant would be to see how they are applied. To do  
5 that, you almost have to look at the actual computer code.

6 MR. LANDRY: We have not been doing that, Dr.  
7 Wallis.

8 MR. ZUBER: Did they tell you at least what is the  
9 difference between the code you reviewed and the one which  
10 was intended for distribution?

11 MR. LANDRY: That is why, Dr. Zuber, I said that  
12 we are going to be very specific in our safety evaluation in  
13 calling out the exact version of the code which we reviewed  
14 and are writing about in our safety evaluation, so that  
15 anybody who picks up a different version of the code and  
16 picks up the safety evaluation should immediately have a red  
17 flag raised that if their version is not the version that we  
18 are writing about, because that is not the version that  
19 we're approving.

20 MR. ZUBER: That is really not a safe approach,  
21 because you leave the door open to somebody to violate and  
22 play games.

23 MR. LANDRY: Well, when I get down later in the  
24 presentation, I'll talk about the user guidelines; the need  
25 for documentation from the user of the code, but we plan on

1 covering that.

2 MR. ZUBER: Yes, okay.

3 MR. KRESS: Ralph, what do you mean the code being  
4 distributed? What's the implications of that? Distributed  
5 to who, by who, for what?

6 MR. LANDRY: The code being distributed to the  
7 user community.

8 MR. KRESS: Well, how do they distribute it? Do  
9 they just send copies for review and comment or for use?

10 MR. LANDRY: No, for their use.

11 MR. KRESS: For their use?

12 MR. LANDRY: The members of the maintenance group,  
13 the members of the RETRAN community obtain from EPRI a  
14 particular version of the code.

15 MR. KRESS: And that's the one that's supposedly  
16 been fixed?

17 MR. LANDRY: That's our understanding.

18 MR. KRESS: Okay; but you didn't -- you've  
19 reviewed -- so far, you've reviewed the one that wasn't  
20 fixed.

21 MR. LANDRY: Correct.

22 MR. KRESS: Okay.

23 MR. LANDRY: We have now received the RETRAN-3D  
24 mod 3 code itself.

25 MR. KRESS: That's the one that's being

1 distributed?

2 MR. LANDRY: From what we've been told, that is  
3 supposed to be the one that's being distributed. In fact --

4 MR. KRESS: The answer to your question what's to  
5 be reviewed is that one, right? If that's the one they  
6 intend to use.

7 MR. LANDRY: This whole discussion points out the  
8 concern which we've raised and have pointed out in the plans  
9 for the reg guide and for a standard review plan, that when  
10 a code is submitted to us for review, it has to be a frozen  
11 version of the code; that we cannot review developmental  
12 versions, because the code that we're reviewing is supposed  
13 to be the code that is going to be used. This experience  
14 has pointed that out very clearly to us, that we have to be  
15 very specific that what we review is a frozen version of the  
16 code, and that is a pointed question we've asked each of the  
17 next two vendors which we'll be discussing this morning in  
18 their meetings with us: is this the frozen version of the  
19 code, that we will not review a moving target again.

20 [Pause.]

21 MR. SCHROCK: Just the implication that you've  
22 accepted this new version for review or that you may look at  
23 it to see if it's acceptable for review?

24 MR. LANDRY: We had so many problems with what we  
25 were reviewing that we really have to look at these new

1 models.

2 MR. SCHROCK: I understand that, but what I'm  
3 searching for is the status of the understanding with EPRI  
4 with regard to this new version that you've just received.  
5 Do they think that you've accepted it for review?

6 MR. LANDRY: At this point, the whole review has  
7 been placed on hold until we get the latest information, and  
8 we will be talking with Mr. Swindlehurst later to find out  
9 what the guidance is. Are we to now to pick up the review  
10 and continue where we left off? So, that's the best I can  
11 answer your question.

12 MR. KRESS: Do you have a definition of what you  
13 mean by frozen code?

14 MR. LANDRY: Generally, what we mean by frozen  
15 code is the code that is going to be used for production  
16 calculations; that this is not a code which is known to have  
17 significant errors and is known to be under further  
18 development.

19 MR. KRESS: But you will allow some changes in it?

20 MR. LANDRY: Yes; we have to allow some changes.  
21 If errors are found --

22 MR. KRESS: Yes; I was just wondering if you had a  
23 firm enough definition that people could look at and say  
24 yes, this is a frozen code, even though they're working on  
25 it and making minor changes.

1 MR. LANDRY: We've always allowed changes in  
2 codes. That has been within the requirements of 50.46, that  
3 when errors are found in a code, they are corrected. We've  
4 used that same philosophy, that when errors are found in the  
5 code, of course, we expect them to be corrected.

6 MR. KRESS: Well, when you make a rule or  
7 something that says for us to review this code, it has to be  
8 frozen, my concern is you have a firm definition for what  
9 frozen means.

10 MR. LANDRY: Yes; it's the code that's being used  
11 for production calculations.

12 MR. KRESS: That's the definition?

13 MR. LANDRY: A code which is undergoing major  
14 revision, such as when we began the review of RETRAN-3D, the  
15 code was submitted to us, and we learned that even before  
16 the code was submitted, it was known that the five-equation  
17 flow field model was wrong, and that was being further  
18 worked on and further developed at the time the code was  
19 submitted. That is a major change in the code. That means  
20 that the code is really in a developmental stage at the  
21 point at which it's submitted and is known to not be frozen.

22 MR. KRESS: But I was wondering if frozen has  
23 other attributes like what sort of experimental validation  
24 it has behind it.

25 MR. LANDRY: That gets on further into --

1 MR. KRESS: That shows up somewhere else, I guess.

2 MR. LANDRY: That gets into the discussion further  
3 down the road.

4 MR. KRESS: Okay.

5 MR. ZUBER: But this is essentially the definition  
6 of the frozen code.

7 MR. LANDRY: It has been assessed.

8 MR. ZUBER: It has been not only assessed; it has  
9 been documented. There are assessment reports available, so  
10 you have a whole package --

11 MR. LANDRY: Correct.

12 MR. ZUBER: -- on which to make a judgment.

13 MR. LANDRY: Right, that this is the code that's  
14 going to be used for production work.

15 MR. ZUBER: But the test will give an assessment.

16 MR. LANDRY: It should have an assessment. It  
17 should have a quality control program. It should have a  
18 configuration control program, that this program is under  
19 configuration control; it cannot be altered without going  
20 through a long series of steps. These are all factors that  
21 go into a frozen code.

22 [Pause.]

23 MR. LANDRY: Let me jump ahead to the --

24 MR. WALLIS: What about number seven, which I  
25 don't have?

1 MR. LANDRY: That's because we decided to skip  
2 that for now, because that's in new material that we got,  
3 and I want to take time to look at the material.

4 MR. WALLIS: I see; so, you're not ready to  
5 discuss it at this time.

6 MR. LANDRY: Right, right.

7 As I said, we pointed out in the first round of  
8 REIs on this code that there was a very great problem with  
9 the assessment. The assessment did not appear to us to be  
10 complete. We find this out in telecons. We pointed out  
11 that new models were added, five-equation and assessments  
12 had not been done. The assessments were not rerun on those  
13 new models. Our conclusion at this point is that the  
14 individual user will be required to fully assess the code  
15 for each application, that based on the assessment which is  
16 contained in the materials we have, each user is going to  
17 have assess the code every time they use it.

18 MR. WALLIS: Let me go back to where we were on  
19 this -- in our discussions earlier, and it seems to me that  
20 you've assessed this not only for its applicability to  
21 nuclear transients, but you accept this as a document which  
22 gives credibility to the whole process in the technical  
23 community.

24 MR. LANDRY: Right.

25 MR. WALLIS: And if you approve a document, then

1 that community can see it; although the results seem to be  
2 okay, there are parts of the rationale which don't make any  
3 sense, let us say. It appears that way in parts of the  
4 technical community. The fact that it seems to work on  
5 nuclear transients is not really good enough as an  
6 explanation, it seems to me, and I'm not sure that the REI  
7 process fixes some of those basic problems of would this be  
8 acceptable on a whole work solution type of question.

9 MR. LANDRY: Yes.

10 MR. WALLIS: Do your REIs actually require that  
11 that basic rationale be also rewritten?

12 MR. LANDRY: Well, the purpose of the REI is to  
13 point out to the applicant where there are problems with the  
14 material that has been submitted. Now, in responding to the  
15 REI, the applicant should explain why what they have done is  
16 correct and acceptable or, if it has an inherent flaw, they  
17 should explain how they're going to fix and go back and fix  
18 their documentation to adequately explain the phenomenon  
19 you're talking about.

20 MR. ZUBER: See, now, my problem in treating this  
21 is it's a more or less -- and it's just like we're producing  
22 more paper, more noise. There is no signal in this -- I  
23 mean, seriously; pure almost white noise. It's essentially  
24 loading you and whoever reads it in more papers, and you  
25 really cannot make sense out of it, and I think that what

1 Graham said is really important. You have to have something  
2 which can be defended in the technical community. These  
3 REIs are really just obfuscation. That's the best thing I  
4 could describe it.

5 MR. WALLIS: Well, you could say they're papering  
6 over.

7 MR. ZUBER: Well, papering over, under, whatever  
8 it is, but it's really not in the -- at least I wouldn't be  
9 able to explain and defend if I said this is going -- I  
10 could not do it, and I think this is important when you  
11 think about it.

12 MR. LANDRY: Ralph Caruso would like to add a  
13 word, I believe.

14 MR. CARUSO: I'm trying to understand where Dr.  
15 Wallis' concern comes from. The review process amounts  
16 really to a dialogue back and forth between the licensee or  
17 the applicant, in this case, EPRI, the EPRI users' group and  
18 the staff to determine the acceptability of the code for a  
19 nuclear application, and the dialogue includes an exchange  
20 of information back and forth and publishing the information  
21 in public records so that the public can see how the  
22 dialogue was carried out and can understand how we come to  
23 the conclusions that we come to. I guess just are you  
24 saying that you're not sure that the conclusions would be  
25 defensible to the general technical community? Or I'm not

1 quite sure what the concern is.

2 MR. WALLIS: The concerns that this committee have  
3 about the last code we reviewed for you is right up front:  
4 it wasn't -- or it doesn't supply the nuclear; it was that  
5 we look at the derivation of some equation, and we'd say  
6 gee, whiz, this doesn't follow from that, you know; this  
7 equation doesn't follow from that equation. That was at a  
8 very fundamental level. That was the argument that we had.

9 MR. CARUSO: Right.

10 MR. WALLIS: That's the sort of thing that  
11 students look at when they look at this thing and say gee,  
12 whiz, people really do that in the world? That's what I'm  
13 getting at rather than in spite of all that, it may still be  
14 that the code is useful for certain nuclear applications.

15 MR. CARUSO: I'm not sure -- I think the problem  
16 that we're talking about appears to have been mainly a  
17 problem in -- I want to say it's a documentation problem.  
18 It's the simplification. The code users seem to have made  
19 certain simplifying assumptions which are not necessarily --  
20 they haven't been well-documented, and we've received some  
21 more information from them to explain how they've made those  
22 simplifications, and we're going to review them. We're  
23 going to document our acceptance or rejection of that.

24 I'm a little bit concerned about saying that the  
25 information needs to be transparent to -- I'm not sure what

1 level of expertise the information should be transparent to.

2 MR. ZUBER: You say -- for the last 20 years, and  
3 this is -- it is in the, I would say, obfuscation, that you  
4 really see it in the REIs; it's somewhat six inches thick.  
5 You cannot defend it; you cannot even read it. You cannot  
6 read it and say this is something said based on that  
7 information, and I think what you're really doing is really  
8 -- I think this is dangerous.

9 MR. CARUSO: If you could point to some specific  
10 examples.

11 MR. ZUBER: Well, like the point about 10 inches  
12 of paperwork. Don't worry.

13 MR. WALLIS: I think you understand what we're  
14 saying.

15 MR. CARUSO: I do to a certain extent, but I also  
16 recognize that engineering involved making simplifying  
17 assumptions when it's more difficult or too difficult to  
18 calculate things according to first principles and --

19 MR. ZUBER: You cannot defend something if you  
20 minor in first principles. When they held the ECC hearing  
21 35 years ago --

22 MR. CARUSO: But sometimes, you have to make  
23 simplifying assumptions.

24 MR. ZUBER: I'm saying you can make good  
25 assumptions. They cannot violate principles. And what

1 you're really doing is arguing that these are violating  
2 principles.

3 MR. CARUSO: No, I don't think so. I think I'm  
4 explaining that the dialogue that goes on between the staff  
5 and the licensee is an attempt to explain how those  
6 simplifications are made and explain why they're acceptable.

7 MR. SCHROCK: I guess what you've said, Dr.  
8 Caruso, sounds to me like a defense of mediocrity in serious  
9 computations that affect public safety. I can't understand  
10 how one can make an argument that it's unclear what the  
11 level of transparency of the exposition of technical  
12 matters, explanations of simplifying assumptions of the  
13 rigorous equations, all of those matters, can be left in an  
14 obscure manner. There is no excuse for any Federal agency  
15 taking such a position.

16 MR. ZUBER: It's dangerous.

17 MR. WALLIS: Well, I think it's not clear what the  
18 viewpoint of this committee is, and I think we're going to  
19 keep raising these thoughts and questions if we have to, but  
20 it may be that in your judgment, in spite of all that, that  
21 it's all right for your purposes. That's up to you.

22 MR. ZUBER: Let me say: if you have so many  
23 coefficients in these codes, and if they have a good  
24 assessment procedures, they can justify many of these  
25 shortcomings. But if they have shortcomings and inadequate

1 assessment, then, you are left with nothing to defend.

2 MR. LANDRY: And we agree with that. We agree  
3 that the information and the methods need to be documented  
4 and justified and the limitations of the methodologies need  
5 to be well-understood so that the users don't use them in an  
6 inappropriate fashion.

7 MR. WALLIS: We're talking generalities. We will  
8 see if this comes back again what you approve, and then, we  
9 will have something definite to talk about.

10 MR. LANDRY: Okay.

11 MR. WALLIS: We should move on.

12 MR. LANDRY: This does lead into the next area of  
13 discussion. That is the user guidelines. We pointed out in  
14 the first round of REIs that there are user guidelines  
15 needed for this code because of what was just discussed:  
16 there are so many coefficients; there are so many  
17 correlations; there are so many models; there are so many  
18 options, and there is so much flexibility in the code that  
19 the lack of user guidelines allows the user to do almost  
20 anything with the code. The response of EPRI was that user  
21 guidelines will be provided two to five years in the future  
22 after they gain more experience with the code.

23 In August, when we had our training at Idaho Falls  
24 with the contractor's office, this reemphasized the need for  
25 user guidelines. While the training was very good -- we had

1 no complaints about the calibre and the quality of the  
2 training -- it again pointed out to us that the code has so  
3 much flexibility that user guidelines are absolutely  
4 essential for this code. Based on that, we're prepared to  
5 say that each applicant will be required to provide and  
6 justify every assumption, every option, every model and  
7 every correlation chosen in the use of the code.

8 MR. WALLIS: Ralph, that is a great statement, and  
9 I just wonder how practical it is. I looked at the new code  
10 we're going to review, this Siemens code, and on almost  
11 every page of about 100 pages, there are correlations,  
12 options, smoothing functions chosen, numbers chosen to 0.2,  
13 0.5 or something with various amounts of justification for  
14 those numbers chosen. This underrelaxation was slipped in  
15 here and there. On almost every page, there are these  
16 things. And if you check all of that, it's going to be  
17 impossible.

18 MR. CARUSO: Well, the difficulty here is we're  
19 talking specifically about RETRAN.

20 MR. WALLIS: Yes, but, I mean, if this is user  
21 guidelines really for all codes, isn't it? You're saying  
22 that?

23 MR. CARUSO: The problem here with RETRAN is that  
24 -- well, there's a difference --

25 MR. WALLIS: With RETRAN, you're going to apply

1 this fourth bullet?

2 MR. CARUSO: Right now, we're stating this for  
3 RETRAN because of the lack of user guidelines and because of  
4 the amount of flexibility in the code.

5 MR. WALLIS: So you're really asking for this to  
6 be done where they have options.

7 MR. LANDRY: Where they have options, they have to  
8 justify it.

9 MR. WALLIS: And every assumption; the code is  
10 full of assumptions, on almost every page.

11 MR. LANDRY: When they're allowed to choose from  
12 the assumptions. They have 10 to 12 different two-phase  
13 models that they can choose from; they have to justify which  
14 one they chose.

15 MR. CARUSO: The RETRAN situation is different  
16 from the situation with the vendors, because in the case of  
17 RETRAN, you have a code that's being developed by a central  
18 organization, EPRI, and then distributed to a very large  
19 community of users throughout different utilities, and those  
20 different users have varying amounts of expertise,  
21 experience, knowledge. They're using the codes in very many  
22 different ways.

23 The vendor codes that we're going to talk about --  
24 S-RELAP5 for Siemens and TRACG -- will be used only by GE  
25 and by Siemens, so those people, that's a much smaller

1 community. They're working closely with the code  
2 developers, and it's a different situation. In this case,  
3 if we have -- we're trying to review and approve a general  
4 purpose code for general purpose application by anyone, and  
5 that's what makes it especially difficult in the case of  
6 RETRAN.

7 MR. ZUBER: I have a question which begs the other  
8 discussion. If they have so many options, presumably, each  
9 option may give you a different result, and what it means is  
10 that each applicant will have to select options then do an  
11 assessment and submit an assessment report.

12 MR. LANDRY: That's right.

13 MR. CARUSO: That's what makes this a really  
14 difficult problem for RETRAN.

15 MR. ZUBER: Especially if they have different  
16 technical capability and knowledge.

17 MR. CARUSO: That's right.

18 MR. ZUBER: This makes it very difficult.  
19 Actually, it makes it even difficult for us to say this is a  
20 good code, because if you have five correlations for a key  
21 transfer coefficient, you don't know what kind of answer you  
22 are going to get for each one.

23 MR. LANDRY: That's exactly the problem we're  
24 facing.

25 MR. CARUSO: Not only that, Novak, but this next

1 item, that you have to demonstrate that the code has been  
2 used within the range of validity of those correlations and  
3 models. We found models and correlations in RETRAN-3D that  
4 were assessed -- one was assessed for steam or for water and  
5 air, and yet, it's going to be applied for water and steam,  
6 and it's in a correlation that is extremely fluid-dependent.  
7 Are you using this correlation within its range of  
8 applicability? The user is going to have to not only show  
9 what they've used, but they'll show that they've used it  
10 within the range of applicability of that correlation.

11 MR. WALLIS: Because almost none of these  
12 correlations have been used for conditions in a nuclear  
13 reactor that are full-scale.

14 MR. LANDRY: But at least to have it assessed  
15 against the right fluid.

16 MR. WALLIS: You've got to be very careful of  
17 that, because many of the assessments are for straight  
18 pipes, let's say, and you're going to apply it to all kinds  
19 of geometries which are nothing like straight pipes in  
20 reactors. It's a real jungle out there.

21 MR. LANDRY: We realize that. We're trying to,  
22 with this level of flexibility in a code, get a grasp on  
23 what we're seeing come in for the application of the code.

24 MR. ZUBER: How can you do it if you don't have an  
25 assessment document to really say I'll run this with these

1 correlations, and these are the results, and these are the  
2 observed -- this is where I can improve?

3 MR. CARUSO: Well, what we've been doing so far,  
4 we have this problem with RETRAN because of the large number  
5 of users, and until now, for RETRAN-02, we have been  
6 reviewing each application of RETRAN-02 by each individual  
7 user. We require them to provide us with an assessment  
8 document that tells us exactly which scenarios they're going  
9 to use, exactly which models, and we approve those specific  
10 models for those specific applications. And what we're  
11 saying is that's what we're going to have to do for  
12 RETRAN-3D also.

13 With the current RETRAN-02, when the applicant  
14 comes in or the licensee comes in, they're submitting  
15 300-page documents for every calculation they do with the  
16 code to justify the use of the code, and what we're saying  
17 is that's going to continue, because when we started this  
18 review, we were under the impression that we were going to  
19 have a fully-assessed code and that all we would have to see  
20 is I used RETRAN-3D for this calculation; these are my  
21 results. We are not going to be able to say that.

22 MR. ZUBER: The industry could have saved quite a  
23 bit of money had they used this approach: one document, one  
24 assessment; then, you pass it, and it's okay. Now, you  
25 leave it to every applicant to change something, and my own

1 guess is they're going to present documents with inadequate  
2 assessments.

3 MR. LANDRY: Then, we'll have to -- we'll be  
4 reviewing each one of those documents also. That's what we  
5 do today. We spend a lot of time reviewing each document  
6 and asking questions about what was done.

7 MR. ZUBER: Okay; now, let me ask you what is our  
8 function, really? We don't have documents with the  
9 assessment; we have 10 documents with which we cannot really  
10 review, because we don't have your documents.

11 MR. WALLIS: Well, we have to review, we have to,  
12 I think, give advice at a high level. We don't have the  
13 time to go into all of the details.

14 MR. SCHROCK: But what I understand you're saying  
15 is that you've accepted the fact that you're going to have  
16 to approve a very large number of combinations out of a very  
17 large number of options available for the operation of this  
18 code and accept them as best estimate computations for  
19 specific scenarios in specific plants, even?

20 MR. LANDRY: Yes, yes.

21 MR. CARUSO: Each utility that wants to apply  
22 RETRAN to a specific transient in a specific plant has to  
23 send an assessment report in that explains how they're going  
24 to use it, how they're going to apply it, what their  
25 assessment is, and we have to review it. That's the way

1 we've done it in the past.

2 MR. SCHROCK: I could visualize 100 or more best  
3 estimate versions that would be defined, and you are going  
4 to review them individually in terms of assessment, and I  
5 don't think you have the resources to do that.

6 MR. CARUSO: Well, that's what we've been doing  
7 for the past --

8 MR. KRESS: I don't think they have any choice,  
9 Bert. Each plant is so specific that they will have to  
10 review, at some level, they will have to review it on a  
11 plant-specific basis anyway. I don't think there is any  
12 option.

13 MR. ZUBER: No problem; my problem is if you have  
14 options in that code for different, I mean, heat transfer  
15 coefficients for different processes, and you have five for  
16 each one, you have a matrix of possibilities, and you are in  
17 a forest.

18 MR. KRESS: It makes you wonder why we're even  
19 reviewing --

20 MR. ZUBER: That's exactly.

21 MR. KRESS: -- the code in the first place if  
22 we're going to have to go back and review each one  
23 individually. I think there may be some value in reviewing  
24 the first one, but I don't know what approval of that code  
25 means when you do that.

1 MR. SCHROCK: That's the problem.

2 MR. KRESS: Yes, that's the issue.

3 MR. WALLIS: Well, it would be very interesting  
4 for you to require that they actually exercise several of  
5 the options; if you have five options for this equation and  
6 six for that and three for another, well, the matrix where  
7 you look at all of the perturbations and look at all of the  
8 answers and see how they're different.

9 MR. KRESS: That's a tremendous --

10 MR. LANDRY: If you properly justify the use, you  
11 have to do that.

12 MR. WALLIS: Are we going to get to that sort of  
13 level?

14 MR. LANDRY: Well, the applicant has to justify  
15 the way in which they're used.

16 MR. WALLIS: Well, I've seen applicants -- they  
17 get a curve which looks good. Now, that may be because they  
18 jiggled the options until they got a curve that looked good.  
19 They just give you one curve; then, they can go back and ex  
20 post facto justify what they did.

21 MR. LANDRY: This is not an easy job.

22 [Laughter.]

23 MR. SCHROCK: We've seen enough of these presented  
24 to know that with the same options then applied to a  
25 variation in initial or boundary conditions, and you get a

1 very poor result. So how, then, are you going to be able to  
2 say that you approve a version of this code for that kind of  
3 an application?

4 MR. LANDRY: We're saying if we approve the code,  
5 we would be saying that the code is approved for use  
6 provided that the individual user comes in and justifies  
7 every application that they've used the code for, that  
8 they -- I'm sorry?

9 MR. ZUBER: How long does it take to make a run?

10 MR. LANDRY: A small transient, on the order of  
11 minutes.

12 MR. ZUBER: And a large brick?

13 MR. LANDRY: This is --

14 MR. ZUBER: If we okay it as a transient.

15 MR. WALLIS: There's something fundamentally --  
16 are you going to base this review only on materials  
17 submitted by them, or are you going to take the code and run  
18 it ourselves?

19 MR. LANDRY: We have been running the code --

20 MR. WALLIS: It seems to me the only way I could  
21 do it if I were to put myself in your shoes and say I want  
22 to be sure that this code is okay is not just accept what's  
23 given to me, but to take it, I've got to have some -- in my  
24 case, it would be a graduate student or someone -- say go  
25 and try it with a different option and see what happens.

1 I'd have to do that.

2 MR. LANDRY: That's what we have done in the  
3 review of this code.

4 MR. WALLIS: I hope you continue to do that.

5 MR. LANDRY: And we do have, as I said, the  
6 RETRAN-3D mod 3, and we have it installed and built. We  
7 haven't run it yet because of other work, but we do have  
8 that version of the code also. And that is our intent: to  
9 keep the code and to keep the capability of running it.

10 MR. CARUSO: That will allow us, when we have  
11 individual applications to come in, to see exactly what  
12 people are doing.

13 MR. KRESS: Yes; that would sound to me like a  
14 very useful thing to do.

15 MR. WALLIS: Are you going to run it before you  
16 actually do that? Or at the level you are now, you say you  
17 haven't run it yet?

18 MR. CARUSO: Actually, I believe the physics --  
19 didn't Tony run the neutronics portion of it? And I believe  
20 we had one staff member do a study on pressurizer phenomena  
21 using the code.

22 MR. KRESS: Do you have another code that you  
23 would say is the equivalent to this that you could compare  
24 the results with?

25 MR. CARUSO: Well, the agency has its own

1 thermal-hydraulic codes which are --

2 MR. KRESS: You do?

3 MR. CARUSO: -- ELAP and TRAC.

4 MR. KRESS: And TRAC?

5 MR. CARUSO: And for the physics calculations, we  
6 have other physics codes.

7 MR. KRESS: When you get the new TRAC, you'll have  
8 that one to --

9 MR. CARUSO: That is correct, and for neutronics,  
10 we do have our own in-house codes for the physics, and we  
11 did use them to benchmark the --

12 MR. KRESS: Is that RAMONA? Is that the one you  
13 used?

14 MR. CARUSO: No, I don't think you used RAMONA.

15 MR. LANDRY: For the physics, we ran it against  
16 NESTLE and a transient code. We ran it against a diffusion  
17 code and a transient code both.

18 MR. SCHROCK: The information your slides on  
19 kinetics indicated that the new material contains some  
20 updates to the 3D kinetics model.

21 MR. LANDRY: Right.

22 MR. SCHROCK: And new cross-section evaluations  
23 and so forth. You've already done enough to write a  
24 statement in here that says you're satisfied with the 3D  
25 kinetics part of this package. It seems strange, then, that

1 they've come in with some modifications to it. What's the  
2 reason for that?

3 MR. LANDRY: We don't know. Our person who  
4 reviewed that isn't here. We have not looked at that  
5 material yet. It just arrived last night.

6 MR. SCHROCK: And so, your conclusion is probably  
7 more generous than it should have been, and I'm trying to  
8 say why I think that. You required them to do a check  
9 against SPIRT because they claimed there was no experimental  
10 data so --

11 MR. LANDRY: That is correct.

12 MR. SCHROCK: -- they went and did an assessment  
13 of a SPIRT test, and they got pretty good agreement, but  
14 that SPIRT reactor is very small. I mean, it's pretty much  
15 a zero-D kind of thing from the kinetics point of view.  
16 You've used the code on something else, where you had  
17 basically a supercritical small region in a big core  
18 surrounded by a subcritical core in a very 3D situation.

19 MR. LANDRY: Right.

20 MR. SCHROCK: The ability to check that against  
21 reality, check the computation against reality, doesn't  
22 exist. You don't have any such experiment in the database.

23 MR. LANDRY: That's right.

24 MR. SCHROCK: I don't think.

25 MR. LANDRY: And that is where we --

1 MR. SCHROCK: When I read your statement, it looks  
2 as though the 3D aspect of this code has been checked by the  
3 NRC staff and found to be satisfactory for the purposes.

4 MR. LANDRY: Well, that's because we checked it  
5 against the SPIRT data, and we checked against other codes  
6 doing the hypothetical problems which we do not have data  
7 for, and we were getting very similar results using other  
8 diffusion models and using other transport models.

9 MR. SCHROCK: I'm not criticizing what you've  
10 done, Ralph. I'm simply pointing out that the final  
11 statement that you make about that assessment is more  
12 generous than it ought to be. I mean, you really haven't  
13 done an experimental verification --

14 MR. LANDRY: Yes.

15 MR. SCHROCK: -- of the 3D features embedded in  
16 this computation.

17 MR. LANDRY: Right; I would grant you that, yes.

18 MR. SCHROCK: Okay.

19 MR. LANDRY: All that we are saying at this point  
20 is that we do have more confidence in what we've seen on  
21 that part than some of the others.

22 MR. SCHROCK: Sure.

23 MR. WALLIS: If you finish very shortly, we'll be  
24 on time.

25 [Laughter.]

1 MR. LANDRY: These are the conclusions.

2 [Laughter.]

3 MR. WALLIS: We've actually discussed most of  
4 them.

5 MR. LANDRY: We've discussed most of these points,  
6 yes.

7 MR. KRESS: Well, let me ask you about the third  
8 bullet.

9 MR. LANDRY: Approval to use RETRAN-3D as a  
10 RETRAN-02 substitute.

11 MR. KRESS: With those constraints, why would  
12 anybody ever choose to use RETRAN-3D as a substitute,  
13 replacement, for RETRAN-02?

14 MR. LANDRY: We raised that same question, and  
15 what we were told was that there are people who are taking  
16 RETRAN-3D and want to use it for other work in-house. They  
17 don't want to maintain two codes.

18 MR. KRESS: Ah.

19 MR. LANDRY: RETRAN-02 that is approved for use;  
20 RETRAN-3D which is not approved. So they want to have one  
21 code --

22 MR. KRESS: So, they want to use it as one -- have  
23 one code and use it for other purposes.

24 MR. LANDRY: Right. And use it in an 02 fashion.

25 MR. KRESS: I still have the question, because

1       apparently, they've already done something with RETRAN-02 --

2               MR. LANDRY:   Correct.

3               MR. KRESS:   -- to have permission to do something  
4       or other, and supposedly, they want to do something  
5       different than what they are doing, but they have to show --  
6       and it would be based on the results of a code calculation,  
7       but they have to show that the results are identical to  
8       RETRAN-02.  Therefore, I don't understand -- I still don't  
9       understand why they would ever use it as a replacement for  
10       what they have already done with RETRAN-02.

11              MR. LANDRY:   Simply because if they have 02  
12       approved, they don't want to get 3D approved, but they want  
13       to -- but they don't want to maintain two codes, and they  
14       want to use 3D in place of 02, and what we're saying is if  
15       you're going to do that, you have to demonstrate that you  
16       are getting equivalent results and that you are using no  
17       models, no correlations, that are not contained in 02.  You  
18       have to lock out every correlation, every model, that is not  
19       in 02.

20              MR. KRESS:   I see what you're saying.  They may  
21       want to change their plant and would have used RETRAN-02 to  
22       justify their change.

23              MR. LANDRY:   Right.

24              MR. KRESS:   But now, they're going to use --

25              MR. LANDRY:   3D.

1 MR. KRESS: -- RETRAN-3D to justify it, and you're  
2 saying, well, we want to know --

3 MR. LANDRY: If you're going to use it in an 02  
4 mode, it has to be a true 02 mode.

5 MR. KRESS: I understand; can they actually do  
6 that, do you think?

7 MR. LANDRY: They've assured us that they can.

8 MR. KRESS: I would have my doubts that that could  
9 actually be done.

10 MR. LANDRY: That's why we're going to be very  
11 specific in that statement.

12 MR. KRESS: Yes.

13 MR. WALLIS: Any other questions on the  
14 conclusion?

15 [No response.]

16 MR. WALLIS: Can we move on, Ralph? We'll see you  
17 again this morning. It seems to me that when we ask these  
18 questions and make these statements, they may appear to some  
19 outsider to be criticizing, but it looks to me as if we're  
20 more sympathizing.

21 MR. KRESS: I think that's right.

22 MR. WALLIS: I'd like to ask EPRI to address this  
23 same code.

24 Mr. Swindlehurst, please?

25 MR. SWINDLEHURST: My name is Greg Swindlehurst,

1 and I work for Duke Power Company, and I'm the manager of  
2 the Safe Councils Organization of Duke, and I've been  
3 involved with this RETRAN-3D review from its inception, so  
4 I've been chomping at the bit back here to answer some of  
5 the questions you've asked, Ralph, so hopefully, you'll  
6 reask some of those if I don't remember to address them.

7 I've only prepared a short presentation, but I  
8 think there are a couple of key points I'd like to make.  
9 This is a subset of the chronology which Ralph presented  
10 earlier, and the reason I wanted to put this up is because I  
11 wanted to focus on our process, as Ralph Kress also  
12 mentioned. This is how we have licensed and reviewed  
13 documents like the code, okay? We submit the documentation;  
14 the NRC goes through a preliminary review to see if the  
15 documentation is suitable. They issue an acceptance review,  
16 meaning they're ready to do a full-blown technical review of  
17 the code, and they start reviewing it.

18 As they mentioned, we have phone calls, emails,  
19 meetings. We discuss things. We find out how the review is  
20 progressing, and then, NRC staff formulates their questions  
21 in the form of REIs, and we answer them.

22 MR. ZUBER: Okay; let me ask you.

23 MR. SWINDLEHURST: Sure.

24 MR. ZUBER: The code they are reviewing, is this a  
25 developmental code or a frozen code?

1 MR. SWINDLEHURST: Okay; I'm not going to use the  
2 term frozen, okay?

3 MR. ZUBER: Well, they have been using this for  
4 the last 20 years.

5 MR. SWINDLEHURST: Right.

6 MR. ZUBER: And if you want, I'll engineer another  
7 word, another thing; let us know, because at least as far as  
8 I'm concerned, we've always discussed frozen codes for  
9 approval.

10 MR. SWINDLEHURST: Okay; for this review here, we  
11 initially submitted RETRAN-3D mod 2 with the original  
12 submittal. This code is not a frozen code in terms that  
13 EPRI is continuing to work on it, to improve models, to make  
14 error corrections, things of that nature, okay? In August  
15 of 1999, we submitted revision mod 3, and it was our intent  
16 that the NRC's review was going to shift gears at that point  
17 in time to review the new code, and the new code, mod 3  
18 versus mod 2, only includes a few changes. I'd like to read  
19 those for you, because we keep thinking this is a big change  
20 of code version, and it's really not that big.

21 MR. WALLIS: So you change nothing from the model;  
22 you just changed a few correlations here and there?

23 MR. SWINDLEHURST: Well, here is what changed,  
24 okay? And this, by the way, I'm reading from a document  
25 that we just submitted on March 6, and unfortunately, I just

1 found out today it didn't arrive until yesterday. I can't  
2 explain why it took nine days for this document to get here.  
3 We were hoping, you know, it would get here a week before  
4 this meeting so that the staff could read it and react to  
5 it.

6 The five main changes are that the  
7 three-cross-section model was revised for the 3D kinetics  
8 model. There was a user convenience added for inputting the  
9 thermal-hydraulic part of the 3D model so that we would use  
10 a channel representation, which would allow the user to  
11 automate his inputting of the channel description, okay, so  
12 that's not even a -- that's not a technical change; it's a  
13 user convenience improvement.

14 MR. SCHROCK: Did it change the noding and the  
15 channel representing the --

16 MR. SWINDLEHURST: Yes; you can then propagate the  
17 same input for multiple channels instead of having to  
18 respecify it each time, okay? Say you've got a model with  
19 15 channels in it; and you want to expand it to 50, just as  
20 an example. It's just an automated way of doing that  
21 instead of having the guy have to go in and renumber each  
22 cell, each junction, et cetera. It's a user feature.

23 The non-kinetics with gas equations were revised.  
24 The staff found an error early on in the review of that. We  
25 fixed that, and that was revised. The five-equation

1 interfacial mass transfer models were changed, and that's  
2 the big change we've been talking about, okay? Staff has  
3 characterized that as us sending in a code with a known  
4 error, and we disagree with that. We sent in a code, mod 2,  
5 which had a model for doing this modeling. Subsequent work  
6 done by one of the RETRAN users identified problems with  
7 that. So we fixed that model; we approved it. We  
8 resubmitted it in August of 1999. So that's a natural  
9 evolutionary thing of codes like this. If someone finds a  
10 better way of doing something, and we agree with this; we're  
11 spending money on it, we will reprogram the code and issue a  
12 new version.

13 MR. KRESS: But that's the very fundamental basis  
14 for the whole code are those equations. So when you change  
15 that, you're changing the whole code, it seems to me like.

16 MR. SWINDLEHURST: It's fundamental for the five  
17 equation modeling of the code, which is an infrequently used  
18 piece of this RETRAN-3D. But you're correct that it's a  
19 fundamental change for that one small part of this code, the  
20 arrest and step review. So we will admit: we changed that  
21 model. We wouldn't say we submitted it with known errors.  
22 We didn't know that there were errors and problems with it  
23 when we submitted it. We knew that we were going to work on  
24 it because a user had identified problems.

25 MR. ZUBER: See, this is the difference between

1 the code in development and one which is frozen. With a  
2 frozen code, you have done your work; you have submitted it  
3 to somebody else to assess it, and the process is finished  
4 if you did a good job. What you're really doing is almost  
5 repeating errors: now look at this. And he finds an error;  
6 you have to do it, and this goes to that --

7 MR. SWINDLEHURST: We will continue, in the  
8 future, to work on RETRAN-3D, and if we find new models or  
9 better ways of doing things, we will be issuing a revision  
10 four that will not be -- not have been sent to the staff  
11 yet. It's developmental. Once we send it to the staff for  
12 review as a new version, and if they accept it, then, that  
13 will be the new approved version, but prior to that, the  
14 only thing that's approved and the only thing that will be  
15 used for licensing is what they tell us is approved.

16 MR. WALLIS: I don't know that this committee  
17 needs to be involved in this business. If they need to have  
18 something frozen, then, you have to get it to them. It's  
19 solely between you and them. It's not for this committee to  
20 -- the mechanism fixing which you're working on.

21 MR. SWINDLEHURST: Right; but we all know it's  
22 unfortunate. These codes, errors do come up from time to  
23 time, whether it's this code or other codes.

24 MR. WALLIS: There's got to be a mechanism somehow  
25 for approving a code, but there has also got to be a

1 mechanism for knowing what you're approving. I don't see  
2 how this committee can make a determination.

3 MR. SWINDLEHURST: Sure.

4 MR. WALLIS: We've got to say go away and work it  
5 out.

6 MR. SWINDLEHURST: The fifth area that's a change  
7 in mod 3 is that there were other errors that were  
8 identified along the way, and we fixed every known error  
9 before we issued that code. And this is the way EPRI does  
10 codes, whether it's RETRAN-01, RETRAN-02, VIPER, GOTHIC,  
11 errors are identified; we fix them, and then, periodically,  
12 there is a release of a new version. But the new version  
13 cannot be used if it's not what's approved per the NRC's  
14 SEI.

15 MR. WALLIS: My question from your speaking is  
16 that the points that are raised by this committee are of a  
17 very fundamental nature, such as saying this parameter we  
18 thought was a vector, a scaler, is treated as a vector or  
19 things like that are not part of these changes. If you  
20 haven't fixed anything that was raised by this --

21 MR. SWINDLEHURST: That is correct; the comments  
22 from this committee and our discussions with the staff on  
23 what to do about the comments in this committee is that we  
24 were to respond to the request for additional information,  
25 okay? We're not supposed to directly respond to this

1 committee. So to --

2 MR. ZUBER: Did you address -- I mean, did you  
3 submit it to the staff?

4 MR. SWINDLEHURST: The second round of questions  
5 was formulated by the staff, and I think -- and correct me  
6 if I'm wrong here, but a lot of the ACRS' comments, you can  
7 trace into that second round of questions. We issued a  
8 response to those questions two months after we received  
9 them, and the staff is looking at our responses, and we have  
10 not heard back yet.

11 MR. WALLIS: You didn't fix the documentation; you  
12 just argued that you were right all along.

13 MR. SWINDLEHURST: If there were documentation  
14 errors, like the equations were entered incorrectly, or when  
15 we sent by electronic media the documentation to the NRC,  
16 and it got garbled, which was some of the problems that we  
17 were having with our equations is the electronic  
18 transmission got garbled --

19 MR. WALLIS: We had questions of the type that you  
20 were applying a method to solve this problem which cannot be  
21 used to solve this problem. That isn't fixed by an REI or  
22 by a new kind of papering over; it's a very fundamental type  
23 of thing, and really, you have to go back to square zero.

24 MR. SWINDLEHURST: I think the way we can answer  
25 that is we were asked a question; we answered it. It's up

1 to the staff whether or not our answer was correct, and if  
2 they reject it, then, we'll be back discussing it some more

3 MR. WALLIS: I think eventually, it's up to the  
4 staff. We can say what we like; it's up to the staff  
5 eventually. But my impression was that you didn't fix the  
6 fundamental kinds of questions that were raised the last  
7 time we met.

8 MR. SWINDLEHURST: We've answered the questions;  
9 we have not changed the code. That is correct.

10 MR. SCHROCK: I had asked what the need was for  
11 modification in the cross-section data in your code. Could  
12 you explain that?

13 MR. SWINDLEHURST: The change from mod 2 to mod 3?

14 MR. SCHROCK: Yes.

15 MR. SWINDLEHURST: I'm afraid I can't give you --

16 MR. SCHROCK: Number one says you revised  
17 cross-sections.

18 MR. SWINDLEHURST: Okay; I can't give you a real  
19 detailed explanation of that, because I personally have not  
20 used this RETRAN-3D cross-section model, but I think all it  
21 was was a different way to get your cross-sections loaded  
22 into this code version, okay?

23 As an example, when we did the SPIRT benchmark  
24 that we just talked about a minute ago, the staff provided  
25 us with cross-sections in a format from the NESTLE code,

1 which is a staff or an industry code, I guess, a university  
2 code. We took those cross-sections as-is and put them into  
3 RETRAN exactly as they were in order to do good validation  
4 comparisons, okay? And that would just be another example  
5 of changing how you load the cross-sections into the code,  
6 but when the equations start pulling those cross-sections  
7 out of their tables, none of that was changed. So it's just  
8 an inputting of the cross-section library. That's all it  
9 was.

10 MR. SCHROCK: I read your response to that, and it  
11 looked as though you have some misgivings about the validity  
12 of the cross-sections that were given to you. Is that the  
13 case? Did I get the wrong impression from words that you  
14 used?

15 MR. SWINDLEHURST: I don't recall that response,  
16 so I'm afraid I can't address it. We used the staff's  
17 cross-sections as-is, and we presented the results of the  
18 analysis; compared it to the data, and it looked quite good,  
19 but I don't recall us stating that we didn't like the  
20 cross-sections. I know it's very challenging when you get  
21 the cross-sections for a small reactor like this, but we  
22 just used the ones which the staff members prepared.

23 Okay; so we've had two rounds of REIs. I assume  
24 some of our answers are acceptable to the staff; some,  
25 they're still reviewing, and we're waiting to hear back from

1 those. We had a meeting -- I met with the staff in  
2 mid-December. The purpose of that meeting was to find out  
3 where are we on this review. We've added two rounds of  
4 questions; we've had lots of meetings. We've had a lot of  
5 ACRS involvement, and we sat down and talked about what was  
6 the remaining problem areas. Mostly the same things which  
7 you just heard from the staff's previous presentation. We  
8 took back that information; put a plan together as to what  
9 do we need to do to answer all of these questions and move  
10 forward with this review. And then, we prepared an  
11 additional submittal, which I mentioned we mailed on March  
12 6, and the staff now has it, and the intent of this  
13 submittal was to be responsive to all the known questions,  
14 all the known issues.

15 And what I'd like to do is briefly describe what's  
16 in the submittal. I was assuming the staff would have had  
17 it, and they would have been talking about it already, but  
18 let me just tell you what's in the submittal, because a lot  
19 of it addresses the things we just talked about. We clearly  
20 defined which code version we're expecting the staff to be  
21 reviewing, and we described what the differences are between  
22 the mod 2 code that was originally submitted and the mod 3  
23 code which was submitted last August.

24 The other thing we defined is what does it mean to  
25 use the RETRAN-3D code in the RETRAN-02 mode? And we just

1 talked about that a little bit. And we've given a specific  
2 list of what input options are usable or are okay to use if  
3 you're claiming you're using RETRAN-3D in a RETRAN-02 mode,  
4 okay? And you're correct: you cannot do this 100 percent.  
5 It doesn't work. But we very clearly stated if a user is  
6 claiming he's using a RETRAN-02 mode, what does that mean?  
7 What options is he not using? What options is he using?  
8 And which ones are different than RETRAN-02.

9 MR. KRESS: You've basically defined what it  
10 means.

11 MR. SWINDLEHURST: We've defined it.

12 MR. ZUBER: Let me ask you: in this development  
13 code, did you really assess the effect of different options  
14 in that code, or did you just put them and let somebody else  
15 sift through?

16 MR. SWINDLEHURST: I'm getting to that, and I  
17 think I'm getting to your answer in just about two minutes,  
18 okay?

19 MR. ZUBER: Okay.

20 MR. SWINDLEHURST: The other thing we've been  
21 asked by the staff repeatedly is what did we ask them to  
22 review with this submittal? And we've clearly defined which  
23 pieces of application or coding were put in the review here.

24 MR. ZUBER: Okay.

25 MR. SWINDLEHURST: One thing we've done is we've

1 looked at the assessment of the various models and, for some  
2 of the models, we freely admit we don't have good assessment  
3 on it. So we've withdrawn some of the models from the  
4 review, and we've indicated that to the staff on a  
5 line-by-line item, okay? So every new RETRAN-3D model or  
6 option, we've said here's the option; here's where it's  
7 described in the theory manual, and here's the section where  
8 it's validated, or here's a reference for where it's  
9 validated. Now, clearly, we think it's adequately  
10 validated. The staff may disagree, okay? But what we're  
11 trying to do with the next step is have them tell us yes, we  
12 agree; this one is validated; no, this one isn't; go through  
13 them line-by-line and let's figure out how to move on, okay?

14 We may decide that it's not worth the cost, or  
15 there's not enough value to the user to continue to argue  
16 about a given option and whether it's validated enough. We  
17 may withdraw it. We may decide we've got to have that  
18 option; we'll find out from the staff what additional work  
19 we need to do, and we'll submit that. So we're trying to  
20 break down this big comment that the validation isn't  
21 adequate to let's get specific.

22 MR. WALLIS: So the documentation hasn't changed  
23 significantly. It's in the details that it may change. The  
24 documentation we reviewed before is still the same that  
25 you're submitting.

1 MR. SWINDLEHURST: There have been minor updates.

2 MR. WALLIS: The up front part where you lay out  
3 the structure of the code, the fundamental equations, all of  
4 that hasn't changed.

5 MR. SWINDLEHURST: Some of it has changed,  
6 because, for example, the RETRAN-02, I mean, the mod 2 to  
7 mod 3 changes I just described, if there are documentation  
8 changes associated with those changes, we've submitted  
9 those.

10 MR. WALLIS: Well, the level that we were at was  
11 we looked at some examples, like -- which seemed to contain  
12 some fundamental errors of conception, which indicated that  
13 whoever worked this out didn't understand how to use the  
14 momentum equation. What's happened is someone simply said,  
15 well, let's take that out so they won't have it to  
16 criticize, or were some on the dime right?

17 MR. SWINDLEHURST: No; those questions were part  
18 of the second round of questions to us.

19 MR. WALLIS: But did you fix it? Did you argue  
20 that it was right all the time, or did you do it right?

21 MR. SWINDLEHURST: If the documentation was  
22 incorrect, either due to electronic garbling of it, or if it  
23 wasn't clear enough, we've rewritten it to our satisfaction,  
24 hopefully to your satisfaction, to explain it better, but we  
25 have not gone back and recoded the fundamental equations.

1 MR. WALLIS: So have you changed the equations,  
2 then?

3 MR. SWINDLEHURST: We changed the two errors that  
4 were identified, one in the noncondensable gas area, and  
5 there was also an error in the momentum equation associated  
6 with the missing term which made that equation not work for  
7 angles that were not multiples of 90 degrees. Those two  
8 things are being fixed.

9 MR. WALLIS: Well, I guess we have to look at  
10 this. It's just that I have a horrible feeling we're going  
11 to have exactly the same question that we had before.

12 MR. SWINDLEHURST: Okay.

13 MR. WALLIS: And I'm not sure that's a good thing.  
14 I know I'm a very gentle kind of person, but you may find  
15 some members of the committee are more hard-hearted.

16 MR. ZUBER: Graham, this is really sad, because  
17 this really opens the door to criticism from the outside,  
18 and this is the same situation as we were in before the ECC  
19 bypass in 1971, and you leave something open where somebody  
20 asks, well, have you negotiated -- will destroy your  
21 credibility. You cannot maintain your virginity once you  
22 have --

23 MR. WALLIS: So we'll just say unless you have  
24 fixed these things, and maybe you have, the way you're  
25 talking suggests that the message has not got through that

1 there is something very fundamental here which needs to be  
2 fixed.

3 MR. SWINDLEHURST: I think your comments have  
4 gotten through, and what we have done is, you know, these  
5 codes have been started perhaps 30 years ago or so, and  
6 they've been evolving, and it's not just RETRAN; it's RELAP,  
7 TRAC, all these codes, and they have different assumptions  
8 and different approximations to be able to cast these  
9 equations into a soluble set of equations which are adequate  
10 for what we do.

11 MR. ZUBER: No, there is a big difference. There  
12 is a difference between approximations and errors. For  
13 approximations, you may get an A-. For the error, you get D  
14 or C, and I think this is the difference, and what you are  
15 really trying to mix both, I don't think is fine. I think  
16 this is dangerous.

17 MR. SWINDLEHURST: Okay.

18 MR. WALLIS: That was a concern we had.

19 MR. SWINDLEHURST: Okay; so, we've got a  
20 line-by-line table for each new model as to how and where  
21 it's validated, and we can discuss those on a case-by-case  
22 basis with the staff to move forward. We've also developed  
23 a user guidance model -- excuse me, a user modeling guidance  
24 section, which goes through all of the new models in  
25 RETRAN-3D and provides the code vendors' state of knowledge

1 regarding the use of that model, limitations, and this is  
2 trying to be responsive to the staff's interests in such a  
3 document, okay? And we'll be updating that into the set of  
4 the code documentation.

5 Another thing we've done is reached the code  
6 validations. We've identified which version of the code was  
7 used and which organization did the work. We've also  
8 addressed why all of the validation work was not repeated  
9 for the latest version of the code. An example would be,  
10 well, the changes going from RETRAN-3D mod 2 to mod 3  
11 weren't -- they didn't change for a specific piece of the  
12 validation work, so there is no need to rerun it, okay?  
13 Those models were not exercised by that, so we've talked  
14 about that.

15 As I've mentioned, we've withdrawn several models,  
16 because we decided it's not worth, at this point in time,  
17 for us to generically provide additional assessment on  
18 those, and that would put that back in the user's ball  
19 court. If he wants to come in and use the new accumulator  
20 model, which we have withdrawn, then, he'll have to do all  
21 of that licensing on his own, okay?

22 We've also provided a 3D core kinetics benchmark  
23 for a steam line break, standard problem, where we see these  
24 standard problems, because the staff had told us that the  
25 rod ejection, pwr rod ejection type of application with the

1 3D model looked pretty good, but we didn't have enough on  
2 steam line breaks, so we've done that. Now, again, that's a  
3 code assessment where we're comparing it to TRAC and RELAP-5  
4 and other codes. That's the best we can do with what's  
5 available for validation data.

6 So, that's a quick overview of our submittal on  
7 the March 6, and the intent is to try to be responsive and  
8 address the known issues. I'm confident we've been  
9 partially successful in what we've done, but I'm sure  
10 there's also some areas which we will not have had  
11 adequately addressed, and we're going to expect to meet with  
12 the staff to decide what to do next.

13 MR. WALLIS: Do you expect to make a presentation  
14 -- if you are successful, are you going to come to this  
15 forum again with the same -- you may have the same  
16 opposition you had last time?

17 MR. SWINDLEHURST: We can certainly have that  
18 conversation again, sure.

19 MR. WALLIS: Thank you very much.

20 Any other questions?

21 MR. SWINDLEHURST: I've got a couple more items  
22 here.

23 MR. WALLIS: Oh.

24 MR. SWINDLEHURST: Just let me tell you real  
25 quick. It shouldn't take more than a couple of minutes.

1 MR. WALLIS: I thought you went through that and  
2 you just touched on this now.

3 MR. SWINDLEHURST: Well, a couple of things I  
4 didn't mention that I want to cover, and I won't repeat  
5 myself. I've been around through RETRAN-01, RETRAN-02 and  
6 VIPER-01 reviews with the staff, and there is no doubt that  
7 this review, for this review, the bar has been raised, and  
8 the review is much more detailed, much more thorough. We're  
9 very familiar that loca codes always go through this kind of  
10 review. RETRAN-3D is a non-loca code, and this is a  
11 dramatic increase in the staff's attention to reviewing  
12 this. In the past, it's typically been subbed out to a  
13 contractor, but with the staff doing it in-house and with  
14 their new approach to reviewing things, including involving  
15 the ACRS, this is a new world, okay?

16 MR. WALLIS: So there's nothing that we've heard  
17 from the staff which I think made us get the impression that  
18 we were doing anything unreasonable.

19 MR. SWINDLEHURST: I'm not saying unreasonable.  
20 I'm just saying this --

21 MR. WALLIS: You're saying the bar has been  
22 raised.

23 MR. SWINDLEHURST: The bar has been raised.

24 MR. WALLIS: That would indicate to me that it was  
25 too low in the past.

1 MR. SWINDLEHURST: The reason I'm saying that --  
2 that's a reasonable interpretation. The reason I'm saying  
3 that is because based on our past experience, we had a  
4 certain understanding of what the staff's expectations would  
5 be on submitting a new code like this, and given that we're  
6 really just submitting new models, you know, the RETRAN-3D  
7 models to be added onto an already-approved RETRAN-02 code,  
8 we thought we were in good shape on what we submitted, and  
9 it's been a challenging review, and we're working with the  
10 staff to try to come to a successful conclusion.

11 MR. ZUBER: If I could just make a comment. The  
12 same shortcomings, basic shortcomings, which are now in the  
13 RETRAN-3D, they're the same in RETRAN-02. It only can say  
14 that the bar was too low, and you should be really happy  
15 that this bar is there in the position that it is, because  
16 if it's approved, you can defend yourself in front of the  
17 technical community.

18 MR. SWINDLEHURST: We have no problem with the  
19 fact that the bar has been raised. I didn't want to leave  
20 that impression. I'm just stating that that is our  
21 perspective on what has happened.

22 MR. WALLIS: That's good.

23 MR. SWINDLEHURST: There has been two code errors  
24 I mentioned. We've taken care of those. If you back up  
25 further, to another point in time, we had an independent

1 design review of the code done by a group of senior industry  
2 people uninvolved with the development of this code. They  
3 also identified code errors. Those were all addressed, and  
4 this is a normal and good thing for us to find these errors  
5 and get them fixed.

6 I've already mentioned we've withdrawn some  
7 models. One thing that is perhaps getting lost is that we  
8 believe that RETRAN-3D is a much better code than RETRAN-02.  
9 RETRAN-02 is being used out there for a lot of purposes by a  
10 lot of organizations, including internationally, and we  
11 think this is a step forward in safety to be moving forward  
12 with the new models, because this is a better code, and that  
13 may not be evident to everybody.

14 The other thing I'd like to mention is that we  
15 need to keep in mind what is this code being used for? What  
16 types of plant transients? What type of severity of core  
17 response, plant response are we modeling with a non-loca  
18 code? And our opinion is that it's lower. It's still  
19 obviously extremely important, but most of you and a lot of  
20 people in industry are very focused on large-break loca-type  
21 codes and modeling, where the dynamics of the plant  
22 transient are really fast-moving and rapidly changing. A  
23 lot of the applications of this code don't fall into that  
24 category, and we need to keep that in mind when we're  
25 thinking about how important is a certain option in the code

1 to the ultimate application of the code.

2 MR. ZUBER: Well, that is interesting, because it  
3 comes time and time again: one thing about -- although in  
4 the discussions, we brought up that if it is something which  
5 is so obviously wrong from the basic principles, what is  
6 more true as applied to reactor applications? Or it is not,  
7 and you try to fix it?

8 Now, let me say: 25 years ago, we had the same  
9 problem with RELAP-03 and RELAP-04. The momentum it created  
10 was in error, and we found it. And what happened, what the  
11 NRC -- I mean, the AEC at that time -- did, we ran these  
12 codes just to see what the effect is and what you can do if  
13 you want to change this code, these basic errors. You can  
14 run it and show that this error is minimal, and you can say  
15 this is the error because of this fundamental shortcoming.  
16 And I think you can address it. But to say I addressed two  
17 errors, but I'm not addressing the fundamental errors, you  
18 are really not resolving the problem. My advice would be  
19 look: you have it, something which broke up. If it makes  
20 the wrong calculation, then show the effect. And if the  
21 effect is small, you can leave it, and you can make an  
22 argument. I think this is what I would advise also the  
23 staff to do.

24 MR. WALLIS: The problem is that they have in the  
25 documentation, I think, four or five examples where you can

1 see that the answer given is completely wrong. What should  
2 we suppose about more complicated examples that are involved  
3 with a reactor? That's the level we're at now. And I think  
4 -- I hope you can come back with something that puts us --  
5 our concerns to rest.

6 MR. SWINDLEHURST: I understand what you're  
7 saying.

8 MR. WALLIS: If you haven't addressed those  
9 things, I'm not sure why we should look at it at all.

10 MR. SWINDLEHURST: And do we agree that --

11 MR. WALLIS: When you say that two is one, and we  
12 say we don't believe it, and you come back with a new thing  
13 which says two is one, then, we're just where we were  
14 before. So I hope that doesn't happen, but I can't see,  
15 from what I've heard today, that there's any change in your  
16 contention that two is one. Maybe that's true, but we'll  
17 have some difficulty grasping the concept at the level I was  
18 at last time.

19 MR. SWINDLEHURST: I understand what you're  
20 saying.

21 MR. WALLIS: Okay.

22 MR. SWINDLEHURST: The last comment here is -- and  
23 I'm pretty sure the staff agrees with this -- it's a good  
24 thing for people in utility organizations to be looking  
25 after their own plants in terms of safety analysis and

1 transient analysis as opposed to not having these kinds of  
2 capabilities, and EPRI codes like this are where this  
3 technology comes from for these types of organizations, and  
4 we think it's a good thing, and we'd like to be able to move  
5 forward with this in terms of improving the software, and we  
6 think RETRAN-3D is an improvement.

7 MR. ZUBER: This is one more reason to make them a  
8 good tool which can be defended, so that they can get  
9 trained with something which is really solid, at least on  
10 basic principles.

11 MR. SWINDLEHURST: And I think we may never get to  
12 the point where everybody likes this code, but we have  
13 other --

14 MR. ZUBER: It's not a beauty contest. It is  
15 something which is in error, and we addressed it or how bad  
16 it is.

17 MR. SCHROCK: We're trying to make a responsible  
18 technical assessment.

19 MR. SWINDLEHURST: Well, we've worked on the  
20 assessment, and we will continue to work on it with the  
21 staff until we decide which models are valid and approved  
22 and which are not. It's the same process we've gone through  
23 before in codes like this.

24 MR. WALLIS: But there will be a problem for  
25 everybody if you work with the staff and then you all come

1 back, and you say well, we've beaten this thing to death,  
2 and we agree, and yet, the professional community looking in  
3 from outside says gee whiz, how did they ever do that?

4 MR. SWINDLEHURST: Okay.

5 MR. ZUBER: You are putting the monkey on the  
6 staff.

7 MR. SWINDLEHURST: No, not really; we're just --

8 MR. ZUBER: Because they have to approve something  
9 which cannot be defended.

10 MR. SWINDLEHURST: It's up to us to work with and  
11 through the staff to get something either approved or not  
12 approved. That's the process we use.

13 MR. WALLIS: I understand.

14 MR. SWINDLEHURST: Okay; thank you for your time,  
15 and do we have --

16 MR. WALLIS: We all agree that having a good code  
17 is a very, very useful thing. That's what we hoped to see  
18 when this thing started.

19 MR. POWERS: The previous speaker seemed to  
20 portray a rather dismal forecast in front of anyone who uses  
21 this code; that is, they would have to submit 300-page  
22 documents justifying each line of coding, each option in the  
23 code and things like that. Do you have any response to that  
24 statement?

25 MR. SWINDLEHURST: Sure, I do. What he describes

1 is exactly what we've been doing for the last 20 years. For  
2 example, the RETRAN-02, an organization like myself at Duke,  
3 we have to submit a document describing to them how we model  
4 our plant using this code and why we can show that we know  
5 what we're doing from modeling the types of transients that  
6 we're modeling, okay? And that is a thick document. It  
7 takes a year or more for the staff and us to work through a  
8 review on that and to eventually come to some conclusion,  
9 and an SER is issued. That's the normal way we've been  
10 doing it in the past, and we expect that that's perfectly  
11 acceptable to us to continue doing that in the future.

12 Now, the thing that we've hoped for when we submit  
13 the code is that a lot of the staff's questions will get  
14 resolved about the code, the options, et cetera, and that  
15 will make the review by each utility for their application  
16 of that code a smaller task. But clearly, when they come in  
17 and say we're going to use RETRAN-3D to model our plant, the  
18 burden is on them to provide whatever is necessary and  
19 answer all of staff's questions to get through that  
20 licensing process, and we accept that.

21 MR. WALLIS: Thank you very much.

22 [Pause.]

23 MR. WALLIS: Ralph, can you get us back on  
24 schedule?

25 MR. LANDRY: I'll try.

1           The next plan, the next code we want to talk about  
2 starts on page 12 of the handout. This is the Siemens  
3 SRELAP-5 code. Greg just made a comment about things maybe  
4 being a little looser for a transient review, for transient  
5 use than for a loca code. Well, here, we have a code that  
6 is used for both. This is a submittal to use SRELAP-5 for  
7 both small-break loca and for transient. The documentation  
8 and the code have been submitted for the staff's review.  
9 The staff's acceptance letter is in the concurrence chain at  
10 this point in time. We've conducted our acceptance review,  
11 and we've written our letter, and it's going through the  
12 concurrence procedure.

13           MR. WALLIS: You're simply accepting the  
14 submission of the --

15           MR. LANDRY: For review.

16           MR. WALLIS: All right; you're agreeing to review  
17 it.

18           MR. LANDRY: Correct.

19           MR. ZUBER: This is a frozen code.

20           MR. LANDRY: Yes, that's our understanding. We've  
21 asked that question several times, and we've been told  
22 absolutely.

23           MR. ZUBER: And has the complete assessment?

24           MR. LANDRY: I'll get into that.

25           Now, there is good news and bad news. The staff

1 is very familiar with RELAP-5. We've had a lot of  
2 experience with the code. But the code that is submitted in  
3 the SRELAP-5 code package for review is neither RELAP-5 mod  
4 2 nor RELAP-5 mod 3. It started out as RELAP-5 mod 2; has  
5 some of the models from mod 3 put in plus some evaluation  
6 models. This code is used for evaluation model loca  
7 reviews. So the code is not completely RELAP-5 mod 2 nor is  
8 it completely RELAP-5 mod 3. So that presents us with a  
9 little bit more challenge in review. We can't just say  
10 okay, this is RELAP-5 mod X; we know what this code contains  
11 and proceed very quickly. We've had to step back and look  
12 at the assessment of material for this a little bit more  
13 carefully, because it is a hybrid version of the RELAP-5  
14 code.

15 We met in November with Siemens, and they  
16 submitted to us the chapter 15 transient non-loca use of the  
17 code for review. They submitted in January a request for a  
18 small-break loca use of the SRELAP-5 code. In February, we  
19 received the full code. In looking at those documents which  
20 we received back in November and in January, we said that  
21 this material is fine in that it describes what you want to  
22 use the code for, but it doesn't describe the code itself,  
23 and we noted that the code at that point was a hybrid, and  
24 we need a great deal more information.

25 So in February, Siemens submitted to us the full

1 documentation on the code itself, the models, correlations,  
2 et cetera. In March, we met with Siemens and went through a  
3 walk-through of the code, the models in the code, what the  
4 documentation covers, what the review objectives are and the  
5 endpoint of the schedule. Now, I'm going to put up a little  
6 later a staff cut at this schedule for this review. The  
7 internal parts of that schedule, Siemens has not seen yet.  
8 We've only talked with them about the endpoint of the  
9 schedule for the review.

10 This lists the documentation we have received; the  
11 models and correlations, programmers' guides, input  
12 requirements, and the two applications of the code.

13 In reviewing the code for acceptance for the  
14 review, we have noted that we have the acceptance letter in  
15 the concurrence chain at this point. The documentation  
16 appears to be thorough. We have not reviewed the  
17 documentation in fine detail. We have done an acceptance  
18 review to determine that yes, there is adequate  
19 documentation there to perform a review. There are  
20 shortcomings. We've discussed these with Siemens. Right  
21 off the top of our head, we looked at the material and said  
22 hey, there's kind of thin assessment here, and we've pointed  
23 that out to Siemens when we met with them two weeks ago, and  
24 we'll be going through the documentation in detail, pointing  
25 out more and more details of assessment that is necessary.

1 MR. WALLIS: Seems to me that's the key thing is  
2 the assessment. That's what you said earlier. The  
3 documentation is really remarkable in terms of the enormous  
4 number of correlations, coefficients and so on there, and  
5 so, it looks as if you could do almost anything with this.  
6 The assessment is very important.

7 MR. LANDRY: That's right, and we will be looking  
8 at the assessment, and particularly, we will look at the  
9 models and correlations which are not in mod 2 or mod 3.  
10 We'll look at the assessment, and a concern that we have, of  
11 course, because it's a hybrid is the interaction of some of  
12 these models and correlations which are not in either code  
13 that we're familiar with and how do they affect the behavior  
14 of this code?

15 We have installed the code. We've built the code;  
16 it does run.

17 MR. KRESS: When you install code on your system,  
18 there needs to be some sort of reactor it's applied to,  
19 because that's part of the code.

20 MR. LANDRY: Right.

21 MR. KRESS: Do you use the surrogate reactor or a  
22 specific reactor?

23 MR. LANDRY: Well, RELAP-5 comes with set cases.

24 MR. KRESS: It has some set cases?

25 MR. LANDRY: Right.

1 MR. KRESS: As part of the input.

2 MR. LANDRY: Yes.

3 MR. KRESS: Okay.

4 MR. LANDRY: When you build the code, anytime you  
5 build RELAP-5, there are set cases that run. You have to  
6 physically tell it don't run these cases when you build.  
7 Otherwise, the default is to run them to test and see that  
8 the installation is correct, that it has built the code and  
9 that it is functioning properly.

10 MR. KRESS: That sounds like a good idea.

11 MR. LANDRY: Yes; that's been in RELAP-5 mod 1,  
12 mod 1.5, mod 2, on every generation of RELAP-5.

13 MR. WALLIS: Isn't this the big contribution of  
14 the LOFT program, which sort of justified the code as the  
15 code could be made to eventually fit LOFT?

16 MR. LANDRY: Thank you for bringing that up.

17 [Laughter.]

18 MR. LANDRY: That was one of the high points back  
19 in the LOFT program, as one that worked on LOFT for years  
20 that we kept RELAP-5 -- we felt it was an important code and  
21 kept it as part of the LOFT program in its initial stages.

22 [Pause.]

23 MR. WALLIS: These -- the pieces that are put  
24 together are from, very often, academic experiments in  
25 systems that look very different from a reactor system.

1 Amazing that they work when applied to something as  
2 complicated as LOFT.

3 MR. LANDRY: LOFT was -- not to prejudice my  
4 discussion, but LOFT, I thought, was an excellent tool.

5 MR. WALLIS: You'd have to have something like  
6 that. Without the big experiments, we don't have much to  
7 stand on.

8 MR. LANDRY: I enjoyed working on the LOFT project  
9 very much. It was a unique program in that it was a real  
10 nuclear reactor that we could take through locas,  
11 transients, et cetera, the only program that has ever  
12 existed that we could do that. I guess you don't want to  
13 hear a sales pitch on that.

14 [Laughter.]

15 MR. LANDRY: The schedule which we have put  
16 together, and as I said, Siemens has not seen this internal  
17 part yet, we have done the acceptance review. We have  
18 completed the acceptance review. That is moving through the  
19 concurrence. Our plan at this point is to issue REIs  
20 formally to Siemens in early to mid-May. We plan to issue  
21 to them electronically, through email, questions as they  
22 come up and then follow up with a formal list of REIs in  
23 early to mid-May. We would ask that they respond to those  
24 by mid-July, or, if they can't respond by mid-July, then,  
25 we'll have to negotiate an end date again. We need

1 responses by mid-July so that we can aim for an SER dealing  
2 with the small-break loca use of the code by the end of the  
3 fiscal year, the end of September, and we would also aim for  
4 an SER on the transient application, the chapter 15  
5 application, of the code by the end of the calendar year.

6 Now, this is a very aggressive schedule. We feel  
7 like we can go with an aggressive schedule like this because  
8 we know RELAP-5 to begin with very thoroughly. It's the  
9 additions and the interactions of those additions that we  
10 have to look at and that we want to understand with this  
11 code.

12 MR. ZUBER: Let me ask you: does that provide the  
13 justifications for making a hybrid code for making these  
14 changes?

15 MR. LANDRY: Yes, because what they've done is  
16 they've taken the ANF RELAP code, which is the predecessor,  
17 built it in to more modern numerics, more modern models  
18 taken from mod 3 into the code, and they've put in some  
19 evaluation models into the code, and they've tried to get  
20 rid of some of the necessity that they had with ANF RELAB of  
21 having input from rod X into the code then feed this into  
22 2D2 and do the entire calculation by going through a series  
23 of codes. They've tried to streamline it into one more  
24 modern code to do the entire calculation.

25 Now, this code is also the basis for their best

1 estimate of more realistic loca, which they have not  
2 submitted yet but which we will probably be receiving  
3 sometime in the future, so this is an interim stage in the  
4 path to getting the realistic loca.

5 MR. SCHROCK: I misunderstood that. In your  
6 introduction, I thought you said it is for best estimate  
7 transients.

8 MR. LANDRY: No, it's for non-loca transients, and  
9 it is for small-break loca but in an evaluation model mode.  
10 This has the models to meet the evaluation model  
11 requirements, Appendix K requirements.

12 MR. SCHROCK: Yes.

13 MR. WALLIS: The word conservative appears several  
14 times in the documentation.

15 MR. LANDRY: Yes.

16 MR. WALLIS: A conservative choice and  
17 correlation, which indicates that it's not best estimate.

18 MR. LANDRY: Because they're trying to follow the  
19 path of Appendix K evaluation model at this point. The  
20 realistic loca is coming at a later date.

21 MR. KRESS: Where do we fit into this schedule?

22 MR. LANDRY: We haven't negotiated that yet with  
23 the chairman, but we would have to meet with you in time to  
24 get REIs or get your comments back.

25 MR. WALLIS: That's why I'm a little nervous about

1 that, so I'm not sure where we should fit in there. I've  
2 read as far as I got on the documentation, and the way I  
3 review it is that I write down comments almost every page.  
4 But it seems rather inappropriate to send all that stuff to  
5 Siemens.

6 MR. LANDRY: Yes; we need to talk with you and get  
7 your feedback sometime today or in the next few days after  
8 you've had time to think about it; get the committee's views  
9 on when you would like to discuss this code further.

10 MR. WALLIS: Today, we have 15 minutes for  
11 Siemens, which isn't going to be time for anything.  
12 Someday, we're going to have two days with Siemens or  
13 something, aren't we, where they actually walk us through  
14 and give us -- do we intend to do that?

15 MR. LANDRY: We haven't discussed that with them  
16 at this point.

17 MR. WALLIS: Or do we rely on you to do such a  
18 good job that we just see what you did at the end?

19 MR. LANDRY: I would prefer to have Siemens  
20 present their code.

21 MR. WALLIS: Okay; so, we'll work on that. We'll  
22 work on the schedule.

23 MR. LANDRY: That's all I had on the SRELAP-5.  
24 Jim Mallay from Siemens is going to present --

25 MR. WALLIS: You've almost got us on schedule.

1 MR. LANDRY: Jim Mallay from Siemens is going to  
2 present their information.

3 MR. WALLIS: We're looking forward very much to  
4 hearing from you.

5 MR. MALLAY: I need some instruction on the  
6 turn-on here.

7 MR. WALLIS: That's the first test.

8 MR. MALLAY: That's the first test. On the front  
9 thing? Yes.

10 MR. WALLIS: Or are you too big to notice?

11 MR. MALLAY: Yes; perhaps a little dark.

12 Good morning; I'm Jim Mallay. I'm director of  
13 regulatory affairs for Siemens Power Corporation, and I just  
14 wanted to take a moment to do a little introduction. I've  
15 brought three other people here from Siemens. Sitting  
16 behind you is Robin Feuerbacher. He's our vice president  
17 of engineering, and I want him to say a few words later on  
18 here. Sitting next to him is Jerry Holm. Jerry is the  
19 manager of our PWR product licensing, and the next gentleman  
20 is Larry O'Dell. Larry is the manager of research and  
21 technology for U.S. and Far East for Siemens, and he is also  
22 specifically the project manager for the SRELAP code.

23 The reason I've brought these people is that this  
24 is the team you're going to be seeing. If we have to make  
25 presentations before you, I just wanted to let you know who

1 these people are. Each is going to say a couple of words  
2 here this morning, but I thought it was important that we  
3 introduce ourselves so you know who we are.

4 MR. ZUBER: Let me ask you: are you going to use  
5 this same code in Germany or only in the States?

6 MR. MALLAY: I'll let Mr. O'Dell address that, if  
7 you would, Larry.

8 MR. O'DELL: It's already being used in PWRs and  
9 BWRs in --

10 SPEAKER: Could you identify yourself for the  
11 record?

12 MR. O'DELL: Larry O'Dell, Siemens Power  
13 Corporation. We're already using the code in Germany. It's  
14 being used for PWR plants in both Europe and South America,  
15 and it's also being used for BWR plants.

16 MR. ZUBER: This same version that you're going to  
17 get approved here?

18 MR. O'DELL: Well, in essentially the same  
19 version. We can get into the code control process if you  
20 want, but the way that we control the code is that we have  
21 specific versions. Those versions never change. So from  
22 that standpoint, it's frozen. The code that's been  
23 submitted with the submittals here for the non-loca and  
24 small-break loca, those are frozen versions of the code. If  
25 you come back 10 years from now, assuming that I have a

1 computer that I can still compile an older code on, I will  
2 have the code to compile, okay? So in the code control  
3 process, that is a frozen version of the code.

4 MR. MALLAY: Thank you, Larry.

5 What I'd like to do this morning is introduce a  
6 few key people, which I've done. I wanted to summarize our  
7 strategy for the application of the S-RELAP5, and Larry  
8 O'Dell is going to take a few moments to do that for us, and  
9 our third purpose here is to get to know a little bit more  
10 about what your expectations are of us, and of course, we've  
11 heard that a good deal this morning in terms of the  
12 discussion of some of the other codes.

13 MR. POWERS: Let me ask Larry one question in that  
14 regard. This subcommittee tends to ask questions like  
15 what's the numerical algorithm that's being used here;  
16 what's the physical basis of this; why is it experimental.  
17 Who is going to answer those kinds of questions among these  
18 key people?

19 MR. MALLAY: Mr. O'Dell will address those, not  
20 today, of course, but, yes, eventually.

21 MR. POWERS: Okay; so, he has an intimate  
22 understanding of all of that?

23 MR. MALLAY: Absolutely; yes, he does.

24 MR. WALLIS: Do you want feedback on the last item  
25 there?

1 MR. MALLAY: Yes, if you're prepared to do that,  
2 I'd certainly like that. On the other hand, no, if that's  
3 something that we can take care of in a future meeting,  
4 that's fine, too, but what I wanted to let you know is --

5 MR. WALLIS: The overriding expectation is at a  
6 somewhat high level, we want to get a distinct impression  
7 and more than an impression sort of assurance that what's  
8 being done here is being done in a thorough, professional  
9 way, that we don't find surprises. We don't look at some  
10 formulation, at some part of the documentation and say wait  
11 a minute.

12 MR. MALLAY: I think we can assure you that from  
13 the standpoint that the code has been used in a number of  
14 applications already, and we have dealt -- worked with the  
15 code for the last 2 years to try to shake it down as best we  
16 could. We come with a commitment.

17 MR. ZUBER: This is really not a straightforward  
18 answer, because if you have something which is basically  
19 wrong, and you have so many coefficients, you can adjust;  
20 presumably by joining these coefficients, I can predict  
21 something, you still didn't address the earlier questions,  
22 is that really physically the approach; the physics is  
23 incorrect or not.

24 MR. MALLAY: Part of the documentation we're going  
25 to be submitting is individual test cases of separate

1 effects tests, if you will, not just an integral test, but  
2 also, we've been asked by the staff to demonstrate that  
3 individual physical processes are modeled properly. I think  
4 that answers your question.

5 MR. WALLIS: In terms of completeness, it's a good  
6 -- the technical documentation is good. It's readable; it's  
7 understandable. You can follow the arguments and so on.  
8 There are not many mistakes in there. But there seemed to  
9 me to be omissions that, for instance, we bring up now: you  
10 have a momentum equation for straight pipes with a very slow  
11 area change. Now, that's fine as long as reactors are made  
12 out of straight pipes with slow area change. How do you  
13 apply it to a real reactor geometry? That's not at all  
14 clear to me.

15 MR. MALLAY: I'm not sure we're prepared to  
16 address that today in terms of the time we have.

17 MR. WALLIS: That's the kind of question we have,  
18 I think, as an overview.

19 MR. MALLAY: Right.

20 MR. WALLIS: Is yes, they've done this, and  
21 they've given this thing for a straight pipe. I don't see  
22 how they're going to use that in all of the situations in a  
23 nuclear reactor. That's the sort of level I think we're  
24 going to be at.

25 MR. MALLAY: Okay.

1 MR. WALLIS: Occasionally, we may go down and say  
2 why did you choose Zuber's correlation, which we know is  
3 false.

4 [Laughter.]

5 MR. WALLIS: But not very often.

6 [Laughter.]

7 MR. ZUBER: It depends on how much life insurance  
8 you get.

9 [Laughter.]

10 MR. MALLAY: No, I think we understand that  
11 expectation.

12 Anyway, I'd like to introduce Larry O'Dell. He  
13 will take you through, very briefly, what our expectations  
14 are for the application of the S-RELAP5 code to our PWRs and  
15 also eventually to our BWRs.

16 Larry, it's all yours.

17 [Pause.]

18 MR. O'DELL: As Jim indicated, I'm manager in the  
19 Siemens Power Corporation Research and Development area. I  
20 have also within my assignments the project manager of the  
21 realistic large-break loca.

22 MR. ZUBER: Are you located here, or are you in  
23 Germany?

24 MR. O'DELL: I'm in the Richland facilities in  
25 Richland, Washington.

1 MR. ZUBER: Okay.

2 MR. O'DELL: And I think one thing I would like to  
3 correct relative to what Jim said is I'm not the S-RELAP5  
4 code expert. The S-RELAP5 code itself will be defended by  
5 Joe Kelly and Dr. Hu Ming Chow, which Chow has been  
6 intimately involved in the development of the S-RELAP5 code,  
7 I think essentially from the very beginning.

8 MR. WALLIS: So we can ask Joe Kelly the questions  
9 that he asked when he was here.

10 MR. O'DELL: It would be an opportunity to turn it  
11 around, I would think, yes.

12 [Laughter.]

13 MR. ZUBER: You can see the elasticity that Joe  
14 has.

15 [Laughter.]

16 MR. O'DELL: The objective of today's discussion,  
17 I think, is just to introduce the Siemens overall strategy  
18 for the application of the S-RELAP5 code in the performance  
19 of safety analysis. In the near term, as we already have a  
20 couple of the submittals in for the PWRs and in the  
21 long-term application to the BWRs in the U.S.

22 As I believe Ralph Landry already indicated, the  
23 code -- the original basis of the code is the RELAP5 mod 2,  
24 INEEL Cycle 36.02 version of the code. Siemens has made  
25 significant modifications to support the use of the code for

1 chapter 15 loca and non-loca transients. Our primary  
2 concentration in S-RELAP5 was originally and continues to be  
3 the realistic loca work. One of our biggest changes with  
4 the addition of 2D thermal-hydraulic capabilities to the  
5 code; we've also included RELAP5 mod 3 features and models.

6 MR. KRESS: 2D thermal-hydraulics, is that testing  
7 the core region?

8 MR. O'DELL: No, in the realistic loca, for  
9 example, it can be applied in any volume within the model,  
10 okay? But we apply it right now in realistic loca and  
11 downcomer core in Upper Plymouth.

12 MR. KRESS: Thank you.

13 MR. WALLIS: I noticed in reading the  
14 documentation, quite often, you make statements such as  
15 something which was in RELAP5 mod 2 didn't work too well, so  
16 we have changed it to something else. It occurs fairly  
17 often, so a better correlation or something is called for.

18 MR. O'DELL: Right, as we've gone through the  
19 process of assessments and stuff, we've tried to do that.

20 MR. WALLIS: And that isn't always justified, that  
21 you've changed it.

22 MR. O'DELL: Yes.

23 MR. WALLIS: I assume that somewhere, there is a  
24 justification for why what you put in is better than what  
25 was there before.

1 MR. O'DELL: Okay; what you'll see in the  
2 realistic loca submittal, you'll have the code documentation  
3 that you've already got, that there will be an extensive  
4 verification and validation.

5 MR. WALLIS: That's at the first model, and the  
6 fact that some detail was changed -- it's hard to see that  
7 that actually made a difference.

8 MR. O'DELL: Probably not in the assessment  
9 document. The assessments document will look primarily at  
10 the current code, the frozen version of the code that we're  
11 submitting and how it performs in the --

12 MR. WALLIS: So, it would be all of the changes,  
13 the vector integral --

14 MR. O'DELL: In effect.

15 MR. ZUBER: Did you assess it against UPTF?

16 MR. O'DELL: Yes.

17 MR. ZUBER: And this is already submitted to the  
18 staff?

19 MR. O'DELL: I believe one of the tests is in the  
20 small break locas, in the UPTF test. But there's a  
21 significant number of UPTF tests that will be coming in on  
22 the realistic locas.

23 MR. ZUBER: Great.

24 MR. O'DELL: As I indicate here, we had kind of a  
25 range of submittals because of the iteration process of the

1 CSMU approach. We were saying originally June to November.  
2 The current best target date, I'd say, is on September based  
3 on the schedules and stuff.

4 MR. WALLIS: Are you following the CSAU approach?

5 MR. O'DELL: Yes.

6 With respect to the RELAP5 mod 3 features, we've  
7 restructured the code for improved portability, and we've  
8 directly included the reactor kinetics control systems and  
9 trip systems out of the RELAP5 mod 3.

10 MR. WALLIS: I'll just note for the record that  
11 Dr. Shack has joined us. He's a member of ACRS, another  
12 expert on thermal-hydraulics.

13 MR. O'DELL: With respect to PWR applications, the  
14 code is currently being used by our counterparts in SKWU to  
15 support both European and South American plants. Our  
16 current U.S. submittals, as Ralph Landry indicated, was the  
17 chapter 15 non-loca analysis and the small break loca  
18 analysis methodology, and our planned submittal for the  
19 realistic large-break loca, as I previously indicated, is  
20 the June to November time frame, with the current best  
21 target being September.

22 The drivers for this is basically to support the  
23 CP&L H.B. Robinson and Sharon Harris plants.

24 MR. WALLIS: Why are they doing large-break loca  
25 at -- are they expecting some change in the plant they want

1 to justify?

2 MR. O'DELL: Well, yes, there are changes in the  
3 plant they want to justify. They want to be able to look at  
4 trying to do such things as delay the time that the diesel  
5 generators have to come on and those kinds of improvements  
6 and just operational capabilities at the plant.

7 Longer-term BWR applications; again, the code is  
8 being used by Siemens KWU to support the European BWRs. The  
9 development projects for the U.S. applications intend to be  
10 initiated next fiscal year. We looked at both uses of the  
11 code for the non-loca transient analysis and small and large  
12 break locas. Again, the PWR realistic large-break loca  
13 methodology, we are following a CSAU approach. We have  
14 reviewed the ACRS minutes relative to the Westinghouse  
15 review and are incorporating that feedback. We've gone  
16 through the code and documentation verification that has  
17 been performed. We have used both Siemens' in-house  
18 personnel, INEEL personnel and Duke Engineering Services  
19 personnel to perform that verification.

20 We've developed the PIRT in-house. We've  
21 performed peer review. Marv Thurgood, Joe Kelly and Dr.  
22 Hochreiter participated in that. I should indicate that Dr.  
23 Hochreiter is acting as a consultant for CP&L in this  
24 process.

25 The nuclear power plant model has been developed.

1 We've performed numerous sensitivity studies, and we've  
2 conducted a peer review of that model and got concurrence  
3 with going forward with the model that we have currently  
4 developed.

5 MR. ZUBER: The peer review, who were the members?

6 MR. O'DELL: Well, there was a number of Siemens  
7 personnel: Jean Jensen, Rich Katulla, and then Joe Kelly  
8 participated in it; Dr. Hochreiter participated in it; Marv  
9 Thurgood participated in it. We've been trying to bring in  
10 both in-house and outside personnel to perform these  
11 reviews.

12 The assessment matrix has been established. It  
13 was based on the PIRT and the results of the sensitivities  
14 we have performed, both on the PIRT phenomena in the plant  
15 conditions. It addresses, we believe, the scalability and  
16 consangair issues, and again, we've conducted a peer review  
17 with basically the same people indicated to obtain agreement  
18 on that assessment matrix.

19 The current efforts, we're in what I would hope  
20 are the final assessments. We're going through those  
21 assessments now to determine the associated uncertainties  
22 and biases. Once we have done that, again, we will have  
23 another peer review of those assessment results to basically  
24 finalize it, we hope. And we're also in the process of  
25 developing the software for performance of the statistical

1 plan analysis. We have, again, bringing in outside support.  
2 We've got statistical support being provided by Dr. John  
3 Jaech.

4 With respect to the realistic large-break loca, we  
5 are striving to meet what we believe and understand to be  
6 the documentation requirements. We intend to provide a  
7 detailed methodology document with a methodology road map,  
8 which I think was indicated in your previous review. We  
9 intend to follow the CSAU outline so that there will be a  
10 one-to-one correspondence in the documentation.

11 MR. WALLIS: The road map, I looked at the models  
12 and correlations code manual. It describes all of these  
13 efforts in the code. Now, before you do a code, you really  
14 need to define the code.

15 MR. O'DELL: Right.

16 MR. WALLIS: You need to say this code is intended  
17 to make these kinds of predictions for these kinds of  
18 systems, and you need to say it's got to be able to handle  
19 these kinds of situations, these kinds of -- and these kinds  
20 of geometries in these kinds of situations. Then, you need  
21 to compare what it will do against those sorts of  
22 specifications for whatever you intend it to do. Is that  
23 done, or is it done sort of backwards? I get the impression  
24 it's done backwards. Some of it, here's the code, and then,  
25 it's applied.

1 MR. O'DELL: Well, I guess I don't agree with  
2 that. We started off our process; we looked at the  
3 possibility of using TRAC; we looked at the possibility of  
4 using RELAP5. We went through an evaluation of the two.  
5 The biggest thing in favor of RELAP5, obviously, was we had  
6 in-house personnel who understood and knew the code, okay?  
7 We have gone through, you know, this is like the third or  
8 fourth iteration on the assessments or a subset of the  
9 assessments, because we didn't have the full assessment  
10 matrix until we went through the sensitivity analysis, and  
11 again, we concentrated on integral experiments, so that you  
12 had the results of those types of calculations, and we  
13 concluded that the code was capable of doing the  
14 calculations with certain exceptions, and we went in, and we  
15 tried to include those.

16 MR. WALLIS: Kind of implied feedback loop there.

17 MR. O'DELL: Yes; there has been a definite  
18 looping to this process as we've been going through it.

19 MR. WALLIS: That was going back to the question I  
20 sort of asked earlier. I see control volume drawn and an  
21 equation derived from the control, but it really doesn't  
22 have anything to do with the kind of control volumes I'm  
23 going to see in a reactor. And I have a question: why  
24 didn't someone say these are the kinds of control volumes  
25 we're going to have in a reactor? This is why we have this

1 equation, which works on all of them, and when it doesn't  
2 work, how do you fix it? I'd like to see something like  
3 that rather than seeing control volume, which is sort of  
4 academic for straight pipe or something or the nozzles.  
5 This really isn't related to the engineering component.

6 MR. O'DELL: Right, and I understand that.  
7 Basically, the way we were looking at the approach was  
8 you've got models, okay, and you come up with the basic  
9 models. The proof of those models is in the assessment  
10 process. It's been going through the assessment.

11 MR. WALLIS: But, as Dr. Zuber said, when you've  
12 got enough coefficients, you can sort of fix it up, and if  
13 you haven't at a very fundamental level said we've got to  
14 develop a structure, a fundamental equation which applies to  
15 the kinds of things that we're going to see in a reactor.  
16 That's the level I think it should be done at, not fixed up  
17 later on with something which might not apply to those but  
18 then with a whole other coefficient so that it works.

19 MR. O'DELL: Okay.

20 MR. WALLIS: That makes the community look sort of  
21 foolish.

22 MR. O'DELL: And I would agree with that. We're  
23 not doing it as part of our submittal. You will get a  
24 document that says this is how we build the plant model;  
25 this is the volumes that are in the plant model; these are

1 the correlations that you use when you're running the  
2 realistic loca calculations. So, you will have a document  
3 in front of you that says we turn on these correlations, and  
4 this is the way we model the plant.

5 MR. ZUBER: But you can then justify why you did  
6 it.

7 MR. O'DELL: And that will be done through the  
8 assessments, because we're going to be --

9 MR. ZUBER: The model can justify even before the  
10 assessments. I'm using this for this and this reason; then,  
11 I'm going to assess and see what -- and I think you're in a  
12 better position then.

13 MR. O'DELL: Okay.

14 MR. ZUBER: Because if you do it after you assess  
15 it, you can always skew the coefficients and the hot issues  
16 okay, and you start from a wrong premise. But if you have a  
17 good base this time using this control rod, whatever it is  
18 for this and this reason, and then, you assess it and you  
19 run a calculation and assess it, you are okay.

20 MR. O'DELL: Right.

21 MR. ZUBER: I mean, after the assessments, how is  
22 this okay? Because you have so many coefficients.

23 MR. O'DELL: And really, we've gone through that  
24 process. It may not be documented in the current  
25 documentation that way, but you obviously go through that

1 process, because when you're putting together the plant  
2 model, you're deciding which one of these correlations that  
3 you're going to turn on and which ones you're not going to  
4 use.

5 MR. WALLIS: It goes back to the higher level that  
6 I see in the documentation, just pick anything, a natural  
7 convection or equations that are there, and they are there  
8 stated to be for large vertical plates in a huge environment  
9 with no convection. Well, you never get that in a reactor,  
10 so what are you going to use this for, because you never  
11 have large vertical plates in a reactor? And I think it's  
12 because they need to put something in the code somewhere,  
13 and they grab something available. I don't see what the  
14 connection is between the equation of correlation developed  
15 for some purpose and then used for another one. That's the  
16 sort of difficulty I have sometimes.

17 MR. ZUBER: See, let me say something. Eventually  
18 -- not this year but maybe in three or four years -- there  
19 will be a need to fit the safety markets, I mean, to come  
20 closer to increase the power. Then, you have to really know  
21 what is the effect of these assumptions? What is the effect  
22 of this approach? And I think if you do it to standard, you  
23 see, what you are really doing, you are really relying on  
24 something which was developed 30 years ago, RELAP and TRAC.  
25 At this stage, you could prepare a document or something

1 which you provides a better basis for what you are doing,  
2 that says I am using this because of this, this, this, this  
3 and this, and the results is this. And then, you are in a  
4 much better position. You are addressing the problem from  
5 the beginning, not to try to justify at the very end.  
6 Because you are doing something which was developed 25 years  
7 ago. And you are going to use this something which you have  
8 the corporate environment for the next 25 years, and you  
9 have to think about that.

10 MR. O'DELL: I understand.

11 MR. ZUBER: And if you prepare a document, let's  
12 say, by December, which will address these fundamental or  
13 basic questions and submit it, you are in a better position.

14 MR. O'DELL: And I think that, you know, that  
15 would go in -- where I would see that going into is the  
16 document that describes the plan model that we use and our  
17 selection of the various correlations and stuff in that and  
18 the justification for why we selected this.

19 MR. SCHROCK: But Ralph gave us a staff  
20 anticipated schedule for the review of S-RELAP5 that  
21 pertains to this application to the EM evaluation of  
22 transients in small-break loca.

23 MR. O'DELL: Right.

24 MR. SCHROCK: And a lot of what you've talked  
25 about here is emphasizing large-break loca. Is this going

1 to be a subsequent review in your review?

2 MR. O'DELL: Yes, yes.

3 MR. SCHROCK: In what time frame?

4 MR. O'DELL: Well, I indicated that because of the  
5 iterative nature of the CSAU approach, we have basically  
6 only been saying like June to November. If you look at the  
7 schedules as currently laid out with where we are, the best  
8 guess target is September for the submittal.

9 MR. SCHROCK: Meaning that you will give to NRC  
10 something to review --

11 MR. O'DELL: Exactly.

12 MR. SCHROCK: -- for the best estimate of  
13 large-break loca at that time.

14 MR. O'DELL: Yes.

15 MR. ZUBER: But, then, you have enough time to  
16 hopefully address some of these questions which were raised  
17 today here.

18 MR. O'DELL: Right, and I can go back and do a  
19 review of the document. We already have, obviously, a draft  
20 of that document put together. We put it together right  
21 after the peer review was conducted. So I would go back and  
22 review that and see if we've got that level of detail in  
23 that document.

24 Okay; I think that's all I've got at this point.

25 MR. WALLIS: Thank you very much.

1 MR. FEUERBACHER: Good morning. My name is Robin  
2 Feuerbacher. My role at Siemens Power Corporation is  
3 vice-president of engineering. In that function, my  
4 organizations are responsible for both the development and  
5 application of neutronics and safety analysis methodologies  
6 for boiling water reactors and pressurized water reactors.

7 Along with Larry and Jim, I'm also located in the  
8 Richland, Washington facility. Again, thank you for the  
9 opportunity to present an overview of our plans with  
10 S-RELAP5 today. Siemens Power Corporation, in conjunction  
11 with Siemens KWU in Germany, has invested a large amount of  
12 resources into the development of S-RELAP5 and for this  
13 upgrade in our safety analysis methodology. The company is  
14 committed to this upgrade. We will continue to assign  
15 resources, both internal staff time and outside expert  
16 consultants, to support a timely review of this process. We  
17 are willing to meet as frequently to discuss the submittals  
18 both here and at our Richland facility if that will  
19 facilitate the reviews.

20 In closing, the S-RELAP5 upgrade of the safety  
21 analysis methodology is very critical to Siemens Power  
22 Corporation supporting our customers with the operation of  
23 their nuclear power plants and their requirements. For the  
24 realistic large-break loca methodology which Larry O'Dell  
25 stated we'll submit in September, we request a timely review

1 of that with the targeted approval by early 2002.

2 Again, thank you for your time and your comments.  
3 Questions?

4 MR. WALLIS: Are we ready for a break? No  
5 statements allowed. Any questions?

6 [No response.]

7 MR. WALLIS: Let's break, and then, we're going to  
8 come back after the break, and maybe we can summarize where  
9 we are.

10 [Recess.]

11 MR. WALLIS: Please come back into session. We're  
12 on time.

13 Back to you, Ralph.

14 MR. LANDRY: Okay; the third code that we have  
15 in-house for review is the TRACG code from General Electric.  
16 TRACG is -- documentation has been submitted for the review.  
17 However, they have not submitted to us the code itself. We  
18 have not received the first code or a binary for the code.  
19 So the actual acceptance review will not proceed until the  
20 code is submitted. We will be meeting with the General  
21 Electric staff tomorrow afternoon, so we will be again  
22 emphasizing that to them that we need the code.

23 Our experience so far has been very positive and  
24 very good of having a copy of the code to work with during  
25 our review.

1 MR. ZUBER: Is there a big difference between  
2 TRACG and TRACF?

3 MR. LANDRY: Yes; this is General Electric's heavy  
4 modifications of the TRAC code.

5 The code that we have in for review is for review  
6 of BWR transient applications, the anticipated operational  
7 occurrences. We've received reports on January, February to  
8 review this material.

9 Some of the documentation which has been  
10 submitted: there's the TRACG licensing application  
11 framework for AOO transient analyses. I believe Jens will  
12 be -- Jens Andersen will be doing the presentation.

13 MR. ANDERSEN: That is correct.

14 MR. LANDRY: He will be doing the presentation  
15 after I get done, and he will tell you a little more about  
16 the code.

17 We've received the TRACG model description  
18 document, the application for anticipated operational  
19 occurrences analyses document; the qualification document  
20 and the users manual. These materials have been provided to  
21 the ACRS staff to make copies for the ACRS subcommittee  
22 members.

23 MR. WALLIS: Are these very large?

24 MR. LANDRY: Yes; it's a sizeable stack of paper.

25 Looking at the material which we have received to

1 date, the documentation does appear to be very thorough.  
2 The code, we note, did receive a very extensive review  
3 during the SBWR review, even though that was a short time  
4 that that was in. The code did receive a fairly heavy  
5 review at that point. There are some materials that have  
6 been improved since then, and I indicated that the actual  
7 review will be able to determine how this compares with the  
8 material which we had during the SBWR review.

9 And, again, I note that the code itself has not  
10 been submitted.

11 MR. KRESS: Is that the three codes that you're  
12 simultaneously reviewing for different purposes? How many  
13 staff is that?

14 MR. LANDRY: It's the gang of four.

15 MR. KRESS: The gang of four?

16 MR. LANDRY: Minus one.

17 [Laughter.]

18 MR. LANDRY: Okay; no, the four of us that did the  
19 review on RETRAN-3D plus one of those staff members is on  
20 rotation to the EDO's staff for two months, so we're --

21 MR. KRESS: You guys are busy.

22 MR. LANDRY: We're scrambling.

23 MR. POWERS: Does that having one of them on  
24 rotation improve or detract from the productivity of the  
25 other three?

1 [Laughter.]

2 MR. LANDRY: Detracts. It doesn't help us.

3 MR. POWERS: Okay.

4 MR. LANDRY: Makes it more of a challenge for us.

5 Once the code itself has been submitted, we'll  
6 take this up, as I said, with GE tomorrow, the acceptance  
7 review will start, and we anticipate, again, one month's  
8 time to perform the acceptance review.

9 MR. WALLIS: It's interesting that you can budget  
10 your time. This seems to me such an open-ended thing; you  
11 never quite know what you're going to find, so this one  
12 month has -- it's a preliminary estimate.

13 MR. LANDRY: That's just to do an acceptance  
14 review. That's not to --

15 MR. KRESS: To look at the material.

16 MR. LANDRY: We had been hoping that these codes  
17 would be staggered with long times between when we were to  
18 receive them. However, they are now starting to stack up  
19 and coming in fairly close together.

20 MR. KRESS: Your criteria for accepting an  
21 acceptance review is that you have sufficient documentation  
22 that's complete enough for you to actually carry on a  
23 review?

24 MR. LANDRY: That is correct.

25 MR. KRESS: Basically?

1 MR. LANDRY: Right; that the documentation appears  
2 to be complete or is sufficient to permit us to do a review;  
3 describes the code; describes how the code was used;  
4 describes how the code is assessed or qualified for the  
5 particular uses, and we also insist on the code itself so  
6 that we can exercise the code ourselves.

7 MR. KRESS: But you have enough that you could  
8 actually carry on the review.

9 MR. LANDRY: Yes.

10 MR. POWERS: When the code documentation  
11 references reports and things like that, do you get those  
12 references, or if you want them, they're just available to  
13 you?

14 MR. LANDRY: That depends on what the references  
15 are. If they're company proprietary references, such as  
16 some documents that GE might have, we can request those  
17 documents. If they're to open literature materials, then,  
18 we can go obtain those ourselves. But if there is material  
19 that is referenced that we feel is essential to the review,  
20 yes, we will request that material.

21 MR. POWERS: You don't accept references like  
22 personal communications?

23 MR. CARUSO: Well, one other thing we do is, and  
24 we've done this a couple of times in the last couple of  
25 months, is we send people to the licensee's site to actually

1 look at the documentation, and that has turned out to be  
2 very useful, because there, they can get at the actual  
3 source documents and the people there to answer the  
4 questions: why did you write this down this way? And we're  
5 doing on-site reviews in some cases.

6 MR. POWERS: Okay.

7 MR. LANDRY: If you mean personal communication as  
8 in answering a question --

9 MR. POWERS: No, I'm -- it says we adopted this  
10 correlation because it's better than something else;  
11 reference communications Joe Blow, personal communication,  
12 Joe Blow, 1995.

13 MR. LANDRY: We'd have to do some digging.

14 MR. POWERS: Yes.

15 MR. CARUSO: I would wonder if something like that  
16 would meet the requirements of appendix B.

17 MR. POWERS: Yes.

18 [Laughter.]

19 MR. LANDRY: I don't know that we've come across  
20 that situation.

21 MR. WALLIS: You don't have a standard review  
22 plan. If you had one, and if it had items in it such as  
23 every correlation must be checked for its application to  
24 full scale, the reactor on the conditions, and this might  
25 take you more than a month to just do that. If you had all

1 of these items really seriously listed out on a standard  
2 review plan, and you did them conscientiously, you might  
3 find that it took a long time.

4 MR. ZUBER: There are two things. If they had it,  
5 this could really expedite your review, because you just go  
6 by items. But that question was raised when the CSAU was  
7 really discussed 10 years ago or 15 years ago, and this is  
8 the reason we wanted to have this development code in the  
9 other documents, and really, this was never really done  
10 properly. It was difficult; actually, Lawson never wanted  
11 to do it, but if you have something like this, and then, the  
12 applicant comes and says yes, this is done because of this  
13 and this, you can do it very fast, and they could also save  
14 money.

15 MR. LANDRY: I think the code models document that  
16 we have with TRACG, we haven't gone through in detail yet,  
17 and we haven't really reviewed for acceptance, but just as a  
18 fast skim-through, has a great deal of this same kind of  
19 information in it.

20 MR. ZUBER: See, but what you can do is prepare a  
21 list of something like this. This is what I would like to  
22 see for them; this is what I would like to see for -- is it  
23 addressed? And you can give it to the applicant: look at  
24 this. Tell me what it is.

25 MR. LANDRY: We're going in that direction with

1 the SRP and with the reg guide as soon as those get out.

2 MR. ZUBER: No, the reg guide is too short, too  
3 short. I mean, you would have a list or something.

4 MR. LANDRY: But the SRP is going in that  
5 direction. We're looking at all of the content of different  
6 transient, different analyses. So that material is coming.

7 MR. WALLIS: When you say acceptance review, that  
8 doesn't mean an SER.

9 MR. LANDRY: No, that means that we are accepting  
10 the material for review.

11 MR. WALLIS: I'm following you.

12 MR. LANDRY: The material is adequate to permit us  
13 to do a review.

14 MR. WALLIS: That's much more realistic. I'm  
15 sorry. I was sort of assuming you were going to do more  
16 than that.

17 MR. LANDRY: The acceptance review is simply to  
18 say yes, there is enough here to permit us to start a  
19 review. It may not be everything we need to write an SER,  
20 and no doubt, there will be REIs. But there is enough here  
21 that we can at least start a review.

22 MR. WALLIS: So you might find that in some areas,  
23 such as assessment, you really don't think there is enough,  
24 and you go back to that.

25 MR. LANDRY: Right.

1 MR. WALLIS: I see.

2 MR. SCHROCK: Ralph, you've been working on the  
3 reg guide and revision of the standard review plan to convey  
4 to the industry what's needed for these reviews. How is  
5 this current batch of things coming in going to be handled  
6 in the context of that new reg guide?

7 MR. LANDRY: Well, the same people are writing the  
8 reg guide and SRP that are doing the reviews, and we are  
9 really conducting these reviews based on what we're putting  
10 in the SRP. They are correspondent.

11 MR. SCHROCK: I guess the question is how is this  
12 formalized in the communications with the industry? Or is  
13 it? I mean, are they going to be able to claim that they  
14 didn't have this information before they gave -you --

15 MR. LANDRY: Well, the SRP and reg guide are not  
16 on the street yet, but we've met with all of these  
17 applicants numerous times, and we've told them every time  
18 we've met with them what we expect and what we need to  
19 perform a review. So anything that we've said in here is  
20 not a surprise, and what's in the SRP and reg guide really  
21 should not be a surprise other than they're reading the  
22 entire document, but the material should really not be a  
23 surprise, because we've discussed this with them repeatedly

24 MR. ZUBER: But this surprise to me today is when  
25 I hear the staff, which is supposed to do a review, arguing

1 where the shortcoming is, okay. This is not necessary to  
2 address, because the outside public is not involved, and  
3 there is no interest in objective knowledge. I think at  
4 that level, this is a standard which NRC should maintain.  
5 And then, we should really justify -- if you have an error,  
6 address and justify why you can -- not just this is okay;  
7 approximations are okay. That's the wrong approach for a  
8 safety agency like NRC. I think my surprise or shock is  
9 just looking at it today addressed at that level. It's a  
10 sad, sad testimony for this agency if you proceed along  
11 these lines.

12 MR. WALLIS: I think the problem is, Novik, some  
13 approximations are okay. Others are not.

14 MR. ZUBER: I agree. I always make  
15 approximations. I justify them, and I say I can live with  
16 that because of this and this. And then, you are okay.

17 MR. LANDRY: Right; that's the direction that I  
18 feel we should be going in. You can't do these analyses  
19 without approximations.

20 MR. ZUBER: Nobody argues that.

21 MR. LANDRY: But how do you justify the  
22 approximations?

23 MR. ZUBER: How you can defend it.

24 MR. LANDRY: How do you defend them, yes.

25 MR. WALLIS: To go back to Dr. Zuber's earlier

1 point, there's a difference between an approximation and an  
2 error, and I think one of your standards has got to be that  
3 you don't let something go through which some independent  
4 person then -- and he tells a graduate student to look at  
5 later on and say that's all of this that you want.

6 MR. LANDRY: That's one of our criteria, though,  
7 that until we have does not contain known errors.

8 MR. ZUBER: Okay; but they maintain that standard  
9 in the evaluation process.

10 MR. LANDRY: Yes; that's what -- we're trying to  
11 do that. We're human, but we're trying to do that. We're  
12 trying to maintain the requirement that the code, the  
13 documentation, does not contain known errors.

14 Approximations, yes.

15 MR. WALLIS: What do you mean by known errors? It  
16 doesn't contain error.

17 MR. LANDRY: Well, it doesn't contain errors you  
18 don't know.

19 MR. WALLIS: But it might contain errors that you  
20 didn't know before but you know now because you thought  
21 about them.

22 MR. LANDRY: If you find the errors, you would  
23 correct the errors.

24 MR. WALLIS: Right; okay, that's what you mean.

25 MR. LANDRY: That's the standard in all of our

1 regulations.

2 MR. WALLIS: It doesn't mean known in the sense  
3 that it was known before.

4 MR. LANDRY: Yes.

5 MR. WALLIS: No.

6 MR. LANDRY: When you find an error, you correct  
7 it.

8 MR. WALLIS: And also, longevity is no excuse for  
9 an error.

10 MR. LANDRY: That is correct.

11 [Laughter.]

12 MR. POWERS: A new piece of philosophy that I've  
13 got to record here.

14 [Laughter.]

15 MR. WALLIS: It may be an excuse for some of the  
16 remarks made by the members of this committee.

17 [Laughter.]

18 MR. WALLIS: But it is not an excuse for a  
19 technical error.

20 MR. POWERS: No.

21 MR. WALLIS: Are we ahead of time here, or do you  
22 have something else? Maybe we gave you too much time.

23 MR. LANDRY: Well, the time was pretty --

24 MR. POWERS: You just gave the members too short  
25 of a break. That's what happened.

1 [Laughter.]

2 MR. LANDRY: The time was evenly broken up, but I  
3 had hoped at this point, because we have so little to say on  
4 this code, to turn more time back to either the vendor or to  
5 the --

6 MR. WALLIS: We can look back at sort of some of  
7 the lessons learned. I mean, you've got these things now,  
8 they've asked for time for another day. You're writing SRPs  
9 on the basis of the lessons learned from these reviews.  
10 Maybe we need another forum to look at what you've learned;  
11 that if you did it again, you'd do it differently and so on.

12 MR. LANDRY: I think that might be a wrapup after  
13 we get through another couple of rounds of reviews and the  
14 SRP to talk about what did we learn.

15 MR. WALLIS: Are we ready to move on?

16 MR. LANDRY: I'll turn it over to Jens Andersen  
17 from General Electric to present the TRACG code.

18 MR. ANDERSEN: Okay; my name is Jens Andersen, and  
19 I would like to present the TRACG code that we at GE have  
20 submitted to the NRC. Personally, I am located at the GE  
21 site in Wilmington, and I have been heading up the group  
22 that has developed the TRAC code and worked on the  
23 application.

24 TRACG, we view that as a realistic code for BWR  
25 transient, and we realistic -- I mean, a code that has as

1 little bias as possible and as small uncertainty as  
2 possible.

3 MR. KRESS: But would that be another word for  
4 best estimate code?

5 MR. ANDERSEN: You could use the best estimate  
6 words name for the code. We're trying to have a realistic  
7 or a presentation of the controlling phenomena and a  
8 realistic presentation of the BWR. We have not attempted to  
9 build in conservatism in the models.

10 Okay; the code is applicable for all kinds of BWR  
11 transients, including the chapter 15 transient. It's also  
12 applicable for loca, anticipated transients without scram,  
13 stability, or activity insertions, accidents in reactor  
14 internal pressure differences. However, the focus of this  
15 submittal to the NRC is strictly on the chapter 15  
16 transients.

17 This material is probably familiar to you. TRACG  
18 is based on the TRAC code that came out of the national lab.  
19 These particulars were solved in the corporation; it was  
20 beautiful GE and Idaho National Engineering Lab in the late  
21 seventies and early eighties on the development of the BWR  
22 version of TRAC, and that's the basis for this code. It has  
23 a multidimensional model for the vessel that allows two- and  
24 three-dimensional simulation of the flow in the reactor  
25 vessel component. For the remaining internal BWR components

1 like channel, guide tubes, jet pumps, separators, the  
2 one-dimensional model is used.

3 The structure is modular, allowing a simulation of  
4 the reactor vessel as well as simulation of test facilities  
5 that are used for assessment, and this is an example on how  
6 we do it for the BWR. The kinetics model is the GE 3D core  
7 simulator that's been adapted, which is the same model that  
8 we use for our current design calculations, the PANACEA  
9 module.

10 It has a six-equation model plus additional  
11 equations for liquid boron and noncondensable gases. It has  
12 an extensive set of constitutive correlations, starting with  
13 the flow regime map and correlations for sheer heat transfer  
14 that are used dependent on the flow regime and used  
15 consistently by all of the components in the system. In  
16 addition, we have a separate component model for some of the  
17 specific components like the recirculation pump, the jet  
18 pumps, the steam separators and spatial models for the fuel  
19 channels.

20 The code has been extensively qualified, and we  
21 have done that in four steps, starting with the separate  
22 effects test; done qualification and begins component data  
23 that involved full-scale BWR component and a core system  
24 effects test that is a scaled simulation of the BWR; and  
25 finally, particularly in support of this submittal, we have

1 done an extensive amount of assessment against full-scale  
2 plant data. We have a large quantity of full-scale plant  
3 data available from plant startup testing and various events  
4 that have occurred at operating reactors, and we have used  
5 that in our assessment of the code.

6 MR. SCHROCK: Jens, would you remind us what RIPD  
7 is?

8 MR. ANDERSEN: Reactor internal pressure  
9 differences.

10 MR. WALLIS: I think that it's great that you've  
11 got full-scale plant data. It seems to me that the codes  
12 always have suffered from a lack of that, and the more that  
13 you get and the more you can use and feed back into the core  
14 evaluation, the more confidence we can have in the code.

15 MR. ANDERSEN: We have used that for that purpose  
16 and also to address the issue of scalability of the code to  
17 the full-scale conditions.

18 TRAC has been used in the past for numerous  
19 applications, and I just want to point out that the code has  
20 been around for a long time. It was used in the eighties as  
21 the benchmark for SAFER. It has been used to address issues  
22 that have come up over the time, such as the time you're in  
23 axial power shape. That's used for transient. It was used  
24 extensively for evaluation stability following the LaSalle  
25 event in 1988. It has been used for the ABWR and numerous

1 other applications, particularly, I want to point out the  
2 SBWR. It was used extensively on the SBWR project and was  
3 reviewed extensively by the NRC staff as part of this  
4 project.

5 So in summary, it has been applied for a wide  
6 range of reactor applications, and many of these have been  
7 reviewed and accepted to a various degree by the NRC.  
8 However, the current submittal, again, focuses on the  
9 applications of the chapter 15 AOO transients.

10 MR. WALLIS: What does Nordic mean here?

11 MR. ANDERSEN: Excuse me?

12 MR. WALLIS: What does Nordic mean here?

13 MR. ANDERSEN: That is the Scandinavian countries  
14 plus Finland. We have used it for some of the reactors over  
15 there.

16 Specifically, the scope of the application, we  
17 want to apply it to the current operating BWRs in the United  
18 States, BWR226. We want to apply it for the anticipated  
19 operational occurrences or transients as specified in  
20 chapter 15, which are events that involve increase and  
21 decrease in reactor pressure; increase or decrease in core  
22 flow; changes in the reactor coolant inventory and decrease  
23 in the coolant temperature in the reactor.

24 These are the same events that we are currently  
25 licensing with the ODYN/TASC code that are design codes in

1 use today.

2 Documentation that we have been submitting, same  
3 that was mentioned by Ralph Landry. It is the document that  
4 describes how we intended to use the code; a detailed model  
5 description; qualifications report and an application report  
6 where we define the statistical methodology that we use for  
7 the application of TRAC to the AOO transient. In addition,  
8 we have also supplied the users manual.

9 MR. WALLIS: Are you supplying them with the code  
10 itself?

11 MR. ANDERSEN: We will be discussing the details  
12 on how to do that within our --

13 MR. WALLIS: But you are going to do it.

14 MR. ANDERSEN: Yes.

15 MR. ZUBER: I have a question. Where did you put  
16 the stability?

17 MR. ANDERSEN: It is not included in the current  
18 submittal.

19 MR. ZUBER: I see.

20 MR. ANDERSEN: We have included stability plant  
21 data as part of the assessment of the code, but we are not  
22 asking for approval.

23 MR. ZUBER: Well, how can we not know what -- if  
24 you don't address the potential problem? I mean, the  
25 stability is really -- something can occur.

1 MR. ANDERSEN: Yes.

2 MR. ZUBER: You will ask for approval.

3 MR. ANDERSEN: We are asking for approval to the  
4 chapter 15 transients, which do not include stability.

5 MR. ZUBER: Where have you included it?

6 MR. ANDERSEN: It is not part of the chapter 15  
7 event.

8 MR. ZUBER: Where is it included?

9 MR. ANDERSEN: It's a separate issue that you have  
10 to address in fuel licensing.

11 MR. WALLIS: For these legal things.

12 MR. ZUBER: Well, that's -- it's difficult to  
13 rationalize that there is something which is not really a  
14 loca, either large or small or something, which can occur in  
15 the course of an operation, and I wouldn't, from a technical  
16 point, I would put it in operational transients, something  
17 which can occur, and if you tried to get approval for this,  
18 I would then put it under this chapter.

19 MR. ANDERSEN: Okay; the review scope is that we  
20 are requesting a safety evaluation report for the  
21 application of TRAC to the BWR transients, and we are really  
22 focusing on the application report.

23 MR. ZUBER: Let me go back. Are you going to ask  
24 or submit something which addresses the stability problem?

25 MR. ANDERSEN: I can answer your question in two

1 parts. There is an SER that has been issued by the NRC on  
2 applications to the option three plant, and TRAC is approved  
3 in that SER for some stability applications. So part of the  
4 applications of stability has already been approved.

5 Whether we want to submit applications for NRC approval  
6 beyond the AOO is something that we may do in the future,  
7 but we have not made a decision on that.

8 MR. ZUBER: But, then, you are going to have an  
9 approval with a different code and not for this code at all.

10 MR. ANDERSEN: Right now --

11 MR. ZUBER: Just I'm trying to understand; I mean,  
12 what you intend to do and how.

13 MR. ANDERSEN: Right now, stability analysis is  
14 approved with a number of codes that we have been using in  
15 the past for analysis of stability, and those approvals are  
16 still in place. We may decide to go in and ask for  
17 additional review for stability now. Technically, most of  
18 the stability analysis that is being done in support of  
19 licensing is done with frequency domain codes, where TRAC is  
20 the time -- code, and I do not foresee that we will abandon  
21 the use of frequency domain code for stability applications.

22 Okay; the reasons we are doing it are we are  
23 combining the analysis of the AOO transient into a single  
24 code. Right now, to do the analysis, we are applying a  
25 series of four or five computer codes, so we eliminate the

1 potential in errors in the data transfer between the codes.  
2 I also think we are getting a better analysis of and  
3 understanding of the process, and this would include all  
4 organizations: utilities, vendors and the regulatory  
5 organizations.

6 We get a more realistic response to the plant  
7 transient that, eventually, I believe, leads to improved  
8 safety and also can be used to justify improved operating  
9 limits for the plants by reducing the uncertainty in the  
10 code predictions. And we get a better quantification of the  
11 overall uncertainty of the code.

12 MR. KRESS: Will that be a part of this submittal,  
13 some sort of uncertainty analysis in the code?

14 MR. ANDERSEN: Yes, that is; and if I can wait  
15 just a couple of seconds to one of my next slides, I'll try  
16 and address your question.

17 MR. KRESS: Sure.

18 MR. WALLIS: You used the word better several  
19 times. Is this is an improved version of TRAC in some way?

20 MR. ANDERSEN: This is the version that was  
21 developed as a result of the cooperation between Idaho  
22 National Engineering Lab and General Electric. We worked  
23 together to develop the BWR version of TRAC, and that was  
24 the joint project between GE and Idaho National Engineering  
25 that lasted up until probably the mideighties. After 1985,

1 we made a number of additions to the code; probably most  
2 important for this application is that we incorporated the  
3 3D kinetics model that's consistent with the GE design  
4 methods. At that point, the only kinetics option that was  
5 available in TRAC was the point kinetics model.

6 MR. SCHROCK: As I recall, there was an issue at  
7 that time about whether NRC wanted to incorporate your 3D  
8 kinetics into its version of the code and make it climb. Is  
9 that --

10 MR. ANDERSEN: I don't believe that it has been  
11 discussed whether to incorporate the GE model into the NRC  
12 version of TRAC, but I think there were extensive  
13 discussions about whether a kinetics model should be  
14 incorporated into TRAC.

15 Okay; I'd like --

16 MR. WALLIS: So this hasn't changed very much from  
17 the previous TRAC.

18 MR. ANDERSEN: There have been a number of minor  
19 changes to the code, to the previous version of the GE  
20 version, but no major changes.

21 I'd like to just point out that the major  
22 differences between the currently approved process and what  
23 we are proposing to do with TRAC, that we have the same  
24 objective of scope as if we want to use it to calculate the  
25 operating safety limit. Currently, we are using a set of

1 code. The two dominant codes, main code is ODYN and TASC,  
2 where ODYN calculates a core average power response, and  
3 then, we use the TASC code to calculate the limiting hot  
4 fuel bundled response in the core and, in particular,  
5 calculate the transient CPR response for that channel.

6 In TRAC, we have a three-dimensional kinetics  
7 model, and we use parallel channels to represent hydraulic  
8 response in the core, and so, we get the three-dimensional  
9 response, and in the same calculation, we both get the core  
10 average response as well as the limiting channel response.  
11 So that's the major difference in the model.

12 The other major difference is how we do the  
13 statistical analysis and quantify the accuracy of the code.  
14 In the current ODYN/TASC, we estimate the uncertainty in the  
15 prediction of the plant power response and then to a  
16 transfer, we determine how much that affects the critical  
17 power response. That model of uncertainty is determined  
18 currently by comparison to jet full-scale plant data like  
19 the peak.

20 There are three of those tests, and that is what  
21 is used to determine the uncertainty. What we are doing  
22 here is that in TRAC is that we have said, well, a more  
23 rigorous approach is the CSAU type approach, and we are  
24 following that type of approach where we go through the CSAU  
25 step by starting at the individual model uncertainties and

1 finally coming up with a combined overall uncertainty. And  
2 then, we go back and do the comparisons of the plant data  
3 like the tests in order to confirm that when you apply that  
4 statistical methodology, you actually bound the plant data  
5 that we have.

6 So those are the major differences between the  
7 current process and what we are proposing to do.

8 The major document in the submittal to the NRC is  
9 the application methodology, and we have decided up front  
10 that the CSAU approach was the best approach to take, and  
11 so, we have gone through the 14 steps of the CSAU started by  
12 the plant specification and the event definition, which is  
13 the BWR226 and the chapter 15 events. We then went through  
14 the PIRT process to identify all of the important phenomena,  
15 and we did that for all of the event categories, and we have  
16 ranked them by their impact on the critical safety  
17 parameters, which, for chapter 15 events, is the critical  
18 power ratios, the peak vessel pressure, the water level and  
19 the thermomechanical response of the fuel.

20 And what we decided to do in the end was that in  
21 the statistical approach, we decided to include all high and  
22 medium-ranked phenomena. I believe that in the original  
23 CSAU approach, only the high-ranked phenomena were approved,  
24 but we thought that it would be easier to include the  
25 medium-ranked.

1 MR. SCHROCK: Did you do that for a specific BWR  
2 model? BWR6, for example?

3 MR. ANDERSEN: We have looked at these rankings  
4 for all of the BWR226s.

5 MR. SCHROCK: For all of them?

6 MR. ANDERSEN: Yes.

7 We then went through the process of evaluating the  
8 code applicability, and we have actually done it in two  
9 steps. One was that we looked at the basic structure, the  
10 formulation of the equations, the models and the  
11 correlations and the numerical solution, and that part of  
12 the documentation of the applicability is documented in the  
13 model description, and we have included sections in the  
14 model description that document the range of applicability  
15 of the various correlations that we are using in order to  
16 justify their application to the BWR.

17 And we then cross-referenced it against the PIRT  
18 table that we developed up here to make sure that all of the  
19 high-ranked phenomena were, indeed, adequately modeled.

20 MR. ZUBER: How many options do you have? I mean,  
21 the heat transfer coefficients -- how many rules have you --

22 MR. ANDERSEN: We have very few options in this  
23 particular version of the code. There are a few options for  
24 some of the models. For example, at the separator, we can  
25 choose between the two-state and the three-state separator,

1 because there are variations between the plants. We can  
2 choose between different critical power correlations because  
3 they are fuel-type dependent, but we don't have several  
4 different correlations for a given heat transfer regime. We  
5 have put in the one we believe is the best, and that's the  
6 only one that's available.

7 The only options that really exist in the code are  
8 the options that allowed us to do the sensitivity studies in  
9 support of the CSAU methodology. But those will not be  
10 available to the users for production-type applications.

11 MR. ZUBER: Very interesting to see here two  
12 different philosophies, one of which is open to question and  
13 the other one which seems to be a little bit more robust.

14 MR. ANDERSEN: Well, we are doing that in the --  
15 our internal QA philosophy, because there is really a step  
16 in our process that is not described here, and that is that  
17 once we get the SER, we will define a set of procedures that  
18 specify this is how you prepare every single number as input  
19 to the code, and this is how you learn the code, so that  
20 really, the application of the code is fixed, and there is  
21 only one way you do it.

22 We have done extensive assessment to quantify and  
23 determine the code uncertainty, and again, we have several  
24 effects components, integral and full-scale plant data, and  
25 again, we did a cross-reference to the PIRT table, and all

1 of that is included in the application methodology report  
2 in order to make sure that everything that was medium and  
3 high importance were included in the qualification basis and  
4 also that we had the data that allowed us to quantify the  
5 accuracy of the code for the statistical assessment.

6 In addition, in the application methodology, we  
7 also include the effect of reactor input, operating  
8 parameters and the state of the reactor. Do you analyze it  
9 given the cycle? Do you analyze it end of cycle? Do you  
10 analyze the transient response for top peak? For bottom  
11 peak power shape? You include these effects in the  
12 application methodology.

13 The final step is determination of the combined  
14 and total uncertainty, and we have done that by doing  
15 sensitivity studies and statistical calculation following  
16 the CSAU approach.

17 MR. ZUBER: Is this -- everything is already  
18 submitted to NRR?

19 MR. ANDERSEN: Yes; that is in the application  
20 methodology report. And essentially, for the critical  
21 safety parameters, we have determined a one-sided  
22 statistical limit as the bounding value for that parameter,  
23 and that is demonstrated in the application methodology that  
24 we have submitted. We have, in the application methodology  
25 report, we have included the PIRT tables. We have

1 quantified the uncertainties. We have done the sensitivity  
2 studies for the plant to show which parameters really are  
3 important and affecting the critical safety parameters and  
4 which are not, and we have demonstrated the applications of  
5 the statistical methodology on actual plant calculations.

6 MR. SCHROCK: Does this mean that you don't have  
7 an adder as you had in your large-break loca application?

8 MR. ANDERSEN: Well, you end up with something  
9 that's similar to an adder, because you can view the  
10 difference between the nominal calculation and the  
11 statistical upper-bound calculation as an adder.

12 MR. WALLIS: The cartoon on the right is  
13 fascinating.

14 MR. ANDERSEN: Well, this is just to show -- I  
15 mean, we have our TRAC code here. We have internal  
16 documents that we put in place to satisfy our own QA  
17 requirements. Out of this comes the model description, the  
18 qualification reports that we are submitting to the NRC.  
19 The application methodology ties the code together with the  
20 regulatory guidelines, which is the guidelines that are  
21 specified in the general design criteria; the NUREG 800 and  
22 the appendix B requirement. And out of this, we hope to get  
23 a safety evaluation report from the NRC.

24 MR. WALLIS: Sort of a representation of a core of  
25 technology which explodes into a big sphere of paperwork.

1 [Laughter.]

2 MR. ANDERSEN: Well, we have generated quite a bit  
3 of paper in support of this submittal.

4 MR. ZUBER: You didn't put ACRS in that circle.

5 MR. ANDERSEN: No, but you will be included.

6 [Laughter.]

7 MR. ANDERSEN: Basically, what we have submitted,  
8 the key report is the application methodology report, which  
9 describes the application methodology. We followed the  
10 CSAU, and it references the models and the qualification  
11 report. In going through these processes in the application  
12 report, we have described which models are important for the  
13 transient application, so it specifically tells the NRC what  
14 is it in the model description that's important for this  
15 application?

16 Similarly, for the assessment, which are the  
17 assessments that demonstrate the applicability of the code  
18 to these events? A cross-reference between the PIRT tables  
19 and the assessment will show what is important in the  
20 qualification report. The model description and the  
21 qualification reports are revision two of those reports.  
22 Earlier revisions have been submitted to the NRC and were  
23 reviewed as part of the SBWR program. What we have done is  
24 that we have expanded on the descriptions; we have tried to  
25 address all of the questions that were asked during the SBWR

1 review and incorporated the response to those questions into  
2 the document, and that's what's in revision two.

3 We have eliminated some of the models in the model  
4 description that are specific to the SBWR, because we are  
5 limiting the application and the review to the operating  
6 BWRs.

7 MR. WALLIS: Let me get this straight. You say  
8 requested review is application methodology. Does that mean  
9 that the model description qualification already approved,  
10 and the only thing at issue is whether it applies to certain  
11 transients?

12 MR. ANDERSEN: It doesn't mean that the model  
13 description and the qualifications are already reviewed, but  
14 what we are asking NRC to review and approve is that the  
15 model description and the qualification is sufficient and  
16 adequate to support the application to AOO transient. We  
17 are not asking the NRC to review whether the models and the  
18 qualification is sufficient for large-break loca.

19 MR. WALLIS: But everything on here is up for  
20 review, so that one could go back and look at the details of  
21 the model and say some part of it is a little bit iffy for  
22 this particular transient and that sort of thing.

23 MR. ANDERSEN: You could do that, and you could  
24 look at a model and say this model is not important for this  
25 transient.

1 MR. WALLIS: Right.

2 MR. ANDERSEN: You can look at it from both sides.

3 MR. WALLIS: Right.

4 MR. ANDERSEN: And we have tried to provide all of  
5 the information in the application report that specifies  
6 exactly what is important and what is not important.

7 MR. BOEHNERT: Jens, you labeled that slide  
8 proprietary, but you don't really mean that, do you?

9 MR. ANDERSEN: That is -- I was not intended to  
10 mean that.

11 MR. BOEHNERT: Yes.

12 MR. ANDERSEN: All of the other ones are not  
13 labeled proprietary.

14 MR. BOEHNERT: Yes.

15 MR. ANDERSEN: So --

16 MR. WALLIS: Somebody failed to remove it?

17 MR. BOEHNERT: Well, there's nothing proprietary  
18 on there.

19 MR. ANDERSEN: You could take that out. There's  
20 no proprietary information in that report.

21 So, in summary, the scope is application to BWR226  
22 transients. We have met and intended to meet all of the  
23 regulatory requirements that are specified in the general  
24 design criteria appendix A and B. We have demonstrated the  
25 applicability of the model for these events. There has been

1 extensive prior reviews and acceptance of TRAC, and we have  
2 addressed the comments that we have received as part of  
3 those prior reviews.

4 We have followed the CSAU methodology because we  
5 believe that that is the best methodology available to  
6 quantify the uncertainty in the code, and we have gone  
7 through that step and essentially evaluated one-sided  
8 opposite statistical limits for all of the critical safety  
9 parameters, and in the application methodology report, we  
10 have demonstrated that for all of the event types that we  
11 are asking for approval for, and what we are asking for is  
12 an SRC SER safety evaluation report for TRAC for these  
13 events.

14 Thank you.

15 [Pause.]

16 MR. WALLIS: Any questions from the members of the  
17 committee?

18 [No response.]

19 MR. WALLIS: The committee is remarkably silent.

20 MR. ZUBER: There's a big difference between your  
21 presentation and Siemens, which are really professional, and  
22 the one we heard this morning. It was sad.

23 MR. WALLIS: Of course, we have yet to see any  
24 equations.

25 MR. ZUBER: The thing of my concern was the

1 attitude, the attitude that errors can be just glossed over.

2 MR. WALLIS: We don't know that yet until we get  
3 into the details.

4 MR. ZUBER: Well, I can only hear what was said.

5 MR. WALLIS: It sounds as if we are ready to take  
6 a break for lunch. We cannot start before 12:45. I think  
7 we could aim for 12:45. Just go back and stay on the  
8 original schedule. We will reconvene at 12:45. Thank you  
9 very much.

10 [Whereupon, at 11:35 a.m., the meeting was  
11 recessed, to reconvene at 12:45 p.m., this same day.]

12

13

14

15

16

17

18

19

20

21

22

23

24

25

## A F T E R N O O N   S E S S I O N

[12:45 p.m.]

MR. WALLIS: Let's come back into session. We're looking forward to hearing about pressurized thermal shock this afternoon. We have an excellent cast of characters. We're looking forward very much to hearing from Farouk, Farouk Eltawila.

MR. ELTAWILA: I have nothing much to say, and everybody is deserting me, so I --

[Laughter.]

MR. ELTAWILA: Thank you, Professor Wallis.

I think maybe I will just yield my time right now and let Dave Bessette and Professor Jose Reyes talk about our activities in this area of thermal hydraulics, and we are looking at it in a very integral fashion compared to the previous work that we have done in this regard. I would like to hear from the committee, and I would be happy to address any questions that you might have during the course of the presentation. So I will let Dave start.

MR. BESSETTE: Yes; for the moment, I've changed professors. Professor DeMarzo and me were together for so long that now, I have Professor Jose here.

MR. WALLIS: They changed your professor because you didn't finish your thesis under the first one?

[Laughter.]

1 MR. BESSETTE: Well, you know that's not a bad  
2 idea for changing professors.

3 [Laughter.]

4 MR. WALLIS: This is a fatter document than we had  
5 before. It's very substantial. It feels substantial.

6 MR. BESSETTE: It was being added to as recently  
7 as a few minutes ago.

8 [Pause.]

9 MR. BESSETTE: So, we're going to talk about the  
10 thermal hydraulic input to the PTS screening re-evaluation  
11 program. The purpose is to give an overview of the thermal  
12 hydraulics input into this whole program. The purpose of my  
13 talk is to briefly review the existing fluid-fluid mixing  
14 database for reactor geometries; discuss the results from  
15 the prior PTS studies that were carried out and discuss some  
16 plans for our future calculations.

17 You are the first to see this view graph. We just  
18 put it together this morning. This is kind of the general  
19 structure of the thermal hydraulics work. As I say, we want  
20 to review the prior PTS studies just as a baseline, and the  
21 idea is to try to decide what revision on these to those  
22 prior studies, and we do this together with the revisions to  
23 the PRA work, the prior PRA treatment of PTS that was done  
24 at the same time in conjunction with these studies to see  
25 what transients we need to reanalyze, and the idea is we

1 review these calculations, and then, this is an iterative  
2 process between us and the PRA people as to how this feeds  
3 into our view of the risk-dominant sequences.

4 MR. ZUBER: You did this already, or you are going  
5 to do it?

6 MR. BESSETTE: Well, this part, we're doing right  
7 now.

8 MR. ZUBER: Are you going to describe this PRA  
9 method?

10 MR. BESSETTE: The PRA people will discuss that.

11 MR. ZUBER: Today?

12 MR. BESSETTE: Tomorrow.

13 [Pause.]

14 MR. BESSETTE: You know, the prior PTS studies  
15 have these extensive fault trees that were done and  
16 probabilities attached to each branch of the tree. Then, we  
17 have this code validation box, where we considered the PIRTS  
18 that have been done for PTS in the past and also these prior  
19 fluid-fluid mixing experiments that have been done and  
20 decide what code assessment requirements we need and compare  
21 it to the available assessment information and decide if we  
22 need additional code assessment specific to PRA scenarios.  
23 And part of this feeds into this APEX PTS experimental  
24 program that Professor Reyes will discuss and I will discuss  
25 also later on.

1           Then, we end up with, let's say, a code validation  
2 for the PTS scenarios we're trying to analyze. And all of  
3 this gets input down to Oak Ridge, where they analyze the  
4 probability of vessel failure using this FAVOR code.

5           MR. WALLIS: Where are you now? You said you were  
6 up on the top there. Where are you on the left, on the code  
7 validation side?

8           MR. BESSETTE: Right; we're in these boxes here.

9           MR. WALLIS: You're at the top of that as well.

10          MR. BESSETTE: Yes, we're in these boxes, and  
11 also, we're preparing for these experiments also.

12          MR. WALLIS: But we don't have any experimental  
13 results yet.

14          MR. BESSETTE: Not yet.

15          MR. WALLIS: Not for awhile. So there won't be  
16 any answers there for awhile.

17          MR. BESSETTE: The answers improve with time,  
18 hopefully.

19          MR. WALLIS: The experiments are needed to get  
20 answers.

21          MR. ELTAWILA: I think the experiment, this  
22 protocol, the experiment at the APEX facility is very  
23 important, because we want to look at the variation in the  
24 temperature in the down comer, because, as you know, the  
25 FAVOR code is a two-dimensional code, and if there is a

1 large variation in the down comer, it might have impacts on  
2 additional development in the FAVOR code that we might have  
3 to go 3D. So, I agree with you that we really need to get  
4 this data as soon as we can and hopefully today, after you  
5 hear the presentation from Jose about the scaling analysis  
6 for that experiment and we get your endorsement, we'll try  
7 to run these tests as soon as we can.

8 MR. ZUBER: I've got a question. Reading what I  
9 got from Paul, my question was you have a facility at  
10 Maryland. Why are you not using that one also?

11 MR. BESSETTE: We've been thinking about it, and  
12 we may -- we haven't formulated anything yet, but it's in  
13 the --

14 MR. ZUBER: What made the choice? I mean, APEX  
15 versus the Maryland facility?

16 MR. BESSETTE: Well, the immediate --

17 MR. ZUBER: That was a question I had. First, why  
18 did you not use it, and the second is are you going to use  
19 it?

20 MR. BESSETTE: We may use it. We have to discuss  
21 it still. But the reason that we've focused so far on APEX  
22 is it looks very much like a CE plant, and the -- let's say  
23 the first plant in line in terms of PTS is Palisades, which  
24 is a CE plant, and it's configured quite closely to APEX,  
25 and that's why this has been the focus of initial attention,

1 but we haven't -- I think we were thinking about using  
2 Maryland for PTS testing. We haven't formulated anything  
3 yet.

4 MR. ZUBER: But that is also a CE plant.

5 MR. BESSETTE: No, it's not.

6 MR. ZUBER: You are right.

7 MR. BESSETTE: I mean, in fact, we've done mixing  
8 tests at Maryland, but they've been focused more on the  
9 boron mixing. The two are quite similar but --

10 MR. SCHROCK: That would give you a good handle on  
11 scaling if you had both.

12 MR. BESSETTE: To some extent; of course, the  
13 geometries are different, and they're similar enough for  
14 this purpose.

15 MR. ELTAWILA: If I may add, Dave, I think what we  
16 -- there is a decision made in the Office of Research that  
17 we are going to start this fiscal year; actually, we are no  
18 longer supporting the facility at the University of  
19 Maryland. So that will require a reverse in our decision  
20 and require to get additional budget. But I agree with  
21 Professor Schrock: if we have the two facilities, we can  
22 address the scaling rationale, and we will be in a much  
23 better situation than we were with the single facility. But  
24 with the budget situation, I don't think we will be able to  
25 run any tests at the University of Maryland.

1 MR. ZUBER: Well, let me say one of the reasons  
2 was that, again, you have two facilities, and some  
3 geometries are different. The two tests will be not only  
4 for scaling but also for the core.

5 [Pause.]

6 MR. WALLIS: I think what we're asking for is a  
7 statement of what you need to do in order to get the answers  
8 that you need. And then, you have to look at what you can  
9 do in terms of the core and sort of separate the two a bit,  
10 and it will help you.

11 MR. BESSETTE: Yes.

12 MR. WALLIS: What you'd really like to do is get  
13 these scaling studies and so on, but you can only afford  
14 thus and so, and therefore, you do this.

15 MR. ZUBER: See, but those are the quota. They  
16 have to verify the core. I think two facilities is --

17 MR. WALLIS: So that's probably what you would  
18 like to do. You have to ask can you afford it?

19 MR. BESSETTE: Well, this is by way of background.  
20 So, this goes back to one of the key principles in terms of  
21 why we worry about PTS is that they can't allow the vessel  
22 to fail, and this led, in 1966, to the establishment of the  
23 heavy section steel technology program at Oak Ridge and  
24 continued attention to assure vessel -- the probability of  
25 vessel failure remains low. Until about 1978, it was

1 postulated that the most severe thermal transient vessel  
2 experience would be following a large-break loca, and this  
3 just gives some description of what would happen in that  
4 event. But the mitigating thing with a large-break loca, of  
5 course, is there is no pressure on the vessel.

6 [Pause.]

7 MR. WALLIS: But you can still set up thermal  
8 stresses.

9 MR. BESSETTE: You can get thermal stresses, but  
10 by themselves, thermal stresses are not sufficient to fail  
11 the vessel. And, in fact, the thermal stresses that you end  
12 up with are not particularly more severe than some of these  
13 over coolant transients that we have from higher pressures.

14 [Pause.]

15 MR. BESSETTE: So, when PTS was born with an event  
16 that occurred at Rancho Seco in 1978, this event led to an  
17 actuation of high pressure injection for an extended period  
18 of time. We felt that in the primary system, going  
19 water-solid and discharging liquid out the PORV, I changed  
20 that, but unfortunately, I incorporated the wrong -- it's  
21 not the safety valves; it was the PORV.

22 So, following the Rancho Seco event, the  
23 pressurized thermal shock was designated as an unresolved  
24 safety issue A-49. So, the basic idea is should an  
25 overcooling event occur in conjunction with high pressure in

1 an embrittled vessel in an existing flaw, the potential  
2 exists for that flaw to propagate into the vessel wall.

3 This is a diagram of the Oconee vessel, one of the  
4 three plants that we studied under the prior, old IPTS  
5 study, but for the purposes of this, you can choose any one  
6 of the three vessels. Basically, you have the cold lights  
7 coming in around this elevation; the anti-cold liquid would  
8 come down the down comer. Let's say the embrittled part of  
9 the vessel is between these two elevations here. So, these  
10 are -- the temperatures in this vicinity are the ones you're  
11 interested in, and you have this region. So, even if it  
12 comes in as a plume, you have some distance to go. This  
13 distance is about six feet; some distance to go before the  
14 plume would reach the relevant part of the down comer. So  
15 there is some dissipation length here.

16 [Pause.]

17 MR. BESSETTE: This is by now the classic  
18 Theophonous picture of the process, where we're showing --  
19 this is the cold side of the system. The steam generator is  
20 here. You go through the loop; seal the pump; cold leg; the  
21 down comer; and the characterizers assist them in these  
22 mixing regions, the first being where the high pressure  
23 injection enters the cold leg, and then, it -- at least for  
24 those plants, it comes in as a jet and then stratifies along  
25 the cold leg and then flows toward the down comer.

1 MR. WALLIS: Excuse me; is this cold water under  
2 hot water?

3 MR. BESSETTE: Yes, cold water under hot water.

4 MR. WALLIS: Is there steam there?

5 MR. BESSETTE: There can be steam at times during  
6 the cold break or during the small-break locas. So, you can  
7 either have steam up here, steam, water and then steam, hot  
8 water and then cold water or just hot water and cold water.

9 But although this is stratified, there is some  
10 pre-heating that occurs.

11 MR. WALLIS: This is a strange picture, because  
12 the cold water comes in usually, as I remember, with such  
13 velocity that it actually swells up around the sides of the  
14 tube. It doesn't just go and lie on the floor.

15 MR. BESSETTE: Not all the time. In the CE and  
16 the Westinghouse plants, this velocity is not that high.  
17 It's on the order of a couple of feet a second or something  
18 like that.

19 MR. WALLIS: It's a bigger pipe.

20 MR. BESSETTE: It's a big pipe. It's about --  
21 yes, an 8 or 10 inch diameter pipe. So this pipe, the thing  
22 is -- the high pressure injection line comes into this pipe,  
23 which is sized for low pressure injection. So this pipe has  
24 been sized for a flow rate 10 times the high pressure  
25 injection flow, so that's why the velocities are not that

1 high.

2 And then, you have this mixture region three or  
3 mixing region three, where the flow comes in and makes this  
4 turn as it enters the down comer, and then, you have this --  
5 that's this region here. Then, you have a plume dissipation  
6 region, and then, you end up with some uniform temperature  
7 distribution all the way around the down comer at some --

8 MR. SCHROCK: What does TJ represent?

9 MR. BESSETTE: TJ is -- let's see.

10 MR. SCHROCK: You have the --

11 MR. BESSETTE: Oh, here?

12 MR. SCHROCK: Yes.

13 MR. BESSETTE: Yes; the temperature of the jet as  
14 it enters the down comer from the cold leg.

15 [Pause.]

16 MR. WALLIS: Is this based on someone's  
17 imagination or on something else?

18 MR. BESSETTE: Well, it's reality, actually.

19 MR. WALLIS: This is based on experiments?

20 MR. BESSETTE: Experiments show the same thing.  
21 The fluid mixing experiments show this kind of behavior.  
22 The one thing to point out, though, this region here is not  
23 present in BMW and CE plants, because BMW plants, the cold  
24 leg comes this way, and then, it inclines like this before  
25 it gets to the pump. So there can't be any back flow. And

1 the CE plants have some kind of a dam here which prevents  
2 back flow. So, this mixing region is not there for those  
3 two vendors.

4 MR. SCHROCK: It looks almost like TJ is defined  
5 as the temperature, sort of the incoming flow and reaches  
6 the position 2BCL on the left hand side.

7 MR. BESSETTE: Yes; and theo, of course,  
8 differentiates this entrance region from the plume  
9 dissipation region, and this is also how REMIX works. This  
10 is exactly how REMIX works.

11 MR. WALLIS: I think while there are boundary  
12 conditions, such as pressures and flows in the ends of these  
13 things that have to be specified in some way, that changing  
14 with time.

15 MR. BESSETTE: Well, the pressure basically --  
16 well, for the purposes of REMIX or for any of this, once you  
17 have flow stagnation, pressure is essentially uniform, as  
18 everything is being driven by gravity.

19 MR. WALLIS: Well, this is where small pressure  
20 differences, though, could make a difference, so essentially  
21 uniform needs to be described properly, because it may be  
22 that if your gravity head at one foot is driving a flow,  
23 then, the pressure drops half a PSI, it becomes very  
24 significant.

25 MR. BESSETTE: Yes, but, of course, the only way

1 to generate the pressure drops at that point is by the flow  
2 itself.

3 MR. WALLIS: I'm not sure you can predict that  
4 that accurately anyway. I mean, you have a lot of  
5 uncertainty associated with it when it's near stagnation.  
6 There's a little change where it could go this way or that  
7 way.

8 MR. BESSETTE: Well, if you're talking in terms of  
9 TRAC or RELAP, you can get numerical noise that is  
10 significant with respect to these.

11 MR. WALLIS: Well, RELAP may well be predicting  
12 that this is banging around the bottom, because there are  
13 just lots of numerical oscillations in the code itself.

14 MR. BESSETTE: Yes, that's what I mean.

15 MR. ZUBER: I have two questions. That TJ, if you  
16 have in these two regions and this mixing and dissipation  
17 region, that could be that as it is now, this is only  
18 depending on the geometry. I think that mixing the regions  
19 should also really depend on the flow.

20 MR. BESSETTE: The flow velocity.

21 MR. ZUBER: Yes, right.

22 MR. BESSETTE: Yes.

23 MR. ZUBER: So, I think this is a shortcoming, or  
24 it may not be, but it should be looked into.

25 And the second thing is how sensitive; how

1 sensitive are the results to that temperature?

2 MR. BESSETTE: Yes; of course, you know, what  
3 REMIX does, this makes a simplifying approximation as to  
4 what's going on.

5 MR. ZUBER: I know, you see, but the point is --  
6 my question is, I mean, you're right; we're discussing  
7 REMIX, but apart from it, you would expect, you know, not  
8 only to depend on the geometry on the two diameters. It  
9 would depend on the flow.

10 MR. BESSETTE: Yes.

11 MR. ZUBER: And, okay, so, the point is if that  
12 thing doesn't make much difference, that's fine. I mean,  
13 the approximation may be quite good. On the other hand, if  
14 the results are sensitive to TJ, then, this approach, the  
15 initial thing it does, this might not be too good.

16 MR. BESSETTE: Well, I think, as you said, I think  
17 probably, you can show that -- not today, perhaps, but we  
18 can show eventually, I hope, that once we get down to this  
19 region, down to this elevation, this -- that mixing region  
20 three, whatever it's called, is up here, and once we get  
21 down here, according to some of the fluid-fluid mixing data,  
22 it looks like this temperature is going to uniform around  
23 the circumference of the vessel, that already, the plume  
24 will have dissipated by here. There's enough mixing.

25 MR. ZUBER: What were you saying that the TJ ratio

1 has not much influence?

2 MR. BESSETTE: Well, in terms of REMIX.

3 MR. ZUBER: The question is not about information  
4 experimental you have, I mean, to justify it.

5 MR. WALLIS: That sort of surprised me, because  
6 usually, fluids look like your fluid here. They don't  
7 spread very rapidly. And so, it's hard to imagine something  
8 being fully mixed when it's only gone a couple of diameters.

9 MR. BESSETTE: Yes; well, you notice a further  
10 constraint here in that the gap width is about 8 or 10  
11 inches, and probably the incoming plume is of the same  
12 order, the same dimension in terms of its diameter. And so,  
13 when it comes in, of course, it hits against the core  
14 barrel, and there kind of is a tendency for it already to  
15 start spreading circumferentially from that. So, it's not  
16 an unconstrained plume. It's constrained in one of the  
17 dimensions.

18 MR. ZUBER: But that spreading will also depend on  
19 inflow.

20 MR. BESSETTE: Yes; the higher the flow rate, the  
21 more spreading --

22 MR. ZUBER: Yes; but the point is, then, the  
23 question is really what is the effect on the flow rate on  
24 TJ?

25 MR. BESSETTE: Well, we have experimental data

1 from different flow rates in the database.

2 MR. WALLIS: It looks like an easy experiment to  
3 do.

4 MR. BESSETTE: Yes, and that's why it's been done.

5 [Laughter.]

6 MR. BESSETTE: So, just to keep on with the  
7 history of this, the integrated pressurized thermal shock  
8 study, this was done in the early 1980s following this  
9 Rancho Seco event and the establishment of it as an  
10 unresolved safety issue. The research program was initiated  
11 to develop a technical basis for a pressurized thermal shock  
12 rule to aid in the development of guidance for  
13 plant-specific analysis as well as acceptance criteria for  
14 proposed corrective actions.

15 The objective of that study was to provide an  
16 estimate of the probability of a crack propagating through  
17 the wall; determine the most dominant -- risk-dominant over  
18 cooling transients and also to investigate the effects of  
19 plant features and operator actions on the event and also to  
20 determine the effectiveness of potential corrective measures  
21 in terms of changes in the way the equipment set points or  
22 the operator procedures.

23 There was one plant selected from each of the  
24 three vendors, so, for BMW, there's Oconee 1. For  
25 combustion engineering, it was Calvert Cliffs. And for

1 Westinghouse, it was H.B. Robinson, which is a three-loop  
2 plant. I said this is called the integrated pressurized  
3 thermal shock study. These studies for these three plants  
4 were all published in 1985.

5 [Pause.]

6 MR. BESSETTE: So, the result of that was this  
7 current regulatory basis that we have today that is  
8 described in 10 CFR 50.61, which is fracture toughness  
9 requirements for protection against pressurized thermal  
10 shock events and reg guide 1.154, which is this accompanying  
11 guidance format and content of plant-specific PTS analysis  
12 reports. It's interesting that this rule doesn't really  
13 have -- say anything about thermal hydraulics that has  
14 focused on the fracture toughness considerations and  
15 embrittlement considerations, but the reg guide does have a  
16 section that deals with how you analyze these events from a  
17 thermal hydraulic perspective.

18 MR. SCHROCK: What is the basis for the setting of  
19 a requirement in 10 CFR? Do you have any idea?

20 MR. BESSETTE: Well, it's the -- it's -- the basis  
21 was tied up into this outcome of the integrated study that  
22 was done at the time, that involved considerations of risk;  
23 the thermal hydraulics calculations; and the -- what was  
24 known about vessel embrittlement and flaw distribution and  
25 orientation and density. So, in back of it, there's some

1 consideration of limiting the probability of vessel failure  
2 from a PTS event, and embedded in that, so that was the  
3 governing objective.

4           So embedded in that is some probability of getting  
5 to a low -- probability versus -- probability of getting to  
6 different temperature, different minimum temperature. So,  
7 there's a rationale in back of it that includes  
8 considerations of PRA safety goal and the thermal hydraulic  
9 analysis. I don't know if that's clear or not.

10           [Pause.]

11           MR. BESSETTE: So, the objective of the current  
12 re-evaluation effort for thermal hydraulics is to ensure  
13 that for the risk-significant classes of events, you know,  
14 and this again involves some interaction between PRA and  
15 thermal hydraulics and fracture mechanics, the thermal  
16 hydraulics inputs developed at the time in the IPTS study  
17 are still operative or otherwise corrected and updated as  
18 needed and that additional, the objective is to provide an  
19 estimate and a certainty in these thermal hydraulic  
20 calculations.

21           MR. WALLIS: You say risk-significant. Do you  
22 mean the measurement in terms of likelihood or measurement  
23 in terms of consequences?

24           MR. BESSETTE: Well, it's probability and  
25 consequence.

1 MR. WALLIS: The conservative view is to say we'll  
2 just make sure that the things that have big consequences,  
3 the likelihood is so remote.

4 MR. KRESS: I think you said in some of the  
5 writings that it was the risk-dominant sequences, so it's  
6 based on risk-dominance.

7 MR. BESSETTE: It's based on risk; it was based on  
8 a probability of a given scenario times the consequence of  
9 that particular scenario.

10 MR. KRESS: And there were just three or four  
11 sequences that made up 95 percent of the risk.

12 MR. BESSETTE: That's right; you know, they  
13 started -- when the PRA people did the fault tree analysis,  
14 of course, they started with the thousands of scenarios, and  
15 then, about a dozen were analyzed with the TRAC or RELAP.  
16 now, of those dozen, typically about two or three for each  
17 plant that show up as dominating the risk.

18 MR. ZUBER: I've got a question. While you say  
19 the steel operative, the first bullet --

20 MR. BESSETTE: That means that with the  
21 calculations we did back in 1985, do we still believe in  
22 them?

23 MR. ZUBER: Is there any evidence that you should  
24 not believe that?

25 MR. ELTAWILA: No, they are in addition to the

1 changes in the code, there have been changes to the plant  
2 itself, you know, as a result of the PTS regional rule.  
3 They have made a lot of changes to the plant. So, you want  
4 to reflect these changes into our current analysis right  
5 now.

6 MR. BESSETTE: Yes, that's right.

7 MR. ZUBER: What about aging? Plant aging?

8 MR. BESSETTE: Well, the aging, I mean, that's  
9 really the vessel embrittlement. The aging doesn't effect  
10 the thermal hydraulics analysis.

11 MR. ZUBER: No, but I mean, the thermal hydraulic  
12 analysis together with the aging.

13 MR. BESSETTE: Yes, but the aging -- yes, the  
14 aging is strictly the embrittlement, you know, continued  
15 embrittlement of the vessel, in this case.

16 MR. ZUBER: I could say that much of the changes  
17 that you are getting are getting older.

18 MR. BESSETTE: Yes.

19 MR. ZUBER: And therefore, I mean, you have to  
20 have better accuracy in determining the thermal hydraulics.  
21 This will be one way of rationalizing it.

22 MR. BESSETTE: Yes; well, even in the earlier  
23 study, there was a model of the predicting vessel  
24 embrittlement with continued fluence and tracking, you know,  
25 the fluence, the cumulative fluence to the vessel -- I guess

1 fluence is cumulative, but the cumulative flux to the vessel  
2 is tracked and calculated, and so, and it's predicted to the  
3 end of life of the plant.

4 And there is the correlations between fluence and  
5 embrittlement that are projected out to the end of the  
6 plant. So this is tracked on a continuing basis. So,  
7 that's taken into account into the models, and, of course,  
8 the models are continually reverified or updated as --

9 MR. ZUBER: But you're not setting them up in the  
10 thermal hydraulic models, are you?

11 MR. BESSETTE: Not seeking which?

12 MR. ZUBER: Somehow, I don't know really the  
13 justification. Is the problem the reason why you are  
14 revisiting this problem is because originally, the thermal  
15 hydraulics model was insufficient, or you developed doubt in  
16 the models; then, you'll need a better approximation?

17 MR. BESSETTE: Well, I don't see any particular  
18 problems in the thermal hydraulic calculations for the most  
19 part that were done at the time.

20 MR. ZUBER: Then, my question, then, is why do you  
21 need this program?

22 MR. BESSETTE: It's more of a matter of there have  
23 been changes in the probability of different sequences due  
24 to changes in operating procedures and the way the plant --  
25 the operations, then, controls of the plant.

1 MR. ELTAWILA: Can I -- I don't know if I'm going  
2 to answer your question or not, but in the original study,  
3 the fracture mechanical uncertainty was the most dominant  
4 part of the transient. So the emphasis on thermal  
5 hydraulics was not that great, and the -- you know, we did  
6 not really sharpen our pencil and try to get a better  
7 answer, because it was limited on -- because of the fracture  
8 mechanics.

9 Now, with the reduced uncertainty in the fracture  
10 mechanics, they are looking for a better estimate of the  
11 thermal hydraulic condition to be able to take advantage of  
12 all of the realistic assumptions to see if we can come up  
13 with a better answer than what we came --

14 MR. SHACK: But I think the answer is that vessels  
15 are getting closer to the limit, and so, you know, they're  
16 looking for more margins.

17 MR. ELTAWILA: That is correct.

18 MR. SHACK: You know, it's a very practical sort  
19 of problem for at least, you know, 10 or so plants.

20 MR. BESSETTE: Yes, and the other thing is that I  
21 think most plants are looking for life extension, and that's  
22 one of the issues there, too.

23 MR. ZUBER: So, to sum it up, you need better  
24 calculating tools for thermal hydraulics.

25 MR. BESSETTE: Well, of course, like Farouk said,

1 all along, the large majority of the uncertainty has been  
2 embedded in the fracture analysis. But, you know, still,  
3 people want to know, well, what is the uncertainty in the  
4 thermal hydraulics, and what portion of the total is this?

5 MR. ZUBER: Okay; and then, the expression will be  
6 a numeric -- think about it. The improvements you plan to  
7 do, by how much you would improve your uncertainty  
8 calculations, by how much you have really to push it to  
9 bring these two things together.

10 MR. BESSETTE: So, I don't think the codes today  
11 will give much -- for the same input, for the same  
12 transient, I don't think the codes today will give a very  
13 different answer than they did in 1985.

14 MR. SHACK: But when I looked at that round robin  
15 study, you know, and I saw heat transfer coefficients that  
16 ranged from zero to 10,000, you know, as the people did the  
17 calculations the different way, yes, the same code run today  
18 will probably give you the same answer it did, and if it was  
19 wrong then, it's probably still wrong today, I mean, but you  
20 seem to get a variety of answers depending on how you  
21 analyze the problem.

22 MR. BESSETTE: Well, yes; if you vary it from zero  
23 to 10,000, but if you vary it over a realistic range of,  
24 say, 1,000 --

25 MR. SHACK: Well, that's what the code predictions

1 were giving you when they did that analysis with the 21  
2 people or whoever did it. Now, yes, I mean, maybe some of  
3 those guys were producing rubbish; I don't know.

4 MR. SCHROCK: Probably.

5 MR. BESSETTE: You know, if you give them --

6 MR. SHACK: Well, the thing was they were all  
7 predicting the kind of gross features; those were all narrow  
8 as could be. Then, when you got inside the plume, and you  
9 looked at the heat transfer coefficients, they went  
10 everywhere.

11 MR. BESSETTE: Yes.

12 MR. ZUBER: But, no, the reason for my question  
13 here is you have a set of data as a calculating tool for the  
14 last 15 years. Now, we want to do something more. The  
15 question is why, and then, once we determine why, then, you  
16 have to see how far, what kind of improvements, what kind of  
17 refinements, I would need, and can I achieve them? I think  
18 this sets your program into a perspective.

19 MR. WALLIS: I think what Novak is asking for is  
20 the focus of the research. It's easy to say we'll do  
21 research to measure all this stuff, but what's the output,  
22 and how good does it have to be? Where are the improvements  
23 really going to have a payoff and so on is I think what  
24 we're asking.

25 MR. ZUBER: That's the point.

1 MR. BESSETTE: Well, in my view of it, like I  
2 said, I don't think the codes have changed. If you give the  
3 code the same transient, I think it will give much the same  
4 answer today.

5 MR. WALLIS: Be careful to specify your output,  
6 because if you give it to a university, their objective is  
7 to get a Ph.D. out of it.

8 [Laughter.]

9 MR. WALLIS: The criteria for that are quite  
10 different sometimes than your criteria, utility.

11 MR. ZUBER: See, this raises the question of what  
12 kind of data, first, what kind of data do we have in REMIX?  
13 What is the database? What is the database 10 years ago to  
14 verify REMIX? What kind of data do I need to improve REMIX?  
15 Or do I need such data? And what kind of improvement do I  
16 have to do?

17 MR. BESSETTE: Well, I don't think I can cover all  
18 that today. I think there is a pretty good database for  
19 REMIX.

20 MR. WALLIS: I guess next time we see you, we'll  
21 expect you to have a really good answer to that.

22 MR. BESSETTE: Yes; I mean, I can answer that  
23 question.

24 MR. ZUBER: See, when I was reading the thing I  
25 got from Paul, I had all my questions here.

1 MR. BESSETTE: Yes.

2 MR. ZUBER: This is one question.

3 MR. BESSETTE: Because I've looked at the REMIX  
4 assessment, and, you know, I've looked at REMIX and the  
5 REMIX peer review, and, you know, it's okay.

6 MR. ZUBER: Well, to some extent, it's a volume  
7 average thing, and the question is really how do you do it?  
8 What kind of changes do you have to put in the REMIX to  
9 obtain a better answer?

10 MR. BESSETTE: The other thing about this, too, is  
11 I think we can show, like I said before, I think we can show  
12 -- I mean, the whole idea behind REMIX is to model the  
13 nonuniformity of the temperature, the stratification which  
14 was not really considered in the first PTS study back in  
15 1985, and it tended to arise while this study was going on,  
16 and then, a lot of experiments were done afterwards.

17 MR. ZUBER: You see, what would be really helpful  
18 to me is if you said okay, this is where we were 10 years  
19 ago; this is the set of data, and this is the codes. These  
20 were the short comments I would like to improve for the next  
21 10 years or something, something really -- I know, what are  
22 the deficiencies in the REMIX, in that data which were used  
23 to verify REMIX and then what changes I have to do? This  
24 would have specified what kind of experiments you have to  
25 perform.

1 MR. BESSETTE: Yes; well, I hope to be able to  
2 explain that to you someday.

3 MR. WALLIS: I'm not sure we're going to get it  
4 today.

5 MR. BESSETTE: Yes, but not today.

6 MR. WALLIS: We should probably go on, but we're  
7 going to ask this question again.

8 MR. BESSETTE: You know, but that's the purpose  
9 of, like, this box here and these boxes here.

10 MR. ZUBER: This is actually, before you start,  
11 you have to see where I am now; how good it was; what kind  
12 of improvements I have, and this would then set your -- what  
13 kind of tools do you have?

14 MR. WALLIS: And where do I want to be in the  
15 future.

16 MR. BESSETTE: Yes.

17 MR. ZUBER: And where do I want to be in the  
18 future.

19 MR. BESSETTE: Well, I think from what I know of  
20 REMIX, I think it's satisfactory.

21 MR. ZUBER: But I'm not sure, because 15 minutes  
22 ago --

23 MR. BESSETTE: Yes.

24 MR. ZUBER: -- I saw it. It may have been good  
25 for the purpose it was developed. Is it good for where you

1 want to get now?

2 MR. BESSETTE: Well, like I was saying, too, you  
3 know, REMIX, the intent of REMIX was to model this  
4 temperature nonuniformity, and like I said, I hope to be  
5 able to show convincingly that by the time you get to the  
6 region of interest down here, you have a uniform temperature  
7 axially.

8 MR. ELTAWILA: It wasn't one of the problems that  
9 was identified, and that's why we want to do this additional  
10 analysis, is that in the original IPTS study that they  
11 predicted flow stagnation by the code in certain cases, and  
12 for other cases, they did not predict flow stagnation, and  
13 they dismissed the scenario based on this analysis without  
14 any supporting experimental data. The code predicted, so it  
15 was okay that it was predicted, and that's why we would try  
16 to verify some of this -- the basis for -- that some of  
17 these analyses really were based on actual physical  
18 evidence. Is that something that you were looking at in  
19 this program or not? Isn't that part of the work that we  
20 will be doing at OSU?

21 MR. BESSETTE: Yes, I think so.

22 MR. ZUBER: I think Theo did some experiments with  
23 salt.

24 MR. BESSETTE: Yes; I'll talk about all of the  
25 experiments that have been done with fluid-fluid mixing. I

1 won't talk about them all in detail, but I'll list them all,  
2 at any rate. So I'll come to that.

3 So, what's our input to, say, the Oak Ridge people  
4 to the FAVOR analysis? We had to supply them three boundary  
5 conditions: the system pressure, the downcomer temperature  
6 and the region -- axial region corresponding to the core and  
7 a wall -- and a fluid-to-wall convective heat transfer  
8 coefficient. So we've got to tell them whether it's a zero  
9 or a 10,000 or something in between and some uncertainty  
10 estimate in these three parameters.

11 MR. WALLIS: These are a function of time and also  
12 location. The temperature isn't uniform.

13 MR. BESSETTE: That's right; we gave them like a  
14 next --

15 MR. WALLIS: How precise do we need to be in our  
16 sort of --

17 MR. BESSETTE: Nodalization?

18 MR. WALLIS: -- nodalization for temperature  
19 and -- presumably, there's one place where everything is the  
20 worst.

21 MR. BESSETTE: Yes.

22 Now, so we have these three parameters. They're  
23 not necessarily independent from each other, but their  
24 dependencies are not, let's say, not constant. They're  
25 varying as a function of time and conditions during a

1 transient.

2 But given these parameters, what can the codes do?  
3 Well, system pressure is something that's generally  
4 calculated reasonably well with TRAC or RELAP.

5 MR. WALLIS: You're not going to revisit that one,  
6 are you?

7 MR. BESSETTE: Not too much, no. Not through any  
8 experiments or anything. That's -- because this is a global  
9 -- some kind of a global measurement of energy.

10 MR. WALLIS: That's not a part of your research  
11 program, to investigate that boat.

12 MR. BESSETTE: No; this is what I say we do fairly  
13 well right now.

14 I think we can calculate down comer temperature  
15 reasonably well, too, either using TRAC or RELAP or some  
16 combination with REMIX.

17 MR. ZUBER: I have a question. I just heard that  
18 the temperature can go all over the place.

19 MR. BESSETTE: No; he said they use heat transfer  
20 coefficients from zero to 10,000.

21 MR. SHACK: No, they predicted those from the  
22 model.

23 MR. BESSETTE: Yes.

24 MR. SHACK: That's what they were predicting for  
25 the fluid to wall convective heat transfer.

1 MR. WALLIS: They actually predicted zero?

2 MR. SHACK: Yes; very low.

3 MR. BESSETTE: Pretty hard to get zero.

4 MR. SHACK: I'm only reading the report.

5 MR. ZUBER: What was measured? What kind of  
6 variation temperatures were measured?

7 MR. BESSETTE: Are you talking about in terms of  
8 assessing the code now?

9 MR. ZUBER: No, in terms of experiments.

10 MR. BESSETTE: Oh, in terms of experiments.

11 MR. ZUBER: In terms of experiments, I have some  
12 thermal couplers; I have measurements; then, you have the  
13 scatter and oscillations.

14 MR. BESSETTE: Yes; well, that's part of the  
15 reason for the experiment at APEX is they've got additional  
16 data on this, and I have to go back and look at the record  
17 more with respect to, say, the ROSA test that we've analyzed  
18 so far.

19 MR. ZUBER: But in ROSA, you would not have that  
20 kind of details.

21 MR. BESSETTE: But they have a fair amount -- they  
22 have about thermal couplers distributed throughout the down  
23 comer.

24 MR. ZUBER: How many thermal couplers did Theo  
25 have?

1 MR. BESSETTE: He didn't use thermal couplers, I  
2 guess.

3 MR. ZUBER: For the salt.

4 MR. BESSETTE: I don't know how many measurement  
5 locations he had off hand.

6 MR. WALLIS: Well, you're saying you need to get  
7 H&T, but then, you also say the plumes have dissipated so  
8 that they aren't -- it looks to me as if they've dissipated,  
9 none of this matters, does it?

10 MR. BESSETTE: Well, you still need an H&T, but  
11 what you have is more of a global as opposed to a  
12 location-specific. So this is important to the Oak Ridge  
13 people, because they have a one-dimensional -- their code  
14 right now takes a one-dimensional temperature input and not  
15 a two-dimensional.

16 MR. WALLIS: Well, when the plume mixes, there's  
17 no more cold water, is there? It's all sort of the  
18 temperature of everything else.

19 MR. BESSETTE: It's a mixed-beam temperature,  
20 ambient, you know, it's a mixture temperature you end up  
21 with.

22 MR. SHACK: But you're still going to have a  
23 difference to the wall, so that there's a thermal stress,  
24 and the wall is undergoing a transient. The temperature has  
25 changed.

1 MR. BESSETTE: Yes; and that doesn't mean that the  
2 whole -- just because it's well-mixed, that doesn't mean the  
3 whole down comer can't get cold either.

4 MR. WALLIS: Well, my impression is that this  
5 program is fairly vague about the need for the work. We've  
6 asked you that already.

7 MR. BESSETTE: You're focusing now on thermal  
8 hydraulics.

9 MR. WALLIS: Why is it really necessary to do some  
10 more work? If we can reasonably predict these things --

11 MR. BESSETTE: Well, it's like I say: just  
12 because we're being asked to predict different scenarios  
13 than we did the first time around.

14 MR. HARDIES: This is Bob Hardies from Baltimore  
15 Gas and Electric Company, and I'm the chairman of an EPRI  
16 group that is working on this same problem. The program to  
17 reevaluate the basis for the PTS screening criteria is being  
18 undertaken largely because there is a lot of information  
19 that the flood distributions were extraordinarily  
20 conservative that were used in the prior analysis; thousands  
21 of flaws all put on the surface. There has been destructive  
22 analysis and a lot more work done that shows that that's not  
23 the case, and that has a very, very large impact on the  
24 risk, so the NRC has undertaken a program to revisit these  
25 bases. The thermal hydraulics analyses that were done

1 before formed part of those bases, and it was deemed prudent  
2 to re-evaluate the correctness of that thermal hydraulics  
3 analysis work that was done in 1985, not to redo it but to  
4 sort of evaluate it to see if it's good enough or if it  
5 needs to be done over.

6 So this is not an extensive effort. It's merely  
7 to make sure that, as we go forward in re-analysis of the  
8 PTS screening criteria bases, we use something that is  
9 technically justifiable, well-documented, adequate.

10 MR. WALLIS: Flow distribution was very  
11 conservative. That's where the real payoff is.

12 MR. HARDIES: That's right. Now, this work is  
13 just to show that the thermal hydraulics work that was done  
14 before is adequate, that there's a good basis for it.

15 MR. BESSETTE: Maybe I should have said that  
16 before. There's probably at least two orders of magnitude  
17 conservatism in the flow assumptions.

18 MR. WALLIS: Errors in thermal hydraulics are only  
19 10 percent.

20 MR. SHACK: Yes; they're minuscule in comparison.

21 MR. BESSETTE: And so, if you look at the relative  
22 level of effort in this three-pronged approach, most of it  
23 is going into the fracture, you know, the flaws and all of  
24 that. The second tier is the PRA, and it's -- the thermal  
25 hydraulics reanalysis is a relatively minor part in this.

1 MR. WALLIS: Usually, with the uncertainties in  
2 the PRA, you can make the thermal hydraulics uncertainties  
3 go away and move on.

4 MR. ELTAWILA: One more reason for the  
5 re-evaluation of the program; the temperature which was  
6 eventually produced at the 1983-1984 had 152 points of  
7 relationship between -- since that time, a much larger  
8 number of points has become available. At the same time,  
9 the pedigree, so to speak, of those original points was in  
10 dispute and could not be retraced or re-evaluated, so that  
11 basis has been reviewed entirely.

12 MR. BESSETTE: This one last bullet on this, we  
13 did a study that said that within a reasonable range of  
14 uncertainty in the heat transfer coefficient that the  
15 uncertainty in H is small with respect to this influence on  
16 the probability of vessel failure. And that's because this  
17 process is conduction control as opposed to convection  
18 control.

19 So in terms of the thermal hydraulics or the  
20 coupled thermal hydraulics and the convection and  
21 conduction, there are two characteristic times that are  
22 important. That is how fast you cool down the vessels that  
23 the liquid that's stuck in the vessel, in the down comer,  
24 and also how fast you cool down on the vessel walls.

25 So, just to give you an order of magnitude, this

1 is a simple calculation where you just take -- this is the  
2 volume of liquid that you typically deal with that's  
3 contained in the vessel in the cold legs. It's about 60,000  
4 kilograms, and initially, it's around 570 F or so. And this  
5 is the typical high-pressure injection flow rate. It's  
6 about 60 kilograms, and it comes in at about 70 degrees  
7 Fahrenheit. So, the time it takes under these conditions,  
8 the time it takes to cool down this water down to 300  
9 degrees Fahrenheit, which is the first screening criteria  
10 you come to, is on the order of 15 minutes.

11 So once you initiate a high-pressure injection,  
12 once you interrupt natural circulation, the vessel is going  
13 to get cold in about 15 minutes, the water is going to get  
14 cold in 15 minutes. Now, then, the other thing is the  
15 vessel wall time constant. I'm going to show you some  
16 examples. It's three cases, just sort of arbitrary cases,  
17 just to give an idea of what kind of time constant this is  
18 for an 8 or 10 inch thick vessel. This shows a cool-down  
19 rate, the same cool-down rate in each case, from 550 to 150  
20 degrees; same depressurization, from 1,000 psi to 600 psi  
21 and over three different time periods. In one case, this is  
22 a constant rate over 20 minutes, 40 minutes and 60 minutes.  
23 I'll just show these six figures in each case. Let's just  
24 show you these temperature and pressure histories.

25 That's the vessel hoop stress. That includes a

1 residual stress; through wall temperature distribution at  
2 various times and hoop stress distribution at various times  
3 and also the ratio of the -- this is like a stress over the  
4 fracture stress.

5 So, that's a repeat case. One was the cool-down  
6 from initial, 550 down to 150 over 20 minutes. Then, this  
7 is a depressurization from 1,000 psi down to 600 psi over  
8 the same 20 minutes. This shows the -- what this does to  
9 the vessel tensile stress. There, you see the -- this is a  
10 stress that's due to pressure, and you can see how small  
11 this is. At 1,000 psi, you only have, let's say, less than  
12 10,000 psi of stress on the vessel. So that's, you know,  
13 that's about 20 percent of the yield stress or something  
14 like that. So under normal conditions, the vessel pressure  
15 doesn't contribute. It's a very -- it's not -- nowhere near  
16 any kind of failure limits.

17 So, this is a thermal stress that you generate at  
18 the inner surface of the vessel over time, and this is the  
19 total stress.

20 MR. WALLIS: Before, you said that the vessel had  
21 to be pressurized, but it seemed to me that the thermal  
22 stress is the big actuator.

23 MR. BESSETTE: That's right.

24 MR. SCHROCK: It did sound like you said the  
25 opposite before.

1 MR. BESSETTE: No, no, it's because --

2 MR. WALLIS: So what is the matter if the vessel  
3 is pressurized or not? You can still get big thermal  
4 stresses.

5 MR. BESSETTE: Because you can't get the crack to  
6 propagate all the way through the wall. See, once you're  
7 cracked --

8 MR. WALLIS: Pressurize it again later on.

9 MR. BESSETTE: Well, yes, presumably, you look at  
10 it before you restart it.

11 If you just put a thermal stress on the vessel, it  
12 will crack until the stress is relieved, and then, it will  
13 stop. So you need the pressure stress in order to get that  
14 crack to go all the way through the wall. But you can see  
15 that the peak tensile stress at the inside of the vessel is  
16 still increasing when the -- at 20 minutes.

17 MR. WALLIS: There's nothing here about plumes or  
18 anything like that.

19 MR. BESSETTE: No.

20 MR. WALLIS: This is just to the model;  
21 everything's all mixed.

22 MR. BESSETTE: That's right.

23 MR. WALLIS: The plume would make things worse, I  
24 believe?

25 MR. BESSETTE: Well, you know, in all the input,

1 like I say, was that temperature trace I showed you. It  
2 doesn't say anything about local or mixing or anything.  
3 This is just to illustrate the time constant of the vessel.

4 MR. WALLIS: The local cold plume presumably makes  
5 things --

6 MR. BESSETTE: Locally worse.

7 MR. WALLIS: -- the stress bigger?

8 MR. BESSETTE: It makes it locally worse.

9 MR. SHACK: Yes, I mean, you've got 15 minutes  
10 mixing the entire volume.

11 MR. BESSETTE: Yes.

12 MR. SHACK: Whereas, if you were only looking at a  
13 small down comer region, presumably, you could chill it a  
14 whole lot faster, couldn't you?

15 MR. BESSETTE: If you put an ice cube in one spot  
16 and held it or something.

17 MR. ZUBER: See, if you calculate that your 15  
18 minutes is based on the mixed main temperature.

19 MR. BESSETTE: No, I'm not doing anything like  
20 that. I'm only showing you this to give you a feel for the  
21 time constant of the vessel.

22 MR. ZUBER: Okay; the vessel time constant. The  
23 mixing of the plume can be smaller than 15 minutes.

24 MR. BESSETTE: So let's forget about the plume for  
25 a minute.

1 MR. SCHROCK: This argument you make about leaving  
2 the pressure stress to propagate it on through raises a  
3 question in my mind as to whether you can really show this  
4 on a graph like this. Once you begin cracking, you do  
5 indeed relieve the thermal stress. You modify the geometry,  
6 and therefore, you change your thermal stress problem. You  
7 change the location of concern, and it's moving outward into  
8 positions of different thermal stress.

9 MR. BESSETTE: You're talking about a crack that  
10 makes --

11 MR. SCHROCK: Thermal stress itself is changing  
12 due to -- it's more complex than just playing one or the  
13 other. I think it's the hoop stress at the inner surface  
14 over time.

15 MR. BESSETTE: Well, I mean, are you thinking in  
16 terms of maybe a crack that propagates in steps or  
17 something? Or I'm not sure --

18 MR. SCHROCK: What I'm saying -- I'll try to say  
19 it one more time.

20 MR. BESSETTE: Yes.

21 MR. SCHROCK: You argued that you need this  
22 pressure stress in order to propagate a crack on through the  
23 wall --

24 MR. BESSETTE: Yes.

25 MR. SCHROCK: -- because the thermal stress

1 relieves itself as soon as cracking occurs. The cracking  
2 also modifies the geometry for the thermal stress  
3 calculation, and it also moves the location of concern from  
4 the inner surface to someplace out in the thickness of the  
5 vessel.

6 MR. BESSETTE: Yes; let me show you something.

7 MR. SCHROCK: I'm questioning can you simply look  
8 at the thing in terms of stresses at the inner surface, a,  
9 from pressure bloating and, b, from thermal stress of an  
10 intact wall?

11 MR. BESSETTE: I'll jump ahead; I'll skip over one  
12 slide. This is the -- this is the stress on the vessel at,  
13 say, this direction as a function of distance through the  
14 vessel wall. This is the inside surface, and this is the  
15 outside surface. When you cool down a vessel or whatever,  
16 you put the inside in the tension that you see here, and the  
17 tensile stress increases with time as it's getting colder.  
18 You put the outside into compression, and it's similar to  
19 kind of, let's say, bending a beam where one side is going  
20 to be intentions and the other side compression.

21 So, when I say you can't propagate the cracks  
22 through the wall, as the crack starts to run, it runs into  
23 compressive stress.

24 MR. SCHROCK: Those stresses are calculated for  
25 the intact wall.

1 MR. SHACK: You better leave that for --

2 MR. ELTAWILA: Yes, Professor Schrock, I really  
3 think David would like to -- this is the subject of  
4 tomorrow's discussion. If you want to present something for  
5 illustration, lets go through them quickly.

6 MR. WALLIS: Yes; I'm wondering about this,  
7 because I looked at your slides, and they all seem to be  
8 talking about uniform mixed water, and I thought the whole  
9 issue was the plume, and I don't see where the plume is  
10 affecting anything. If you could tell us that you're  
11 uncertain about the plume, it jumps around a lot; that's  
12 where you're doing research. Help us. Where does the plume  
13 come into this?

14 MR. BESSETTE: This is totally different than my  
15 objective of showing this. What I wanted to show was that  
16 the -- you have to put a cold water on the inside of the  
17 vessel and keep it there for something like 15 to 30 minutes  
18 in order to develop, let's say, a PTS-significant stress  
19 distribution in the vessel.

20 MR. ZUBER: Okay; I can say if I have a plume,  
21 presumably, I can keep it there for longer than 15 minutes.  
22 The thing is the way I see the purpose, what would be the  
23 purpose of this research, everything depends on the plume,  
24 and if the plume moves down and keeps it for 15 minutes, I  
25 have a problem. If I can focus on the plume, what kinds of

1 temperature and measurements you have, how you can model it,  
2 et cetera.

3 MR. BESSETTE: I'm going to skip the rest of  
4 these.

5 MR. WALLIS: I question what you're saying.  
6 You're saying that there's a time constant of 15 minutes or  
7 something, because we have to cool down all the water?

8 MR. BESSETTE: No, no, it's how long it takes to  
9 cool down the vessel in order to create a tensile stress on  
10 the inside, and also, you have to cool down the vessel. So,  
11 it's one thing to cool down the water in the down comer, but  
12 that hasn't done anything to you yet. You've got to cool  
13 down the vessel. The vessel really doesn't care what the  
14 water is. You have to cool down the vessel material itself  
15 to below 300 F.

16 MR. WALLIS: You have to cool down the surface of  
17 the vessel.

18 MR. BESSETTE: But not just the surface; you've  
19 got to cool it to a certain depth.

20 MR. ZUBER: You see, the thing is this. You're  
21 shifting two things. If you have a plume, and your argument  
22 is I would have that to make the heat, I mean, the  
23 conductions in the vessel, at a two-dimensional or  
24 three-dimensional rate. Is this what the fracture mechanics  
25 are doing or not?

1 MR. BESSETTE: I shouldn't have started any  
2 discussion of vessels with thermal people, with hydraulics  
3 people.

4 MR. ZUBER: No, look; my question is if what you  
5 are saying is you have to cool the vessel, and you have a  
6 plume, you would have heat transfer around the perimeter and  
7 vertically down. It's a three-dimensional problem.

8 MR. BESSETTE: Let's just forget we ever got into  
9 this.

10 MR. ZUBER: You ask do the fracture people need  
11 that detail or not? If they need it, then, you have to do a  
12 different kind of experiment. If they don't need it, you  
13 can forget it.

14 MR. BESSETTE: That's why I was talking before  
15 about -- that's why I wanted -- we were going to talk about,  
16 we're going to work on the plumes, and we're going to show  
17 that either the plumes are a significant thermal, you know,  
18 thermal -- either the plumes cause a significant  
19 circumferential variation in temperature, or they don't. If  
20 they do, then, you may have to do some kind of a 2D input to  
21 your -- instead of as a temperature boundary condition to  
22 your fracture code, instead of being a 1D temperature  
23 distribution, you might have to use a 2D if the plumes are  
24 significant. That's right, yes.

25 MR. SCHROCK: I don't think it's ever less than

1 3D. I don't know what you're looking at here. Do you mean  
2 to say that you believe that 1D stress analysis will give  
3 you a meaningful answer to this question?

4 MR. ELTAWILA: Can we talk about stresses  
5 tomorrow? Really, I don't like -- let me try to simplify  
6 the purpose of the presentation.

7 MR. ZUBER: I cannot follow it.

8 MR. ELTAWILA: Well, I apologize for that. I  
9 think the purpose of the presentation is to try to look at  
10 the thermal hydraulic condition, and we will try to get  
11 enough data to see if there will be a variation in the  
12 temperature in the axial and the circumferential direction  
13 and assess the code and see the magnitude of the variation,  
14 and we will see the effect of that magnitude on the heat  
15 transfer.

16 MR. ZUBER: Okay; my question, then, is do you  
17 have data from the experiments of Theo to support that you  
18 have this proof of this region -- they would be the first  
19 questions to ask. If you have the proof, then, you have to  
20 address the proof.

21 MR. BESSETTE: Well, I think we are not going to  
22 look just at the data from Theo but also from UPTF and the  
23 Finnish experiments and all the other experiments to do this  
24 and also the APEX experiments. But we're going to show one  
25 way or the other, the plume is significant or is not

1 significant.

2 MR. ZUBER: Based on information that you have  
3 from Theo's test, is it significant or not?

4 MR. ELTAWILA: Not significant.

5 MR. ZUBER: Not significant?

6 MR. BESSETTE: Not significant; so far, all of the  
7 data we have looked at is not significant, but by the time  
8 -- it's not to deny that it's the plume coming into the down  
9 comer, but by the time it gets to the core, it's mixed.

10 [Pause.]

11 MR. WALLIS: Well, hopefully, when you get to  
12 tomorrow, someone can explain why it's not important if you  
13 get a cold area. To my understanding, the thermal stress,  
14 if you have this cold area there, you have to worry about  
15 it.

16 MR. BESSETTE: Well, I think that's right, yes.

17 MR. WALLIS: It's an average around the whole  
18 thing.

19 MR. BESSETTE: No, no, I agree.

20 MR. ELTAWILA: And it's duration of that cold area  
21 is going to be adjacent to the wall of the -- you know,  
22 you're going to get cold water, but is it going to remain  
23 cold for the duration that would sort of produce the  
24 significant load on the vessel or not? And that's the  
25 information that we will try to work together with the

1 fracture mechanic people to decide about the importance of  
2 our findings here.

3 MR. BESSETTE: Yes; the same spot has to stay cold  
4 for the same time. These plumes have a way of kind of  
5 meandering, too.

6 [Pause.]

7 MR. BESSETTE: So, skip all of those other  
8 temperature slides and go on to the phenomena, the PIRT. We  
9 have three PIRTs identified so far. One was done in  
10 conjunction for an H.B. Robinson reanalysis we did about 5  
11 years ago. One was done for -- when we did a Yankee Row  
12 analysis about 10 years ago. And there was one done in  
13 conjunction with the REMIX code.

14 MR. WALLIS: Are you talking about old PIRTs or  
15 new PIRTs?

16 MR. BESSETTE: This is existing PIRTs.

17 MR. WALLIS: These are old PIRTs?

18 MR. BESSETTE: What's an old -- you know.

19 MR. WALLIS: Ancient PIRTs.

20 MR. BESSETTE: Not ancient.

21 [Laughter.]

22 MR. ZUBER: When did you perform them?

23 MR. BESSETTE: Well, H.B. Robinson was about 5  
24 years ago; Yankee Row was about 10 years ago.

25 MR. WALLIS: You're not talking about the

1 eighties. These are recent PIRTs.

2 MR. BESSETTE: Well, the REMIX PIRT, I think, goes  
3 back to the eighties, late eighties.

4 MR. WALLIS: A PIRT is a very primitive stage in  
5 the process. I'm trying to figure out what important  
6 phenomena they want to fix their arms around. I thought  
7 that was all done.

8 MR. BESSETTE: For PTS? You know, the PIRT  
9 process changes with each event you're trying to analyze,  
10 whether it's a small break or whatever.

11 So, a PIRT that was focused -- these are the only  
12 PIRTs that I know of so far that have been focused on PTS.

13 MR. WALLIS: They've ended up showing what you  
14 know already, that you don't get down comer temperature in  
15 the heat passage walls.

16 MR. BESSETTE: The PIRT shows what you know  
17 already, yes, or what you think you know already.

18 [Pause.]

19 MR. BESSETTE: This is the PIRT that was done for  
20 H.B. Robinson. These were the panel members. It was Cliff  
21 Davis from INEO; Professor diMarzo; Professor Griffith;  
22 Professor Hassan; and Professor Barkley-Jones. The four  
23 transients were considered: main steam line break from hot  
24 standby; steam generator overfeed following a turbine trip;  
25 and then a small cold leg break loca and a small hot leg

1 break loca, and of course, the key parameters are what I  
2 already mentioned: down comer temperature; system pressure;  
3 and convective heat transfer coefficient.

4 I list the -- from this PIRT, these were the top  
5 10 phenomena identified in rank order. And, of course, some  
6 of these -- it's a typical thing. Some of these, you can  
7 consider to be phenomena, and some are, let's say, some kind  
8 of a boundary condition for the problem.

9 So, it's accumulator injection flow rate; in this  
10 case, they considered three-dimensional vessel wall heat  
11 conduction to be significant. It's an HPI injection flow  
12 rate; it's the flow distribution in down comer; this is the  
13 plume mixing in the global down comer flows; the accumulator  
14 liquid temperature; break flow; HPI injection temperature.  
15 You see temperatures and flow rates showing up several  
16 times.

17 This is the mixing the HPI jet as it enters the  
18 cold leg and the mixing at that location where it enters the  
19 down comer, so this is, you know, that's these two mixing  
20 regions there.

21 MR. WALLIS: You could write this down without a  
22 PIRT, though, couldn't you?

23 MR. BESSETTE: Well, yes, I think so; well, that's  
24 -- a PIRT is just writing it down. I mean, one person can  
25 write it down, or a group can write it down.

1 MR. SCHROCK: Well, the ranking is a group  
2 process.

3 MR. BESSETTE: Rankings, any individual can write  
4 it down, and then rankings --

5 MR. SCHROCK: And then, you can rerank.

6 MR. WALLIS: Maybe 8, 5 and 4 and 8.

7 MR. ELTAWILA: I think in terms of -- you want to  
8 do some variation on the top ones and try to see their  
9 effects on the overall uncertainty.

10 MR. WALLIS: You can't do the whole problem.

11 MR. KRESS: It's surprising that decay heat enters  
12 that mix.

13 MR. BESSETTE: I wasn't part of this PIRT, but I  
14 think anytime somebody looks at it who wasn't -- the way  
15 these PIRTs evolve to some extent depends on the discussions  
16 amongst the people who were there, and there's a lot behind  
17 these things. Sometimes, people will rank things lower  
18 because they say, well, we know that very well. So, for any  
19 given transient, we know what the decay heat is, so,  
20 therefore, the uncertainty is low. So that kind of thing  
21 enters into people's thinking sometimes.

22 MR. WALLIS: It doesn't help me to understand what  
23 you're doing and why. Perhaps we should go on to that.

24 MR. BESSETTE: Yes; okay. I mean, I don't want to  
25 dwell on this, but I figured somebody was going to ask me

1 about PIRTS, so --

2 MR. WALLIS: Well, you've done a good job on your  
3 PIRTS.

4 [Laughter.]

5 MR. BESSETTE: And so, this is the Yankee Row,  
6 and, of course, those are the people, and they come up with  
7 another list of phenomena which we can puzzle over in a  
8 known set of rankings. And then, the PIRT that was done for  
9 REMIX, of course, as you might expect, it looks just like  
10 REMIX does. So all these things that are ranked high, at  
11 least, are those things, are those aspects that REMIX  
12 focuses on.

13 [Pause.]

14 MR. ZUBER: Well, did anybody confirm the  
15 experimental data, the fluctuations in the different PIRTS,  
16 how they read this process?

17 MR. BESSETTE: Comparing the data directly against  
18 the PIRT?

19 MR. ZUBER: Yes; right. The question is really  
20 did you make any use of the experimental data since that  
21 time? Because here, you have a graph experimental facility.

22 MR. BESSETTE: Yes.

23 MR. ZUBER: Some which has quite a -- presumably  
24 quite a bit of data. What information did you draw from  
25 these experiments?

1 MR. BESSETTE: Bill will tell you that better next  
2 time.

3 MR. ZUBER: I don't mean to be sarcastic. This  
4 you should do before -- when you start a program.

5 MR. BESSETTE: Yes; well, it's difficult to do  
6 everything at once, I know.

7 MR. ZUBER: I looked at --

8 MR. BESSETTE: Well, you know, if you compare this  
9 data, let's say, if you compare these experimental programs  
10 with, let's say, the REMIX PIRT, there's quite a bit of  
11 correspondence. They were all, you know, they were all  
12 inspired, let's say, by the questions that -- after we had  
13 the first PTS studies, the questions that arose with respect  
14 to what's the effect of the plume. So, as a result of that,  
15 we had a number of these experimental programs, and these  
16 were the issues that they were focusing on: how much mixing  
17 is there at the injection location? How much mixing and  
18 stratification is there in the cold leg? How much is there  
19 when you get the junction between the cold leg and the down  
20 comer? And then, the -- trying to find out how much mixing  
21 occurs in the plume and how quickly it disperses.

22 MR. WALLIS: I guess what we're trying to find out  
23 is what is the state of the art of all of this? And we sort  
24 of accept all of this. This is all important. Then, you've  
25 got to go through -- I don't know if you need to go through

1 all of these facilities. What we need to do is get a  
2 picture of what you know now and what you need to know.

3 MR. ZUBER: You see, you have six facilities here.  
4 What kind of information did you get from these facilities?  
5 And where is the whole that you have tested here?

6 MR. BESSETTE: I think the purpose -- I mean, you  
7 know, if you -- well, no, the objective of -- this all  
8 leads --

9 MR. ZUBER: No, no, this summary of the  
10 experiments.

11 MR. BESSETTE: You know, when you go through at  
12 least these first four.

13 MR. WALLIS: We believe that. Let's go on.

14 MR. BESSETTE: Yes.

15 MR. WALLIS: What do you know about all of this  
16 stuff?

17 MR. BESSETTE: What are you trying to do?

18 MR. WALLIS: What's the state-of-the-art?

19 MR. ELTAWILA: Why don't you go over the view  
20 graph that summarized the result of these test facilities  
21 two view graphs later?

22 MR. BESSETTE: Well, I told you: the  
23 state-of-the-art is that the plume seems to be gone before  
24 it reaches the core region.

25 MR. WALLIS: Then what's the problem?

1 MR. BESSETTE: That's what we're trying to say, is  
2 that as far as we can tell, there is not a problem.

3 MR. ZUBER: Then, the normal question: why do it?

4 MR. ELTAWILA: I'm going to repeat myself again,  
5 okay? They have done all what they can do in the area of  
6 fracture mechanics. Some plants are going to be hitting the  
7 PTS limit very soon. And now, we try to do a more realistic  
8 thermal hydraulic calculation to see that the assumption  
9 that we used previously is still valid with the known plant  
10 design modification.

11 MR. ZUBER: Fine.

12 MR. ELTAWILA: Okay.

13 MR. ZUBER: Let me say this: you have six  
14 facilities with quite a bit of data. Then, you analyze  
15 these data to see what you have and determine what you need.

16 MR. ELTAWILA: I think the only remaining issue is  
17 the flow stagnation and interruption and resumption in flow.  
18 What we've seen in some of the tests at OSU and at the  
19 University of Maryland that you have, for a plant that has  
20 two cold legs per hot leg, that if you want, that you will  
21 get flow -- one loop stopped but the other loop circulate,  
22 and that will enhance mixing, and we want to see the  
23 importance of that phenomenon and to get additional data to  
24 assess the flow to be able to do a better, realistic  
25 analysis.

1 MR. REYES: Jose Reyes with Oregon State.

2 Many years back, I was involved with some of the  
3 testing in this. The thing is that where the  
4 state-of-the-art was then as compared to now, back then, as  
5 far as detail of the down comer calculations for fluids,  
6 looking at the plumes, we had two options. We had a code  
7 called SOLA/PTS, which was like a CFD version, and we had  
8 REMIX was the other option. Now, REMIX came about because  
9 SOLA/PTS was taking 10 hours to run 10 seconds of transient,  
10 and, of course we had --

11 MR. WALLIS: When was this?

12 MR. REYES: This was back in 1985.

13 MR. WALLIS: But now, we can do things about 1,000  
14 times faster.

15 MR. REYES: Even better; so, as far as  
16 state-of-the-art, the ability to perform some of these new  
17 CFD calculations is now in reach. So, that's one thing that  
18 is a bit different. The other thing that is really  
19 different was that all of these tests were basically  
20 separate effects tests. So, if you look at that list of  
21 facilities, they were all separate effects tests. Nothing  
22 really looked at the fact that you had multiple loops with a  
23 potential for stagnation in one loop and not stagnating in  
24 the other. The only one that was close to that was the IVO  
25 test facility, Imatran Voima Oi (phonetic) back in Helsinki,

1 and they did do multiple loops, but it wasn't integral.

2           So, for example, things that we've observed that  
3 are really different compared to the tests that were  
4 performed back then is this idea of loop stagnation due to  
5 the steam generator tube draining. What we've seen is that  
6 the top, the long tubes, will drain first, but you'll get  
7 lots of natural circulation flow through the loop until you  
8 finally drain those bottom tubes. So, how well can the  
9 computer codes predict this loop stagnation? The codes that  
10 were used back then were using one tube to model the whole  
11 steam generator. So when that tube voided, you stagnated.  
12 So, in fact, you have, you know, thousands of tubes.

13           So that's one area that I think we will be able to  
14 shed some light on in these experiments. The other thing  
15 which I will show later on has to do with the onset of  
16 thermal stratification and some revisions to that  
17 stratification criteria, which I believe may be necessary  
18 for some of the high injection HPI flows, which we didn't  
19 know before.

20           MR. KRESS: And the point is that these things  
21 have a significant effect on the temperature and pressure  
22 transient on the wall --

23           MR. REYES: Absolutely, absolutely.

24           MR. KRESS: -- and that is an input into the  
25 fracture mechanics.

1 MR. REYES: That is correct; more recently, and  
2 hopefully someone will speak to this tomorrow, Oak Ridge did  
3 approach me with regards to a 3D finite element model of our  
4 vessel, because we're trying to, in essence, sharpen the  
5 pencil; learn more about the fracture mechanics as well as  
6 the thermal hydraulics in order to be able to address, as  
7 Dr. Zuber had mentioned, in order to be able to say, well,  
8 we're getting closer to the limits of these vessels; we need  
9 to know better where we stand. What side of the line are we  
10 on? And so, that's how I see a lot of this work being  
11 directed towards.

12 MR. ZUBER: Which code are you going to use for  
13 the rest of it?

14 MR. ELTAWILA: For which one? For the detail  
15 mixing calculations?

16 MR. ZUBER: Well, you are talking about  
17 stagnations, different tubes; I don't know how many steam  
18 generator tubes are going to participate. Which code are  
19 you going to use to do that?

20 MR. ELTAWILA: We would like to observe the data,  
21 the information in the experiment first, and then, we will  
22 decide. Of course, we have the system code log, the RELAP5  
23 and the TRAC and base on the additional needs. We might go  
24 into a CFD code or something like that. And that's still in  
25 the plan, but we have not developed that work in details

1 until we see some of the data coming out of the experiments.

2 MR. WALLIS: You have two questions, really. One  
3 is can the codes predict the transient, which you know if  
4 you've got stagnation on all of those. And if you do get  
5 stagnation, can some code predict what's happening in the  
6 down comer well enough? Two separate questions. You're  
7 answering both of these questions in effect?

8 MR. REYES: We are developing data for both of  
9 those questions. We will be using two codes, and I will  
10 describe that a little bit later. Of course, this is at our  
11 university level as far as code operations. More detailed  
12 codes, I'll leave that to Farouk to see which ones would be  
13 used for that.

14 The other item that, as far as the difference  
15 between then and now is the operator actions that were  
16 assumed for these transients were very extreme. I think  
17 maybe in our facility, we can model all of the control  
18 systems. We can simulate actual plant controls as well as  
19 feed water control, steam generator level control, steam  
20 flow controls, so we can model some of these things and look  
21 at the effect that the operator actions or the control logic  
22 has on these scenarios, and they do have significant  
23 effects. Whether you repressurize or not depends on -- in  
24 certain transients depends on the operator action, or how  
25 quickly you cool down will depend -- or whether you cool

1 down at all will depend very strongly on operator actions.  
2 So we have that capability to look at some of those issues  
3 also.

4 MR. KRESS: That will change the frequency of the  
5 initiators for these particular events.

6 MR. REYES: Right; the assumptions that you make  
7 as far as operator actions affect which way the transient  
8 will go.

9 MR. KRESS: So you might lower the frequency of  
10 initiating events.

11 MR. REYES: Correct.

12 MR. WALLIS: Now, Jose, you have a presentation  
13 coming up after the break.

14 MR. REYES: Yes.

15 MR. WALLIS: According to that, you have.

16 MR. REYES: My focus will be on the scaling  
17 analysis.

18 MR. ZUBER: You should also address the code,  
19 because this is your primary tool.

20 MR. WALLIS: I just wonder where we're getting  
21 with the present presentation. Are you getting across what  
22 you wanted to get across in terms of a message to this  
23 committee?

24 MR. BESSETTE: Well, I'm not sure. It doesn't  
25 seem like it.

1 MR. WALLIS: What is it that you wanted to tell  
2 us?

3 MR. BESSETTE: Well, I wanted to --

4 MR. WALLIS: You can throw away your slides and  
5 tell us what you want to tell us.

6 [Laughter.]

7 MR. BESSETTE: It's time to go home. That's what  
8 I wanted to tell you.

9 [Laughter.]

10 MR. BESSETTE: Well, let me think. I wanted to --  
11 well, there have been a few things, a few perspectives, that  
12 I haven't touched on like some other people have. One was  
13 that, like was said before, that the thermal hydraulics is  
14 part of a three-prong effort. And why are we doing it?  
15 Because some of the scenarios have changed from what we  
16 analyzed in the first go-round. Like Jose said, there are  
17 conservative assumptions made in terms of operator actions,  
18 like typically, these old calculations, the -- in  
19 combination with initiating event, you had a steam drainer  
20 overfeed, and high pressure injection was never throttled.  
21 So a lot of these old transients, the primary system filled  
22 up water-solid, so that you had an upward pressure of around  
23 2,400 psi.

24 So in terms of why are we doing some of the  
25 calculations, it's because -- it's in conjunction with the,

1 let's say, PRA is what -- what are really the highest  
2 probability, highest consequence scenarios.

3 MR. WALLIS: So, there are some new kinds of  
4 scenarios which either weren't analyzed before or couldn't  
5 be analyzed using the old methods.

6 MR. BESSETTE: Or weren't analyzed.

7 And, you know, like I was saying, one of the,  
8 let's say, outstanding issues that developed during the  
9 first PTS study was this issue of what was the plume effect,  
10 because that really wasn't considered in the bulk of the  
11 calculations. And so, there was this lingering questions  
12 of, well, what happens if you have a very strong cold plume?  
13 That's going to make things much worse for the region where  
14 the plume exists. And so, in the meantime, there were these  
15 six or so different experimental programs that were run to  
16 develop fluid-fluid mixing data in the cold leg and down  
17 comer. And the idea is to show, well, how does this plume  
18 threat?

19 MR. WALLIS: Now, the output from these six  
20 programs in the past was presumably some standing of  
21 phenomenon and some modeling effort and some computer models  
22 which could be used to assess transients.

23 MR. BESSETTE: Yes; well, these were experimental  
24 programs. The only modeling effort, I guess, that I know of  
25 that was associated with it was the REMIX code.

1 MR. WALLIS: Is the problem that in the past, the  
2 experiments were run, but nobody really pulled it all  
3 together, and that's what you need to do?

4 MR. BESSETTE: To some degree. You know,  
5 Theophonus did that to some extent when he analyzed REMIX  
6 against most of this data, but his purpose there was to,  
7 let's say, assess or validate REMIX and not necessarily to  
8 carry it to the point of what is really the temperature  
9 distribution adjacent to the core.

10 MR. ZUBER: See, this is the comment that I have  
11 on most experimental programs carried out by NRC, and I was  
12 part of it 10 years ago. NRC never made a synthesis of  
13 their results. Without it, you have a synthesis of the  
14 broad experiments, but you don't have any synthesis of the  
15 last experiment. There is nothing you can take that says  
16 okay, this is what I have; something you can transmit to the  
17 next generation.

18 MR. BESSETTE: Yes.

19 MR. ZUBER: You and I, we are also here, and most  
20 of the people here, we cannot come now to an agreement of  
21 what we have learned 10 years and 15 years ago, and what it  
22 means is once this cohort of people has gone, a new cohort  
23 will probably come which doesn't know anything about it.  
24 Then, you have to spend more money and more time. But in my  
25 comments to the committee here and the NRC, you need a

1 synthesis of the knowledge you have accomplished 10 years  
2 ago. On the PTS, you would have a document; this is what I  
3 learned from an experiment; this is what was important; this  
4 is where I have holes in my methodologies, and I have to  
5 fill them.

6 MR. BESSETTE: Well, I agree. I mean, I feel like  
7 there doesn't exist a complete synthesis of these  
8 experimental programs, and this is something I would like to  
9 be able to accomplish.

10 MR. WALLIS: Well, it would seem that would be a  
11 starting point for new programs, a work order for the new  
12 program would be to figure out the state-of-the-art for  
13 where we were before.

14 MR. BESSETTE: The other thing, I think we have  
15 adequate database in terms of fluid-fluid mixing from these  
16 programs as far as they go. What I see is missing is what  
17 Jose was just describing as we're doing this program. It's  
18 for the class of events -- many of the events, many of the  
19 PTS-significant events are small-break locas in the cold leg  
20 or the hot leg. There hasn't -- and so, the key to when you  
21 start the vessel cooldown is when you lose loop natural  
22 circulation, so that's a precursor to cooling down the  
23 vessel.

24 There hasn't been a careful look at what are the  
25 criteria: can you predict exactly when you lose loop

1 natural circulation?

2 MR. WALLIS: Do you have this figure up there?

3 MR. BESSETTE: Yes, yes.

4 MR. WALLIS: Can you put it up?

5 MR. BESSETTE: Yes.

6 MR. WALLIS: This is presumably someone's  
7 observations from experiments?

8 MR. BESSETTE: Yes, this is the Finnish  
9 experiments.

10 MR. WALLIS: Simulating conditions which you're  
11 interested in for this problem.

12 MR. BESSETTE: Yes.

13 MR. WALLIS: And what I see here is plumes which  
14 are certainly not very well mixed two diameters below the  
15 pipe. That doesn't go with your statement that everything  
16 is well-mixed when it goes --

17 MR. BESSETTE: Well, let's see. You can't see  
18 here the temperature -- well, like at this elevation here,  
19 you're already well-mixed.

20 MR. WALLIS: That's -- the reactor -- it's not  
21 a --

22 MR. ZUBER: It is more than two diameters below.

23 MR. BESSETTE: There's a lot of other data, too.

24 MR. ZUBER: See, the thing is this is where you  
25 need a synthesis.

1 MR. BESSETTE: I just wanted to show you this to  
2 illustrate the type of -- this is from the Finnish  
3 experiments. This was just to illustrate the type of data  
4 they generated.

5 MR. WALLIS: 70, 70, 70, 70, 60, 60, I mean, those  
6 are the temperature measurements?

7 MR. BESSETTE: Yes; these numbers here you see are  
8 temperature measurements.

9 MR. SCHROCK: What is the technique that produced  
10 those?

11 MR. BESSETTE: They -- I'm not quite sure. How  
12 they get this?

13 MR. SCHROCK: Yes; how is that image created?

14 MR. BESSETTE: From what I can tell from looking  
15 at the report, they took a picture, and this is an artist's  
16 rendition of what he saw. This is like a drawing.

17 MR. SCHROCK: These little hairs are intriguing.

18 MR. BESSETTE: But, yes, you can see the swirl  
19 patterns here, you know.

20 MR. SCHROCK: Somebody say that and drew it is  
21 what you're saying.

22 MR. BESSETTE: Yes.

23 MR. SCHROCK: Okay.

24 MR. BESSETTE: And what you're seeing is -- for  
25 example, this is the same test; this is some period between

1 0 to 3 minutes, and this is between 3 and 6 minutes. Then,  
2 you see how this plume has drifted over here and combined  
3 with the other one.

4 MR. ZUBER: How many temperature measurements did  
5 they take?

6 MR. BESSETTE: They had -- in the down comer, they  
7 had something like 60 this way and that way.

8 [Pause.]

9 MR. BESSETTE: Typically, once you get down to  
10 about --

11 MR. ZUBER: Since you have a thing, I guess you  
12 need more than that, more -- because after that, on the  
13 right picture, you would have that not that far down, two  
14 diameters.

15 MR. BESSETTE: In fact, they ran some tests, and  
16 then, they stopped, and they added more thermal couplers.

17 MR. WALLIS: Well, I think what I would really  
18 benefit from would be a sort of summary paper of the type  
19 that you wouldn't be embarrassed to stand up in front of an  
20 audience at the ASME or at somewhere and say this is the  
21 state-of-the-art. Here are the experiments; this is what we  
22 learned; this is what we know now; this is why we know it,  
23 and this is where the holes are. I don't -- you seem to be  
24 ready for that. It would help a great deal, because there  
25 is so much that seems to be going every direction here.

1 MR. ZUBER: I have a question: when did you start  
2 this program?

3 MR. BESSETTE: Last -- let's say about the middle  
4 of last year.

5 MR. ZUBER: Of 1999?

6 MR. BESSETTE: Yes.

7 MR. ZUBER: When did you determine the need and  
8 then start the program?

9 MR. BESSETTE: Well, on a global basis, when did  
10 we determine the need to revisit the PTS rule? That was  
11 sometime early last year, I think. And then, but, you know,  
12 it took some time to decide well, what do we need to do to  
13 do that?

14 MR. WALLIS: Well, my impression is if I took this  
15 problem here and gave it to an undergraduate honors student  
16 who was familiar with the latest CFD programs, where all you  
17 have to do is put in the geometry and the boundary  
18 conditions and then run it, that this would be over in a  
19 couple of weeks. And the question then might be did the CFD  
20 modeling adequately model things like porosity and mixing.  
21 It can be done.

22 MR. KRESS: Before you ever get to this point in  
23 the transient, though, you have to have reached stagnation  
24 conditions.

25 MR. BESSETTE: That's it exactly.

1 MR. KRESS: And that's the hard thing to predict,  
2 and CFD code won't predict it.

3 MR. WALLIS: Is the stagnation problem the real  
4 problem?

5 MR. ELTAWILA: Stagnation is the key.

6 MR. ZUBER: Which code are you going to use for  
7 stagnation?

8 MR. KRESS: Well, they used RELAP before. And  
9 that was one of the problems. They couldn't really pick out  
10 just when stagnation was occurring in RELAP because it  
11 doesn't have a stagnation flow. It leads you up to it, and  
12 then, you try to decide, well, based on what I know about  
13 stagnation flow, we'll probably get it here or here or here.  
14 And that's the big uncertainty. That fixes all of the  
15 initial conditions for you.

16 MR. ZUBER: Then, the question is any program  
17 which does not address the stagnation is almost doomed to  
18 failure.

19 MR. KRESS: That's probably the truth.

20 MR. BESSETTE: Well, that's why we have the APEX.  
21 That's one of the main reasons we're running APEX tests.

22 MR. KRESS: So you run experiments to help decide  
23 on what criteria to use in something like RELAP to decide  
24 when you're going to have stagnation.

25 MR. BESSETTE: Maybe I haven't said it. We're

1 just as interested or more interested in the stagnation  
2 issue as we are in the plume issue.

3 MR. ELTAWILA: The plume is not an issue.

4 MR. WALLIS: It seems to me that you're in a  
5 transient that will pass through stagnation perhaps, but not  
6 more. I mean, things are happening all the time. It would  
7 be very unusual for stagnation to peter on for several  
8 minutes.

9 MR. BESSETTE: But that is what we are saying. It  
10 takes some minutes. It can take some minutes to go through  
11 stagnation.

12 MR. WALLIS: And the flow stops for several  
13 minutes?

14 MR. BESSETTE: No; the thing is you've got a small  
15 break loca. It's not the interruption of a single loop  
16 that's the thing. You've got a small break loca and a plant  
17 that can have four loops. So all four loops don't stop at  
18 the same time that loop one stops, and then, the other three  
19 loops keep going until loop one, the generator drains. It  
20 takes some time for the generator to drain; the other three  
21 will keep going. And with two stops, and then, that  
22 generator has to drain; and then, loop three stops, and  
23 then, finally, loop four stops. And each individual loop  
24 doesn't stop all at once. It stops over a period of time,  
25 because you've got long tubes; you've got 60 banks or 100

1 banks of tubes. So the longest one stops first; then, the  
2 second-longest and the third longest, so that it's not just  
3 a switch. The stagnation develops over some -- it can be 20  
4 minutes even, 10 or 20 minutes, depending on the break size

5 MR. ZUBER: Question: given that the stagnation  
6 is one of the initiators, the most important one, two, that  
7 we cannot really calculate it very closely or realistically,  
8 on what basis, then, are you going to make a decision that  
9 you can --

10 MR. BESSETTE: Well, what we're trying to do --

11 MR. ZUBER: If you don't have the two, you don't  
12 have a coefficient that you can trust, and this can go all  
13 over the place. How are you going to address this question?

14 MR. BESSETTE: Well, you know, we said well, what  
15 are our key parameters here? System pressure; down comer  
16 temperature and heat transfer.

17 MR. ZUBER: You cannot calculate stagnation if you  
18 go to one loop to another.

19 MR. BESSETTE: Yes.

20 MR. ZUBER: You can start and stop.

21 MR. BESSETTE: So, what do we do? We try to take  
22 the two extremes and see what effect did this have on the  
23 parameters we're interested in. We try to -- we take the  
24 uncertainty range.

25 MR. ZUBER: You must have a code that you can do

1 it with.

2 MR. BESSETTE: Well, you know, the codes will  
3 calculate stagnation.

4 MR. ZUBER: And you want to be conservative.

5 MR. ELTAWILA: The issue is not to reduce  
6 conservativism here. It's to try to validate the analysis  
7 that we have done in the past, and we see that the more  
8 plant improvements and the operator action and things like  
9 that just try to calculate the thermal hydraulic conditions  
10 during this phase of PTS.

11 MR. ZUBER: You cannot calculate that.

12 MR. ELTAWILA: We can calculate it. We can look  
13 at the result of the experiment, and, with several tools --  
14 we have to look at results of the experiment before we can  
15 make a judgment about what modifications are going to be  
16 made to the code or what other codes are going to be used in  
17 this analysis.

18 MR. KRESS: I seem to recall that someone looked  
19 at the RELAP calculations and had a set of what I would call  
20 criteria that he said, oh, if these things hold true in the  
21 RELAP calculation at some time, I will call that the time in  
22 which stagnation is thought. So one of the things you might  
23 be doing is checking to see if these criteria are any good,  
24 because they weren't really based on real stagnation  
25 experiments, now. They were based on what he expected would

1 lead to stagnation. Is my recollection correct?

2 MR. ELTAWILA: I think your recollection is  
3 correct, and I think that's the information we're trying to  
4 get from the OSU facility, and we are trying -- we went  
5 through the painful process of trying to scale the facility  
6 to represent one of the plants in the PTS study at least to  
7 be able to see what can happen in the plant.

8 MR. REYES: Jose Reyes again, and I'll be talking  
9 about that criteria in the next presentation.

10 MR. ZUBER: Okay; thank you.

11 MR. WALLIS: Do you expect some feedback from us  
12 on what you're telling us today, or is this sort of for  
13 information purposes?

14 MR. ELTAWILA: I think we need feedback  
15 particularly on the test program and the scaling analysis  
16 and the criteria that we are going to use for stagnation and  
17 so far.

18 MR. WALLIS: Because my feeling is I would need to  
19 see a more focused presentation before I would know what to  
20 tell anyone. And that's the way the questions from the  
21 committee seemed to go.

22 MR. ELTAWILA: That's fine; let's wait until we  
23 see Jose's -- I think the presentation should have come just  
24 to say that we are running an experimental program to try to  
25 find some thermal hydraulic conditions from which we try to

1 develop criteria that we can use in our codes. We have made  
2 modifications to our thermal hydraulic codes, and the plants  
3 have made some modifications, and we have tried to just see  
4 if we could use or come up with the information that's  
5 needed for the fracture mechanic people to do the work, and  
6 the focus of the presentation is on the scaling analysis and  
7 the tested program.

8 MR. WALLIS: Well, when is there going to be  
9 closure on PTS?

10 MR. ELTAWILA: PTS closure is supposed to be by  
11 December 2001. We're supposed to issue the rulemaking.  
12 You're going to hear more about this information tomorrow.

13 MR. WALLIS: I'm not here tomorrow. Tomorrow is  
14 about --

15 MR. ELTAWILA: Okay; we are supposed to be issuing  
16 the rulemaking. I can get you a copy of the schedule in the  
17 break and review it with you. But the whole activity has to  
18 be finished by January 2001.

19 MR. WALLIS: The road map of activities to get you  
20 from here to there.

21 MR. ELTAWILA: But this is the subject of  
22 tomorrow, and that's what, in the last meeting, I heard a  
23 member, the chairman of the committee, said that we do not  
24 want to have a separate subcommittee meeting, because that  
25 will confuse the issue. This is an integral issue, and we

1 thought that we were going to have a full committee meeting  
2 to discuss the whole issue as a whole and not to direct  
3 stress analysis calculation to people that don't know  
4 anything about it.

5 MR. WALLIS: I thought we were going to hear today  
6 about the thermal hydraulics side and what inputs it needed  
7 to give so that the overall picture -- when I said road map,  
8 I really meant a road map of how you're going to resolve the  
9 thermal hydraulic part, and I don't see that.

10 MR. ELTAWILA: Have you finished your presentation  
11 there?

12 MR. BESSETTE: Yes.

13 MR. SCHROCK: I was looking at your conclusions  
14 from prior calculations, David, and I noticed that the PTS  
15 problem develops on the order of 15 to 45 minutes for some  
16 comments there about the date, the starting time for that,  
17 but those times seemed very long compared to what you're  
18 showing us in this picture. It seems a long time for a  
19 thermal stress problem to develop, 45 minutes.

20 MR. BESSETTE: That's what I was trying to show  
21 you something about these time constants that say that the  
22 time involved to cool down the vessel sufficiently, to get  
23 down to 300 degrees, is on the order of 15 minutes. It can  
24 be longer. And then, the time required to cool down the  
25 vessel sufficiently to develop a stress, the thermal

1 stresses needed, is on the order of 15 minutes. So the  
2 median there is about, you know, 15 plus 15, it gives you  
3 the 30. That's why --

4 MR. WALLIS: You injected ECC into the vessel and  
5 poured it down the wall so that it stayed in the jet, you  
6 could have a problem there.

7 MR. BESSETTE: Possibly, yes, yes.

8 MR. SHACK: I mean, just think of it in  
9 simple-minded terms. If you just cooled the first mill of  
10 the wall, it's not much of a problem. You know, you can  
11 accommodate that easily. So you have to cool a significant  
12 amount of the wall. No, it's really a 1D kind of thing.  
13 You're going through the thickness. I mean, you really have  
14 to chill the surface of the material enough in order to get  
15 a differential strain between that surface and that, and it  
16 just takes awhile to cool, you know, a certain depth of  
17 material. It's really a heat conduction problem, you know,  
18 once you're getting the temperature in there. What his  
19 calculations are showing is that, you know, he's sort of, by  
20 chilling that surface, he's building up that stress there,  
21 you know, and it sort of takes him about 15 or 20 minutes to  
22 really chill it enough to get it dry.

23 MR. KRESS: That time constant conduction leg  
24 going through the wall is not 15 minutes. That's a pretty  
25 short time for it. So it's not that.

1 MR. ZUBER: Another one plume, I mean, something  
2 like you have here, and this can stay there for 10 or 15  
3 minutes. You don't have mixing, and this goes two  
4 diameters, and then, that's where you can obtain the  
5 problem.

6 MR. SHACK: Well, I mean, he's got his  
7 temperatures there.

8 MR. BESSETTE: I mean, other than making the  
9 conduction calculations.

10 [Laughter.]

11 MR. SHACK: It's 8 inches of steel, and it's  
12 stainless steel, and it's not the world's greatest  
13 conductor. I mean, it's not high-tech. You know, I think  
14 one of his earlier points was that there is a time delay in  
15 here, so some of these fluctuations don't become as  
16 important as they might seem, you know, because you are  
17 smearing these things out in dimensions.

18 MR. ZUBER: The picture doesn't show this. I can  
19 obtain the cold plume, let's say, four or five diameters  
20 below for a long time.

21 MR. BESSETTE: You have to realize, this --

22 MR. KRESS: You have to realize this is not a time  
23 constant, the way it goes through the wall. It's a time  
24 constant for cooling the whole wall around this to these  
25 depths.

1 MR. SHACK: Okay; you're cooling --

2 MR. KRESS: So it's not the normal constraints.

3 MR. WALLIS: Well, maybe we should move on to the  
4 later presentation.

5 MR. KRESS: Yes, I think that might help.

6 MR. WALLIS: I think we need to come back to this,  
7 to come back again. Let's have a break and then see where  
8 we are.

9 We'll have a break now. Would you like to break  
10 until 3:00? Ten of 3:00; okay.

11 [Recess.]

12 MR. WALLIS: Let's come back into session. We'll  
13 hear from Jose Reyes about great things happening at OSU.

14 MR. KRESS: I keep forgetting whether that's the  
15 Ducks or the Beavers.

16 MR. REYES: We're the Beavers.

17 MR. KRESS: You're the Beavers.

18 MR. REYES: That's fine; and the Beavers have been  
19 -- we've been beaten by the best.

20 [Laughter.]

21 MR. REYES: Today is March 15, which is the Ides  
22 of March.

23 MR. WALLIS: Right.

24 MR. REYES: So beware the Ides of March, I guess,  
25 was my concern.

1 MR. KRESS: What exactly is the meaning of Ides?

2 MR. REYES: That was when Julius Caesar --

3 MR. KRESS: I know what happened.

4 MR. REYES: -- was killed.

5 MR. KRESS: What's the original Latin meaning of  
6 that?

7 MR. ZUBER: No, he was killed by --

8 MR. KRESS: I think it's the middle.

9 MR. WALLIS: They had -- it was known as the 9th.

10 MR. KRESS: Yes, the numbers was the ninth.

11 MR. WALLIS: I think we can go into a long  
12 discussion of the Ides of March.

13 [Laughter.]

14 MR. WALLIS: And we'll probably be just as  
15 uncertain about that as we are about some of these concepts.

16 [Laughter.]

17 MR. REYES: Before you, I have given you quite a  
18 lengthy presentation. The committee has a proprietary copy.  
19 There are basically two pages there which have some  
20 information which is still considered proprietary.

21 MR. ZUBER: By whom?

22 MR. REYES: By the previous facility. So, it's  
23 tied basically to some of the owners.

24 MR. ZUBER: Okay.

25 MR. REYES: I've given you -- it's a long

1 presentation. There are 70 slides there, and I'm not going  
2 to go through that, so I wanted to encourage you with that  
3 information. For the outline which I present, I will not be  
4 presenting all of that unless you have very specific  
5 questions of some of those things, but I'll start with just  
6 an overview of the program. These are the things that we're  
7 looking at.

8 The number one item there is to review the TASC  
9 peak thermal hydraulics experiments. So that's one of the  
10 things that I've already done quite a bit of that. The  
11 documentation for that sounds like something that you would  
12 like to have right now, so that's something that we will --

13 MR. ZUBER: Before this presentation.

14 MR. REYES: Yes.

15 MR. ZUBER: Before you started the program.

16 MR. REYES: Oh, yes.

17 MR. ZUBER: These tell you what you mean.

18 MR. REYES: Yes; so, that was the first thing I  
19 did. I reviewed the existing data. What you don't have  
20 before you is a document that shows you the results of that  
21 review, and so, I'm remiss in that.

22 MR. ZUBER: Okay; when does the document come  
23 about?

24 MR. REYES: It sounds like I'm going to have to  
25 help with one of my former students who may be able to work

1 with me on this. This could even be put together within  
2 about -- at this point, about 45 days. So we're looking at  
3 a month and a half.

4 So we have all of the references. I've looked at  
5 all of the existing data as far as the mixing data. I'm now  
6 familiar -- this data is in a logical format. And I'll  
7 share with you some of the things --

8 MR. ZUBER: What specific has been plugged in the  
9 holes.

10 MR. REYES: Right, right.

11 MR. ZUBER: Which you have to review.

12 MR. REYES: Right, and some of the holes, I'll  
13 talk about today, and this is why -- this is where these  
14 things come from is basically from that review.

15 Okay; the focus today is on the scaling analysis  
16 of the test facility. We're calling it the APEX CE just to  
17 distinguish, because we have modified some aspects of the  
18 facility. We'll talk about some of the facility  
19 modifications which we knew we would have to make just for  
20 geometric similarity, and so, some of those have been done  
21 already. The scaling analysis, we're looking at three parts  
22 of the loop natural circulation: primary and secondary site  
23 blowdowns, and then, the new area is thermal mixing, thermal  
24 fluid mixing, so I've done some scaling on that which is  
25 different from what you've seen. You may not have ever seen

1 any of this before.

2 Also, we're looking at some of these criteria.  
3 That was mentioned earlier.

4 MR. ZUBER: I'm sorry.

5 MR. REYES: Sure.

6 MR. ZUBER: Are you going to, in that document,  
7 also discuss what there is done by REMIX or just these  
8 experiments?

9 MR. REYES: Actually, I won't just do the modeling  
10 of REMIX in that document. As we go through, I'll show you  
11 what we will do. I've got a team assembled that's going to  
12 do, instead of REMIX, the CSD calculations of all of the  
13 data, okay? So I'll show you that down here below.

14 So, scaling off over here; some facility  
15 modifications. These are the areas that we knew that we  
16 needed to change in order to be geometrically similar to the  
17 plant which we're using as our benchmark. We've broken it  
18 up into three areas here: integral systems tasks; main  
19 steam line breaks; hot leg breaks; getting the pressure out  
20 of the core. The CFD models, where the model is the cold  
21 leg and down comer geometry; it will be half the down comer;  
22 two cold legs; the lower plenum on the steam generator, and  
23 this will be specifically looking at injection into those  
24 cold legs. We'll look at whether or not you're stratified  
25 and what the plume conditions would be in the down comer.

1 That's basically it.

2 MR. ZUBER: If you want to -- this could be also  
3 desirable to prepare a --

4 MR. REYES: Sure; that's --

5 MR. ZUBER: Because then, we have run or at least  
6 fixed the capability to have shortcomings on that one.

7 MR. REYES: Right, right.

8 MR. ZUBER: And not necessarily have another box  
9 on the same level REMIX evaluations.

10 MR. REYES: I'll show you some REMIX calculations  
11 we did for our facility and for Palisades, so we've already  
12 run some REMIX for our own facility.

13 MR. WALLIS: Most CFD models have some sort of  
14 turbulence model in them.

15 MR. REYES: Right.

16 MR. WALLIS: This doesn't do a very good job of  
17 modeling the pressure turbulence by stratification.

18 MR. ZUBER: It seems to me that the model will --

19 MR. REYES: We've been looking at three different  
20 codes: fluid, CFX and one called STAR-CD, and they seem to  
21 have similar models in all three, so that's going to be a  
22 challenge.

23 MR. WALLIS: They traditionally don't do too well  
24 when you get stratification that changes the turbulence.

25 MR. REYES: We also have our RELAP5 model of the

1 APEX facility which we are modifying to simulate the loop  
2 seal, and the changes we are making, we've already made to  
3 the APEX CE facility. So we will be -- again, this is --  
4 you can kind of think of this as predominantly a student  
5 effort. There is a lot of student work involved in these  
6 types of calculations so --

7 MR. ZUBER: Two questions: when did you start the  
8 property -- where do you start?

9 MR. REYES: On the overall program?

10 MR. ZUBER: On this thing here, the first box.

11 MR. REYES: Oh, the first box. We're looking  
12 about -- it's been over 9 months.

13 MR. ZUBER: Okay; how many budgets?

14 MR. REYES: Overall budget for the year is -- with  
15 the modifications, about \$310,000.

16 MR. ZUBER: How many people?

17 MR. REYES: Of course, we have a lot of student  
18 support.

19 MR. ZUBER: No, people.

20 MR. REYES: They're people. I count them, you  
21 know.

22 [Laughter.]

23 MR. REYES: Right now, we have a team. What I've  
24 done in the CFD area is next -- this spring term, they're  
25 teaching a special class on CFD, and I've given them the

1 challenge to the class. I said, well, you know, I've got  
2 all this data, and we've got all of these students. We'd  
3 like the class to take it on as a chance to evaluate all of  
4 this data by using CFD codes.

5 Now, if you had to pay cash for that, that's a lot  
6 of people, so I'll have basically two post docs working with  
7 about five students, so it's a big group.

8 MR. WALLIS: We should bring that solution to the  
9 NRC's review of other codes. Just get classified students  
10 and go to work.

11 MR. REYES: The bright students; that's what you  
12 want to be sure you've got. So, I trust our post docs. I'm  
13 not sure about the rest of them.

14 [Laughter.]

15 MR. BOEHNERT: That's on the record now.

16 [Laughter.]

17 MR. REYES: Uh-oh; I'm sorry. We have excellent  
18 students. They can go anywhere in --

19 [Laughter.]

20 MR. REYES: -- the world.

21 MR. WALLIS: We have the opposite problem: the  
22 ability of the student seems to go down the more they know.

23 MR. REYES: The more they know.

24 [Laughter.]

25 MR. REYES: So, we're looking at the -- so all of

1 this modification information goes to the three different  
2 areas, and what we would like to do is develop an integral  
3 system data from the test loop. We would like to determine  
4 the conditions for loop stagnation, and we're looking at two  
5 conditions primarily. We're looking at loop stagnation when  
6 you have a primary site break, okay, which is going to be  
7 due to -- most likely due to voiding on the tubes, and then  
8 loop stagnation when you have a secondary site blown out,  
9 when you lose your heat sink, okay? So, you can potentially  
10 stagnate under those circumstances, but a single-phase and a  
11 two-phase loop stagnation condition.

12 So we'd like to study that very carefully. We'd  
13 like to study the effect of multiple cold legs and loop  
14 seals on the stagnation condition, and again, one of our  
15 goals here is to also look at thermal mixing, so we've added  
16 lots of plates to our down comer to try to measure the  
17 temperature profiles along the down comer and also in the  
18 cold legs.

19 MR. ZUBER: How many do you have?

20 MR. REYES: In the down comer, we've just added an  
21 additional 50 thermal couplers.

22 MR. ZUBER: How many do you have overall?

23 MR. REYES: So, I think we have a total of 130, I  
24 believe, and I can get you a number. That would be to get  
25 the temperatures in the cold legs and in the --

1 MR. SCHROCK: Would they be on the vessel surface  
2 or --

3 MR. REYES: Those, actually, those are actually  
4 the type that penetrate, so it will be fluid and some wall  
5 frame couplings. I don't know the ratio of the -- I may  
6 have it in a later presentation. So, we're looking at wall  
7 temperatures and fluid temperatures.

8 We had a series of heat flux meters that were  
9 commercially available, and those, we are actually replacing  
10 those because they didn't function quite well. So, integral  
11 systems data will be developed with some of this. We'd like  
12 to feed it to our team over here to provide this for some  
13 RELAP5 calculation assessments. Can RELAP5 predict the  
14 onset of loop stagnation for the tests that we've run. So  
15 we're just going to focus on our own tests and see if we can  
16 run the existing code to kind of see if we're predicting the  
17 onset correctly.

18 On the other side, we've got this separate effects  
19 test data which we're gathering in digital type form to try  
20 to compare to CFD codes, and it would be straightforward to  
21 do REMIX, although in Theophanus' report, he did already  
22 prepare all of these things for REMIX, so that already  
23 exists actually. But you learn quite a bit when you try to  
24 learn a new code.

25 There, we're looking at the assessment of the

1 ability to predict the temperature gradients in the cold  
2 legs in the down comer, and I have one other faculty person  
3 working with me also on the --

4 MR. WALLIS: You're trying to predict temperature.

5 MR. REYES: I'm sorry; temperatures and the  
6 gradients, yes.

7 What does all this go to, well, the results we  
8 would like to provide this data for code validation. We  
9 would also like to provide all of our calculations in terms  
10 of the NRC and in terms of how well do these things compare  
11 to the test data, and more recently, we would like to  
12 provide some of our thermal couplers, actual thermal coupler  
13 measurements from our tests to Oak Ridge so that they can do  
14 some direct analyses for -- they're looking at different  
15 options, but one of them is a 3D finite element type of  
16 analysis, usually with opportune data.

17 MR. ZUBER: How many are around the perimeter?  
18 How many temperature measurements are you taking?

19 MR. REYES: Well, that's the total number for the  
20 whole circumference, about 100 and --

21 MR. ZUBER: No, no, I mean you've got directions  
22 and --

23 MR. REYES: Oh, yes, yes; I don't know if I have  
24 that map or not. I have a map book I'll show you which  
25 shows the -- it's an unwrapped vessel now, I think. Thanks.

1 I thought I had it.

2           Okay; so, that's an outline of the program. The  
3 basis for it, again, was because of our initial review, and,  
4 of course, my experience was with what was lacking in the  
5 previous study, and so I haven't mentioned things like the  
6 control systems and what we're going to do there. But we've  
7 been working very closely with the Palisades plant. They  
8 provide us with lots of data. They provide us with a real  
9 list of control systems and the control logic, so we're able  
10 to model those things, and that's a matter of deciding which  
11 is the best way to execute these transients and what would  
12 be the most realistic, or do we really want to do a  
13 completely realistic study or have some -- how many failures  
14 do we assume kind of thing.

15           Okay; so, in this presentation, I won't be  
16 presenting all of the things that are listed in the outline.  
17 I'll just go and basically talk about two of the main areas  
18 which would be different, and we've talked in the past about  
19 single-phase and actual circulation scaling, and we've  
20 talked about some of the blow-down scaling. So today, what  
21 I'd like to talk about is a little bit about some of the  
22 modifications -- the general scaling methodology; the  
23 modifications of geometric similarities, and then, we're  
24 going to jump down over to the thermal facility mixing  
25 scaling, because there are some interesting criteria, and

1 this is a new area which you haven't seen before. So, in  
2 other presentations, you've seen some of this other type of  
3 scaling behavior. But you're welcome to ask questions on  
4 any aspect of it that you want.

5 MR. ZUBER: What is the schedule that you are  
6 supposed to reach?

7 MR. REYES: The last box, we're shooting to  
8 perform our testing. We would like to go to the shakedown  
9 by the beginning of the summer, because the summertime, of  
10 course, is the best time to do these tests, and so,  
11 hopefully, we will be running several tests over the  
12 summertime, and we will provide data as we get it.

13 MR. ZUBER: When do you complete the program?

14 MR. REYES: The total program, we're trying to  
15 match the schedule with Farouk's needs there, so I'll say --  
16 I'll let -- right now, we have a one-year contract. We'll  
17 try to get as much done in one year if not all of it.

18 MR. ZUBER: You're talking about the whole  
19 facility or for PTS?

20 MR. ELTAWILA: Oh, for PTS, we have to meet the  
21 schedule of -- by next summer, a year from this -- by the  
22 summer of 2001, we will have all of the data and analysis of  
23 method to be put into the fracture mechanics and into -- so  
24 they can proceed with the rulemaking. So that program is  
25 going to continue until that time, but we have long-term

1 plans for the APEX facility.

2 [Pause.]

3 MR. REYES: Okay; so, let's begin talking about  
4 the general scaling methodology. I'm on page 4, the top  
5 slide on page 4. Whoops; I'm sorry. The bottom slide on  
6 page 3.

7 So this is the methodology that I've been using to  
8 do the scaling analysis. The first thing was deciding  
9 whether or not we should even use the APEX facility; it was  
10 a determination of if it was sufficiently similar  
11 geometrically. So if it was going to require quite a bit of  
12 changes and was very expensive to do, then, it might not  
13 have been the best choice to do that. But as I'll show, the  
14 results were actually very good.

15 So the first thing was assessment of the geometric  
16 similarity. The second thing was we had -- having decided  
17 to use the facility, identifying -- stating what our  
18 specific experimental objectives would be, and we actually  
19 performed main steam line breaks or primary side loca, so we  
20 did that. We did have a PTS PIRT available to us, which was  
21 from that one NUREG, and that was related to Robinson. But  
22 we did look at the phenomena on that list. We didn't really  
23 rank it, per se, although in the presentation, I list all 20  
24 items there. When I looked at them, I said, well, these are  
25 the items that I should be looking at in terms of the

1 facility in terms of scaling, so I didn't necessarily rank  
2 one above the other. We just tried to see if we can address  
3 as many of those as we could.

4 In terms of the scaling analysis, I broke it down  
5 into three major areas of scaling. One is natural  
6 circulation scaling; the second is system depressurization,  
7 and that's primary and secondary side blowdowns and then the  
8 thermal fluid mixing scaling. I think this is one of the  
9 areas that you will find interesting. Basically, the way we  
10 performed it, I used the H2TS methodology, and we develop  
11 sets of dimensionless groups or pi groups, and we develop  
12 similarity criteria against each path here. We do an  
13 evaluation of the distortion to determine if it's  
14 significant or not.

15 If it's a new system, of course, you can come up  
16 with some new system designs, but since we have two existing  
17 plants, the Palisades plant and our test facility, there are  
18 a lot of things that are very locked in, so you can't change  
19 those. So the evaluation of the distortion then becomes  
20 important.

21 MR. ZUBER: There was significant distortion?

22 MR. REYES: Right now, I'm looking at our down  
23 comer volume, and for that one, that is large-scale basis.  
24 But I'll show you some of the things that are helpful within  
25 design.

1           So these are the three areas, and what we tried to  
2 do was prioritize them, how we should operate the facility  
3 and come up with very specific specifications that had to be  
4 met with regard to modifications. There were certain things  
5 that we had to modify in order to get the similar results in  
6 our facility that you see in Palisades.

7           MR. SCHROCK: How did you come out on the  
8 geometric similarities?

9           MR. REYES: I was surprised. It actually came out  
10 pretty good. Now, in your handout, I've given you actual  
11 tables with numbers. So I won't be presenting those on the  
12 screen, but we can talk about that.

13           These are the modifications that we did, and  
14 that's coming up in about three or four slides. These are  
15 the modifications to the facility. We had to add four  
16 high-pressure injection lines, four cold leg loop seals,  
17 additional cold leg thermal coupler rates in the cold leg.  
18 We had to add additional flow meters for each of the H  
19 guidelines, and then, we added 50 additional down comer  
20 thermal couplers. So these are the basic modifications.  
21 The remainder of the plant, really, as far as the  
22 similarity, the design that we had compared to the CE plant  
23 is remarkably similar.

24           Sizewise, I said if we were to try to come up with  
25 a closer match, the only other plant out there that probably

1 would match closely is Fort Calhoun. That plant is -- it's  
2 a 500 megawatt electric plant somewhere in that vicinity,  
3 and so, that's already in the zone of where we have already  
4 modeled.

5 This facility, this shows the modifications we've  
6 made. We've added these loop seals. There's a little bit  
7 of a blowup here, so you come off of the steam generator; a  
8 loop seal; and out to the cold leg. So we've added four of  
9 those loop seals.

10 As far as similarities, the next picture shows the  
11 Palisades plant and a CE facility, so you can kind of see  
12 that they're both two hot leg, four cold leg designs. This  
13 is APEX, and this is the Palisades, so your reactor vessel;  
14 you have two hot legs, and you have four cold legs. These  
15 are the reactor cold pumps here. In our facility, the  
16 angles coming out are in the right location as far as the  
17 hot leg; the orientation. These are 2D guidelines which we  
18 valved out, so these would not be operating during a test.  
19 This is a steam generator, steam generator, and then, our  
20 pumps.

21 We've lowered our pumps to the right elevation to  
22 get the loops there, so our pump location, I think on the  
23 next picture, shows it better. Our pump location is not  
24 prototypic, but for the cases of interest, that shouldn't be  
25 -- as far as resistance, that doesn't seem to be a problem

1 in terms of our calculations for loop resistance. So here  
2 is the Palisades plant; the loop seal; reactor cold pump  
3 over here, and here's our facility, a little bit hard to  
4 see. Here's our pumps. So that's one of the big  
5 differences.

6 MR. SCHROCK: Your vessel thickness is very small  
7 compared to --

8 MR. REYES: Oh, absolutely, yes.

9 MR. SCHROCK: So the extent to which it interacts  
10 in the thermal hydraulic strain in cooldown associated with  
11 blowdown, that's going to be rather different.

12 MR. REYES: Right; I have a calculation to show  
13 that. We were expecting to see a much more drastic effect  
14 than we actually did see, but that's why we would like to do  
15 some additional calculations.

16 The next couple of slides, I guess the audience  
17 will have, and these are comparisons of component volumes  
18 for Palisades and for APEX. So we have component volumes.  
19 and then component flow areas and component lengths. And  
20 the thing that I was looking for there, the thing that I was  
21 looking for in an assessment of the geometry of the plant  
22 was do the constants, the flow area ratios, the volume  
23 ratios, the length ratios, do they vary much as you go  
24 around the loop? If there are significant variations, then,  
25 that's going to be a potential spot for some distortion. So

1 I was pleased to find that in general, if you look at the --  
2 for example, the first one, the volumes, the overall volume  
3 scaling ratio for most of the components fell around 1 to  
4 276 is kind of the mid-number; so for almost all of them  
5 except for one component, which was the down comer volume,  
6 which I'd mentioned before, which was about 1 to 95.

7           Early on in the scaling of the facility, one of  
8 the concerns that I had was if your gap is too narrow, you  
9 have an -- you overestimate the amount of -- well, it's kind  
10 of the same -- I call it the semi-scale effect, okay? You  
11 think back to the semi-scale, the gap was too narrow, and as  
12 a result, if you had any type of ECC bypass that was  
13 exaggerated; so, in the literature, what I found was that if  
14 you kept your gap at least two inches wide, you can avoid  
15 some very unrealistic phenomena.

16           MR. WALLIS: Changing the scaling of the booms;  
17 you've got to be changing the down pump.

18           MR. REYES: Right; so, my first assessment looked  
19 at the geometry and said okay, now, we've got the  
20 successively large volume. How is that going to affect the  
21 plumes? And we did some calculations, and this is what --  
22 it turned out better than I was expecting.

23           MR. ZUBER: In the experimental data which we  
24 already have from other facilities --

25           MR. REYES: Yes.

1 MR. ZUBER: -- what does your down comer come? Is  
2 it on the side?

3 MR. REYES: Well, we found with our down comer,  
4 the way they characterized it, as far as the dimension, the  
5 length to the aspect ratio, and ours is one to one with  
6 Palisades, so the advantage, so one of the things as far as  
7 gap size, there was the Finnish facility was two-fifths  
8 scale, and the way they scale it is linearly, so they look  
9 at about a four-inch diameter foot in their terms of  
10 scaling. So, two-fifths of a 10-inch gap is about four, so  
11 they did linear scaling. And the same thing with the  
12 half-scale.

13 MR. ZUBER: Well, you have data from different  
14 facilities.

15 MR. REYES: Right.

16 MR. ZUBER: And you have a discussion in the down  
17 comer. Do you think that spectrum of available data, what  
18 is your -- is it outside the range or --

19 MR. REYES: No, it's within the range. So, the  
20 one-fifth was about a two-inch gap, and our gap is about two  
21 and a half inches. And then, the two-fifths scale is a  
22 four-inch gap. So we're within that scale.

23 Now, as far as L/D, the gap to the length of the  
24 down comer, we're just about one to one with Palisades, so  
25 that was a good thing.

1           So, if I try to summarize, again, the component,  
2 the volume, the flow rates and the lengths, they were  
3 different than the previous testing facility or the previous  
4 design, so that's why you see a difference in one to 276 in  
5 the volume approximately; one to about 70 in the flow areas;  
6 and about one to 3.7 in the lengths, okay? But overall,  
7 they were within a tight band, relatively tight band.

8           MR. WALLIS: I think it's funny, though, because  
9 if you were completely geometrically scaled then --

10          MR. REYES: Right.

11          MR. WALLIS: -- the volume would be the length  
12 ratio, but it isn't at all.

13          MR. REYES: No, it would be the length times the  
14 area.

15          MR. WALLIS: The area, which is the area of the  
16 length squared, so if it were really geometrically scaled --

17          MR. REYES: Yes.

18          MR. WALLIS: -- it would be --

19          MR. REYES: So, if I were to compare our facility  
20 to, let's say, Palisades, we're kind of -- we're a little  
21 bit taller and a little bit narrower, if that helps.

22          MR. SCHROCK: Semi-scale.

23          MR. REYES: But not to that extent. So I expect  
24 to see a lot of the 3D mixing behavior without any problem.

25                 So that's where we are. So, I would say that

1 geometrically, we have -- we look relatively good. I won't  
2 say it's perfect. If we were to design, of course, from  
3 scratch, we could match every diameter and every length.  
4 But we were in the zone where it varied from maybe length  
5 scale from 1.34 to 1.38, so we'll have to evaluate that when  
6 it comes to distortions and see if that's a --

7 MR. WALLIS: The L/D ratio, you'll get something  
8 which would be different.

9 MR. REYES: In our facility.

10 MR. WALLIS: Yes.

11 MR. REYES: Yes; for the down comer.

12 MR. WALLIS: It will be different from the  
13 Palisades.

14 MR. REYES: Right.

15 MR. WALLIS: So you're consistently off on all of  
16 the lengths.

17 MR. REYES: Right.

18 MR. WALLIS: The L/D ratio is a --

19 MR. REYES: Right, right.

20 MR. WALLIS: It's consistently different.

21 MR. REYES: Correct, correct, yes. Yes, we could  
22 only -- that's right.

23 Okay; the types of tests -- so that's the  
24 geometric similarity, just looking at the physical ratios  
25 around the plant. That's not looking at phenomena.

1 MR. ZUBER: The gap.

2 MR. REYES: The gap, yes; that's really the gap  
3 there.

4 So we're looking at two types of integral system  
5 tests or two categories, I should say: hot leg breaks, and  
6 we're looking at the types of breaks where the break energy  
7 is going to be similar close to the decay, so we're trying  
8 to keep the pressure off somewhat, so it's more of a slow,  
9 small break type of transient looking maybe at the top of  
10 the hot leg. Main steam line breaks, looking at a whole  
11 series of main steam line breaks to try to do, in  
12 particular, an asymmetric type of a main steam line break,  
13 so we can look at stagnation on one side of the plant versus  
14 the other. So we will see if that would occur and under  
15 what conditions that would occur.

16 We can also do some of the separate effects tests,  
17 and that might be useful to study the plume behavior a  
18 little bit more carefully. We can set up our facility to  
19 run in a steady state mode basically; get our initial  
20 conditions; done our HPI and then move some very careful  
21 measurements of the plume, so that would be helpful for our  
22 CSD students trying to calculate something that's maybe not  
23 transient.

24 MR. WALLIS: Can they get 15 minutes of stagnation  
25 and maintain it?

1 MR. REYES: Right, right.

2 MR. WALLIS: So, you're having to hope it might  
3 happen.

4 MR. REYES: Right; so, we're looking at both  
5 tests, this integral and separate effects.

6 Okay; since Dave already talked about the  
7 phenomena ranking, what I'd like to do is jump right into  
8 the thermal mixing scaling, so that's way out there on page  
9 18.

10 So, this was a really -- these are always learning  
11 experiences for me. I enjoy it. The literature review on  
12 the thermal mixing part of it is very rich. There is a lot  
13 of work that's been done in the past, and people have been  
14 solving mixing of plumes for a long time. I've got some  
15 excellent papers by Bachelor, by Morton. There was a good  
16 paper by Turner, by Taylor. They were solving these plume  
17 problems way back when, and they didn't have a CFD code, and  
18 it was very interesting to see how they went about  
19 developing some of these similarities solutions to come up  
20 with very useful things.

21 Bachelor, in one of his papers, talks about they  
22 had a problem in World War II, and they wanted to use  
23 heaters alongside the runway to clear out the fog, and so,  
24 they were developing these heated jets on either side of the  
25 runway, basically a tunnel, so that the planes could land

1 and take off in foggy weather. So, the description of that  
2 research effort is really interesting, so I would recommend  
3 it. If you haven't looked at that one, I've got a copy of  
4 it, if you would like.

5 So there is a lot of good research that has been  
6 done, and a lot of it is related to similarity type  
7 solutions and to scaling of plumes, and lots of good  
8 pictures showing plumes at different scale lengths and the  
9 similarities between those plumes.

10 This is the overall approach that I have taken on  
11 the scaling. I want to scale the thermal fluid mixing  
12 behavior in the down comer and the cold leg, and I broke it  
13 up in two regions: the top down scaling and then the bottom  
14 up process type scaling, and the top down scaling, I was  
15 looking at the cold leg in the down comer as a control  
16 volume, and I was basing my calculation equations for that  
17 control volume on the bottom-up scaling and looking at very  
18 specific processes, looking at the high pressure injection  
19 flow rates, the back flow phenomena and high pressure  
20 injection lines. The onset of cold leg thermal  
21 stratification, which was one of the criteria of interest  
22 today, and I actually rederived this in a slightly different  
23 new and improved form.

24 First plume modeling, the lock exchange process;  
25 at the edge of the cold leg going into the down comer,

1 you've got basically a pipe going into a large area, and  
2 that's kind of a classic lock exchange problem, where you  
3 have this countercurrent flow, kind of like the opening of  
4 the window. When it's a hot room, you open up the window,  
5 and you get this countercurrent.

6 So that's very similar to what you see in the down  
7 comer right at the cold leg entrance, or it is the same, and  
8 the down comer plume modeling and down comer heat transfer,  
9 so I won't be talking about every single one of these  
10 phenomena, but I'll try to hit most of them.

11 MR. ZUBER: What page is that?

12 MR. REYES: Page 18, and that's kind of a small  
13 slide there on this, a little hard to see.

14 So, I did go back and look at some of the  
15 behavior. This is a picture of the CREARE one-fifth scale  
16 mixing tests. You can kind of see how this plume developed,  
17 and it is because they had very low flows. The -- in the  
18 real plant, this would be a 10-inch diameter line with a  
19 very low injection flow. What they would do is they use the  
20 accumulator line for the injection point, instead of having  
21 lots of different penetrations. They use the accumulator  
22 line, basically, so we're injecting this cold plume. It  
23 comes in the bottom of the pipe. You can see here, it's  
24 spreading.

25 On this side is the loop seal. On this side, not

1 too easy to see, is the down comer wall to the vessel, so  
2 they're spreading out this way, a little bit further in  
3 time. It's reaching the down comer. You're dropping back  
4 to this pump simulator, and even further in time, now,  
5 you've got a plume which is hard to see in a down comer, and  
6 you've got this countercurrent flow established in the loop  
7 seal, so you have some hot water coming this way and some of  
8 the cold water coming this way, the heavier water this way  
9 and lighter water this way.

10 So there is a lot of this type of data available.  
11 The early CREARE tests were done without a loop seal, and  
12 they did do -- they did include flow in this line to try and  
13 develop this stratification criteria.

14 So, this is the -- Dave's already shown you the  
15 geometry here that's kind of been -- this picture has been  
16 used a lot to describe the phenomena. There are some  
17 differences here, so the next slide is a little bit more  
18 along the lines of what you would expect to see in a plant  
19 like the Palisades plant, okay? And this is the --  
20 basically, you have a side entry condition, so their  
21 injector is on the side instead of the top. So that's going  
22 to affect them in the mixing behavior right there.

23 It is a very low flow. You have the -- the cool  
24 pump has a lip on it, and that lip acts like a wier wall,  
25 and so, in our facility, we've modeled this wall. We've got

1 the height scaled on this volume, actually it's scaled. And  
2 so, basically, it limits the amount of back flow into the  
3 loop seal. So that's a somewhat different arrangement than  
4 we've gotten in the past. So that will be interesting to  
5 see the behavior, but that's the type of thing that we're  
6 modeling in our facility.

7 MR. ZUBER: How do you deal with the thermal  
8 couplers underneath, down on the boom?

9 MR. REYES: Yes; so, we have thermal couplers --  
10 oh, that's -- thank you. This figure shows you the thermal  
11 coupler placement underneath the cold legs. So this is one  
12 hot leg, and these are the four cold legs, and so, these are  
13 all of the -- the ones in red are thermal couplers that  
14 already existed, and the blue are thermal couplers that  
15 we've just added.

16 And you see, we have concentrated them quite a bit  
17 up towards the cold legs, and that gives you an idea of the  
18 distribution. So it's kind of an unwrapped vessel. Then,  
19 these thermal couplers were down there. As far as scale --  
20 let's see -- this is about -- this would be about -- well,  
21 this is about one cold leg diameter here, one cold leg, two  
22 cold leg diameters, three, four, so this is about four cold  
23 leg diameters here. In Palisades, although they're looking  
24 both at the -- they're interested both in the weld material  
25 as well as the base material, so it doesn't necessarily have

1 to fall right on a weld, per se, but they have one weld  
2 which -- circumferential weld, which is about two cold leg  
3 diameters down, and they have another one which is about the  
4 center of the rest, which is about five cold leg diameters  
5 down.

6 So, I used this basic drawing here as a control  
7 volume. This is going to be my thermal mixing volume to do  
8 the top down study and the bottom up analysis, and the way  
9 these analyses are performed, you write your balance  
10 equations, and what I hope -- the key things I get out of  
11 this is how to plot my data and particularly the cool-down  
12 rate, and I'll show you -- we've done some REMIX  
13 calculations using this result, and you can see that it does  
14 collapse. When you plot it in terms of nondimensional time  
15 and nondimensional temperature, you're able to collapse the  
16 data from the REMIX calculations for Palisades and those for  
17 APEX. And so, that's very encouraging.

18 So that means that this analysis at least gave us  
19 the right dimensionless groups.

20 MR. ZUBER: Do you have a slide for that?

21 MR. REYES: Oh, yes, yes.

22 MR. SCHROCK: The Qs now.

23 MR. REYES: Which one? The Qs?

24 MR. SCHROCK: I mean --

25 MR. REYES: Oh, I'm sorry.

1 MR. SCHROCK: -- the subscripts.

2 MR. REYES: Oh, okay.

3 MR. SCHROCK:  $Q_L$ ,  $Q_M$ .

4 MR. REYES: Right, right; this is the volumetric  
5 flow rate for the HPI, volumetric -- the density for HPI.  
6 This is loop flow. So I also included the effect of what  
7 happens if you have a loop -- let me get my picture data --  
8  $Q_L$  would be -- I guess it was on this picture; yes this  
9 picture has the -- so here's  $Q_L$ , and if I have the loop  
10 flow, so if it's not stagnant; this is hard to see here.  
11 This is the hot fluid. This is hard to see here; this is a  
12  $Q_{HPI}$ , and then, this is a mixture of  $Q_M$ , okay, so, it's a  
13 mixed mean type of volumetric thing.

14 MR. SCHROCK: It would seem to me that there ought  
15 to be a parameter something like the ratio of the sensible  
16 cooling capacity of the injected cold water against the  
17 thermal capacity of the vessel, in which case, the thinness  
18 of the vessel --

19 MR. REYES: Would impact.

20 MR. SCHROCK: -- would appear as a more prominent  
21 difference --

22 MR. REYES: Right.

23 MR. SCHROCK: -- between this and the full-scale  
24 plant. Does that emerge here?

25 MR. REYES: Right; yes. I'll show you the group

1 where that appears.

2 MR. SCHROCK: All right.

3 MR. REYES: And for awhile, I thought about  
4 whether or not it needed to be included in the time scale,  
5 because you actually bring that into the time scale, and it  
6 turned out to be a small component.

7 MR. ZUBER: Which one did? The conduction?

8 MR. REYES: The conduction, yes, and the part of  
9 it is because it depends on the metal volume that you use,  
10 so if it's a narrow strip of metal just below the plume, it  
11 turns out to be a fairly small amount, a small amount of  
12 mass compared to the actual behavior on the outside. So  
13 that's one of the things that we found, and that's one of  
14 the things that came out of REMIX also. You have to input  
15 that into REMIX as one of the values, and so, when you look  
16 at that, I was surprised that that number didn't influence  
17 more.

18 We did it both for Palisades and for our facility.  
19 So you can write a mass balance equation; an energy balance  
20 equation, and I wrote the energy balance in terms of --

21 MR. ZUBER: What does this do for the -- you're  
22 cooling as far as -- I mean, the --

23 MR. REYES: Right.

24 MR. ZUBER: -- the solid comes very fast through  
25 the liquid temperature, and then, it stays.

1 MR. REYES: Well, this would say that -- so, if  
2 the heat transfer from your wall isn't playing as large of a  
3 part as I thought it was going to in heating up the plume.

4 MR. ZUBER: Yes.

5 MR. REYES: Yes; okay.

6 So, I wrote this in terms of a dimensionless  
7 temperature.

8 MR. ZUBER: So this would be, to some extent,  
9 noncomparative.

10 MR. REYES: We're saying not the real -- we think  
11 this is probably related to the real behavior. Now, we have  
12 to try it with some real plumes first, so once we have some  
13 measurements, we can see is -- do these approximations work  
14 or not? But right now, the contribution due to the metal  
15 mass is much smaller than I expected.

16 MR. ZUBER: It is?

17 MR. REYES: Yes; we did it also for Palisades, I  
18 mean, the calculation. Now, that could be due to the heat  
19 transfer coefficient that's being used in REMIX; I don't  
20 know. But I'm looking at two heat transfer correlations.  
21 One is a Feuster-Jackson correlation. There's another one  
22 which was some work done by LaBirdie, who is now one of our  
23 -- one of the faculty at OSU, and so, I'll be getting in  
24 touch with him, but he did some of the early work with  
25 Faith, Fayeth. Yes, I think Fayeth was his professor.

1 MR. SCHROCK: It's a transient problem

2 MR. REYES: Right.

3 MR. SCHROCK: And, I mean, the heat transfer  
4 coefficient can't be specified. I mean, it's got to be  
5 calculated at every step along the way. Does REMIX do that?

6 MR. REYES: That's a good question. That's a good  
7 question. I think it just gives you the correlation, and  
8 then, I don't know if it calculates a velocity propagating  
9 down or not. It just seems to -- it's more correlated than  
10 this type of experiment.

11 MR. SCHROCK: I think it's important to scrutinize  
12 that REMIX heat transfer coefficient specification. I don't  
13 know what it does. But I'm sure that in the real world,  
14 it's something that varies -- the hydrodynamic conditions  
15 are continuously varying throughout this whole problem  
16 practically.

17 MR. REYES: Right.

18 MR. SCHROCK: Even when you're in so-called  
19 stagnation, you're growing a thermal plume on the wall.

20 MR. REYES: That's right; yes. That's one of the  
21 things we should check. My gut reaction when I saw the  
22 calculation was that I thought that the wall would have a  
23 bigger role in heating up the plume than what was  
24 calculated. But that's just an observation.

25 MR. ZUBER: How long does it take to do this?

1 MR. REYES: Oh, very fast. Very fast.

2 MR. ZUBER: And then, you can get the feedback on  
3 the coefficient.

4 MR. REYES: Right; now, that's right. It's  
5 getting into the code and actually figuring out how they  
6 input that. These can be written in a dimensionless form,  
7 and in so doing, you come up with your time scale, which you  
8 put in the place of your shell volume and divide it by your  
9 volumetric fill of the HPI, so the focus of the analysis is  
10 -- what should happen is that your mass -- for your  
11 consistency, what should happen is that your mass balance  
12 and energy balance equation should both have the same time  
13 scale.

14 You come up with several dimensionless groups,  
15 which are in terms of density ratios, and I've got those  
16 here. So, here is the time scale. It's just that a density  
17 ratio group, one that describes a loop flow, and that's just  
18 the mass flow rate of the loop versus the kind of a mixture,  
19 like an outage type of an HPI mass flow rate.

20 And then, the ones that would play a larger role  
21 or could play a larger role is the down comer heat transfer.  
22 So, here, you have to come up with an expression for your  
23 down comer heat transfer in terms of some heat transfer  
24 correlation and divide it by basically a mixture energy  
25 transfer.

1           And then, you have a mixture temperature ratio.  
2 Now, for stining condition, all of these  $Q_L$ s would drop out.  
3 And REMIX only does the stagnant condition. It doesn't do a  
4 calculation with flow.

5           So, the top down scaling, you produce these five  
6 groups, and then, from the bottom up, you try to fill in  
7 some of these -- the missing correlations, like the heat  
8 transfer coefficient and things like that. One areas is the  
9 HPSI flow rate. You want to specify a HPSI flow rate for  
10 our facility, and so, we have the same -- basically, all of  
11 our flows are going to be -- we're going to operate our  
12 facility one-to-one time scale, which will be -- it's a  
13 little different from what we've done in the past. We've  
14 operated on a half time scale.

15           Where you do that, all of your flows, all of your  
16 volumetric flows go with the volume, so it's one to 276, and  
17 that's what we've done here. So, and we've done it with a  
18 normalized pressure, so we can program our control system to  
19 respond to a given pressure or a given flow rate. So the  
20 HPSI event is going to respond like the HPSI in the  
21 Palisades plant.

22           The other aspect, once you do come up with your  
23 desired HPSI flow, and this is based on their nominal flow  
24 condition; once you come up with your HPSI flow, then, you  
25 can start looking at some of the other phenomena related to

1 the HPSI operation. One is the back flow, whether or not  
2 you get the back flow in your injection line. Now, these  
3 lines are designed such that you have -- the nozzle comes in  
4 horizontally on an angle, and you have a check valve  
5 immediately after that nozzle. So, the check valve is right  
6 there, so it's really designed to prevent significant back  
7 flow into that line. I don't know if there's a -- if they  
8 get -- experience any chattering or not, but that's what  
9 it's designed for.

10 But flows are low enough to where you would expect  
11 to see back flow in the nozzle.

12 MR. WALLIS: This is where something else --  
13 previously, you had the equation balances; you had -- these  
14 things have a way of sneaking in some of the mechanics,  
15 which is just sort of for --

16 MR. REYES: So, that reaction force type testing,  
17 yes.

18 When we compared the HPI fluid member in APEX and  
19 Palisades for the whole range of flow rates, if we choose  
20 our nozzle ID to be 1.35 inches, we overlay it.

21 MR. WALLIS: That would be --

22 MR. REYES: That's right; so, there's a little  
23 blue dot here, which is Palisades, and you can see up here,  
24 we hope we can reach that flow range, so they fall on top of  
25 each other. So we're satisfied that we can model any

1 important back flow in that line pretty well. So that was  
2 one positive thing.

3 The other big criterion which comes in the  
4 bottom-up is this onset of thermal stratification, and that  
5 was a real interesting problem, because I dug into it quite  
6 a bit. Dave had asked me when he looked at Theophanus'  
7 criteria whether it made sense that the criteria should be  
8 based on a cold leg diameter.

9 [Pause.]

10 MR. REYES: The problem that's being addressed,  
11 basically, is you can have stratified flow, heavy fluid on  
12 the bottom, a lighter fluid on top, and what flow  
13 conditions, if there are relative velocities, would you  
14 expect the fluids to mix? So, intuitively, you would expect  
15 that the length scale for that to scale that would not be  
16 the entire cold leg diameter. It would be the length -- or  
17 what has been done in the past, it would be one of the  
18 lengths, either the light fluid length or the heavy fluid  
19 length. So that got me stirred up.

20 MR. ZUBER: The depth?

21 MR. REYES: The depth; the depth. That's a good  
22 way to put it.

23 So, this is the correlation that was used in the  
24 previous PTS study. Theophanus derived this -- he basically  
25 said that -- where he got this equation from was that the

1 Frude number of the mixture should equal one, and that would  
2 be like the down -- for stratified flow or for a mixed  
3 condition. So that was stated a priori. There was no basis  
4 for that, I mean, no additional information on that other  
5 than you kind of think of, you know, whether a pipe flows  
6 full or not, you think of a Frude number equal to one.

7 Based on a perfect mixing assumption that came up  
8 with this ratio of these betas, which is thermal expansion  
9 coefficients, and you've got this one-plus the loop  
10 volumetric accelerate over the  $Q_{HPI}$  base to the negative  $3/2$   
11 power. He compared this to data that was obtained in the  
12 CREARE one-fifth scale and modified the correlation so the  
13 effect of this data ratio here is to make this exponent just  
14 a little bit larger, and so, he said go for a  $-7/5$  exponent,  
15 so it's 1.4 instead of 1.5, and that would fit the data  
16 better from CREARE. And as a result, this is the criteria  
17 that was used.

18 Now, this Frude number here is kind of a mixed  
19 Frude number. It's based on the HPI length scale and the  
20 cold length mixed scale. That was one of the things that  
21 was kind of confusing.

22 It's defined as follows: so, you're using the HPI  
23 volumetric flow rate, but you're using the flow area of the  
24 cold length, okay? So, it's this kind of a mixed bag there.  
25 And then, you use the diameter of the cold leg, delta roll

1 over roll. So this is the definition for this superficial  
2 Frude number, and the not superficial Frude number is equal  
3 to one plus  $Q_L$  over  $Q_{HPI}$  and raised to the  $-7/5$ . That would  
4 be the boundary, and that's what this boundary is here. So  
5 this is Theophanus' prediction. And this is some of the  
6 early data. We've got some calculations that -- we looked  
7 at some ROSA data and some APEX data. It wasn't really --  
8 we had some steam in our line, so it wasn't exactly the  
9 case, but it did seem to fall in the right -- the five per  
10 sides of the line.

11 We also had some CFX calculations for an AP600  
12 type of a system which sort of fell pretty close to the  
13 line, so we felt like that particular correlation was  
14 working reasonably well, but I still wasn't too pleased with  
15 this length scale, thinking it should be the depth.

16 So I went back and looked at several papers, and  
17 there was some work that was done by Gardner in 1973 looking  
18 at hydraulic jumps, and so, I said well, this would be a  
19 good way to analyze this problem if we did a hydraulic jump  
20 analysis. So that's what I did and came up with a new  
21 correlation, and I'll show you how that works. You have two  
22 stations. You have a light fluid flowing over a heavy  
23 fluid. This is a uniform velocity here; a uniform velocity  
24 here, and my idea is that over a certain -- these two  
25 stations are far enough apart such that a hydraulic jump

1 occurs, and you have a nice uniform mixture velocity coming  
2 out.

3 So you're basically mixing everything up. You  
4 also see that in dilution problems. They study similar  
5 things. And you have this mixture velocity and your initial  
6 incoming velocities. And I defined these area fractions, so  
7 the area of the light fluid here at station one over the  
8 total area is alpha. The area of this light fluid here at  
9 station two over an area would be an alpha two. So the idea  
10 is that in a sense, you're keeping the constituents -- the  
11 identity of the constituents, in a sense, because you're  
12 maintaining this area.

13 However, if you look at it in terms of volume,  
14 you'll see that you get the same result in terms of mass of  
15 hot fluid to a total mass, and you wind up with a very  
16 similar kind of result. So this seems to have a fairly wide  
17 application.

18 MR. ZUBER: There are some data from Farouk  
19 working on something -- I don't have a name -- Bureau of  
20 Standards from the early sixties, and you have flow that  
21 uses a very similar approach.

22 MR. REYES: Okay; maybe this is already in the  
23 literature or something; the National Bureau of Standards.

24 MR. ZUBER: No, no, no, following a student of --  
25 no, this is from the Bureau of Standards.

1 MR. WALLIS: I have a picture of the one we're  
2 coming in trade in the -- you're coming from the --

3 MR. REYES: Well, this is where the -- so, you  
4 have to use your imagination now, okay?

5 MR. WALLIS: Now, on the next page, you have  
6 Bernoulli's equation applied to something which goes from  
7 continuous to discrete.

8 MR. REYES: Yes; let me talk about the  
9 interpretation of this. If you have two emiscible fluids,  
10 okay, you might look and say and say oh, you have one on the  
11 water, and you can actually get some type of them behaving  
12 like this. Or if you have air in water, you might look at  
13 bubbles in a liquid. Because that's kind of where I started  
14 with this, and the more I thought about it, the more I  
15 realized, well, the way in which you treat this, you can  
16 treat it, in an average sense, as a mixture over here, and  
17 if you want to look at the head terms on this side, you  
18 could say, well, it's a row G times an H, you know, times  
19 some type of a fraction. And so, that's kind of where I was  
20 going with that.

21 MR. WALLIS: Your analysis is really for  
22 stratified to stratified. It goes from different  
23 stratified; that would make sense.

24 MR. REYES: And that is correct; that is really  
25 correct. So, in essence, it's just like the hydraulic jump

1 going from one height to another height, but the difference  
2 is that VM. That makes a big difference, that mixture  
3 velocities. Now, I'm saying that both phases are going to  
4 travel or both fluids are going to travel the same mixture.

5 MR. WALLIS: Okay; you need some other piece of  
6 information.

7 MR. REYES: Right; and that turns out to be the  
8 key to --

9 MR. WALLIS: If you don't have that, you can't  
10 solve the problem. You need another piece of information.

11 MR. REYES: Right.

12 MR. WALLIS: You need something else.

13 MR. REYES: Correct; I just put the gavel down and  
14 said this is going to be -- removing out the mixture  
15 velocity. So you're ahead of me, so you're already on the  
16 next page.

17 So you can write an equation at each station, for  
18 the heavy fluid and for the light fluid, and you're saying,  
19 well, the energy is conserved. You can write the continuity  
20 equation, and really, you only need to write one, because  
21 you can relate -- I can relate this mixture velocity in  
22 terms of the volumetric flow, which is what I do next for a  
23 mixture.

24 If you do that, I'll just talk about the process  
25 in a little bit. The idea is if you eliminate the delta-p

1 using these two equations, you write your mixture velocity  
2 in terms of a volumetric flow rate, so it's the DL plus VH  
3 over the flow area gives you an average velocity for the  
4 mixture, and that gives you a governing equation. You can  
5 reduce those two equations basically to this one using the  
6 continuity equation, to this one here.

7 And now, it's starting to look a little familiar.  
8 So this is the density of the hot fluid, the volumetric flow  
9 rate of the -- excuse me, the heavy liquid, the volumetric  
10 flow rate of the heavy liquid, G-delta-thorow times this  
11 length scale or diameter times this area fraction squared  
12 times these terms here, and you get a similar type of a  
13 thing here for the light fluid.

14 Now, you have to make some type of an assumption  
15 here. You want to have a hydraulic jump, and so, you're  
16 modifying the limiting condition so that you make a very  
17 simple critical condition assumption. You say that, well,  
18 alpha two is going to equal alpha one. And under those  
19 conditions, that's going to be basically your maximum -- I  
20 don't know if relative velocity is the correct term, but  
21 your maximum set of velocity conditions that can occur  
22 without a change in area fraction. So it's as if you're  
23 just at the precipice of making the jump, but you're trying  
24 to satisfy those conditions.

25 MR. WALLIS: It says alpha two equals alpha one,

1 and nothing happened.

2 MR. REYES: Say it again? That's right; if -- on  
3 the one hand, you've got this V mixture on that one side,  
4 and on the other side, you've got basically a separated  
5 flow. If you said alpha two is equal to alpha one, and you  
6 didn't do anything about that; we make an assumption about  
7 the velocity.

8 MR. WALLIS: It's pretty hard for me to imagine  
9 how two fluids flow side by side without changing their area  
10 suddenly come to the same velocity. It doesn't seem  
11 feasible.

12 MR. REYES: Right; so, that's why it's basically  
13 the critical condition. It's not the actual condition.

14 So, let me show you what that does. When you make  
15 that assumption, it does two things: it changes this  
16 equation here. Of course, you can use this to plug in alpha  
17 two equals alpha one; it's not a real difficulty. It also  
18 changes your continuity equation, because now, all of a  
19 sudden, you have a relationship to relate the flows at the  
20 inlet to the flows at station one to the flows at station  
21 two.

22 So, when you do that, you make that simple  
23 substitution, alpha two equals alpha one --

24 MR. WALLIS: Is this equation on 121 in my book?

25 MR. REYES: I believe that's probably right. So

1 you've seen this before.

2 [Laughter.]

3 MR. REYES: But wait, there's more.

4 [Laughter.]

5 MR. REYES: You can write it in terms of  
6 volumetric flow rates or velocities, and this is where you  
7 probably see more like due delta roll over -- times an area.  
8 And, of course, you can write them in terms of the Frude  
9 number, by Frude heavy, Frude light equals one.

10 This really is the stratification criteria. You  
11 can rewrite -- I can take this now with the critical  
12 condition, I can take this equation and reformat it in the  
13 way which will look very similar to Theophanus. But the  
14 fact of the matter is this is the stratification criteria  
15 right here. We've had it all along for many, many years,  
16 this equation has been known. But the fact of the matter is  
17 that this is really it.

18 And so, the length scales, then, are the heavy  
19 fluid and the light fluid, those are the true length scales  
20 for the problem. What's interesting is when you apply some  
21 of these assumptions I can show you: one assumption -- this  
22 next one is kind of a -- I'll put it up real quick. If you  
23 change your coordinates for the hydraulic jumps so that  $VH$   
24 is zero, and you look at a rectangular geometry, you get  
25 this result from that previous equation, of course, which

1 can be compared to this final Wallis --

2 MR. WALLIS: No, we got the first one, and we had  
3 to fudge it with a factor of 0.5 to make it --

4 MR. REYES: Oh, I know why that is. So, the next  
5 version of this will explain that point.

6 But if you do the -- if you apply that  
7 stratification criterion to the previous equation, you come  
8 up with a sum of the Frude numbers squared equals one.  
9 Then, if you use the continuity equation that comes from  
10 that critical condition, you wind up with an equation which  
11 is very, very similar to the original one for Theophanus.  
12 You have one plus  $Q_L$  over  $K$ -strike to the  $-3/2$ , so it's the  
13 same next point, compared to what was there before, but you  
14 do get something different up front, okay?

15 So now, our two criteria will diverge, which  
16 always adds a lot to the dramatic tension of things. The  
17 two criteria diverge somewhere, and nine is going to be a  
18 function -- it will depend on density ration, and it seems  
19 to have -- but this, I'm sorry, has to be  $QH$  -- you have all  
20  $QH$ s here or  $QI$ , just to make it consistent with Theophanus.  
21 So same exact term there; some difference in the terms here.

22 So, I have to go through and evaluate -- where  
23 does that make a difference? The next plot shows the  
24 difference here. They do converge. As you go further out,  
25 as your loop flow increases, of course, they seem to

1 converge, and I'll show you on a long scale a little bit  
2 better. But up here, this one will vary. This is the  
3 criterion that I developed; it will vary with density ratio,  
4 so you'll see differences due to the density ratio. And it  
5 is addressing an issue which was a problem for something  
6 that Theophanus had been working on, and that was he  
7 developed two codes, actually. It was a REMIX and a NEWMIX  
8 code, and the NEWMIX code was designed for high injection  
9 flows, which would be high values of QH.

10 I think this is -- I don't have the data, but  
11 unfortunately, the CREARE data goes about to here, point  
12 blank, so I need some data in this area. So it would be  
13 nice to test it out to see if that works, but for the  
14 conditions that we're studying, we're actually over here,  
15 where the two correlations converge quite well. So the next  
16 figure just shows that.

17 Looking at a different density ratio here, this is  
18 log-log scale; that's why there seems to such a precipice  
19 over on this end. This is looking at a typical density  
20 ratio of row light over row H of about 0.7, so they are very  
21 similar when you get further out here, and they are quite  
22 different on that end.

23 And on this side, if, for the case where, of  
24 course, the heavy fluid is much, much heavier than the light  
25 fluid, and if you assume it to be zero, they both go to one,

1 and that's what you get there. Now, for the Palisades  
2 plant, we had that condition -- where we're looking at, it  
3 doesn't really make a very large difference. So basically,  
4 they're almost parallel at this point, and this is the range  
5 of conditions that would be applicable to the injection flow  
6 rate that I showed you earlier on. So the difference  
7 doesn't affect too much at all.

8 And the good thing about that, then, is, of  
9 course, that when you're scaling these things, what you do  
10 to provide a good comparison is if you preserve the  
11 superficial fluid number, and you preserve this  $Q_L$  to  $Q_H$   
12 ratio, keep those to one in the facility of an APEX and  
13 Palisades, where  $Q_L$  is the loop vacillation flow rate, you  
14 should get good matched behavior as far as the onset of  
15 stratification. So that will work for either criterion. So  
16 as long as I preserve that, whether Theophanus' criteria is  
17 correct or my new one is correct --

18 MR. ZUBER: You want to get some data into the  
19 region that is different --

20 MR. REYES: Well, I think later on, when we go --  
21 if we do some higher injection flow rates, you know I'm  
22 going to get into that area just to see how well that  
23 compares.

24 So here's the results. Looking at the criteria  
25 and applying it now to Palisades plant, when their pumps are

1 on, as you'd expect, you know, this is the Palisades  $Q_{HPI}$   
2 data, and this is the superficial Frude number versus the  
3 ratio of volumetric flow to HPI flow. It's going to be in  
4 the well-mixed regime, and that's what you'd expect to see.  
5 And this is the criteria here.

6 MR. WALLIS: By orders of magnitude.

7 MR. REYES: Yes, oh, yes, it's way, way up there.  
8 So that was no surprise.

9 When you trip the pumps, and you go into decay, I  
10 was surprised because the flow was fairly low, and now, on  
11 that one, this is at 2.5 percent decay power. You see that  
12 the data from the pump gets closer to the stratification  
13 condition. And, of course, if you drop the decay power --

14 MR. KRESS: That's why the decay power ended up on  
15 that PIRT chart as being important.

16 MR. REYES: Yes.

17 MR. WALLIS: It's what's driving this.

18 MR. KRESS: It's what's driving the circulation.

19 MR. REYES: It's what's driving the circulation.

20 MR. KRESS: Yes, so it determines when you get to  
21 a --

22 MR. REYES: Right.

23 When you go to 1.5 percent decay power, you  
24 predict that you may have periods of stratification even  
25 when you're at decay power, and you've got enough

1 circulation.

2 MR. WALLIS: What time is this in the accident  
3 that you get down to 1.5?

4 MR. REYES: It's still under analysis.

5 MR. WALLIS: So you're interested in this as being  
6 a problem way out there? An hour after --

7 MR. REYES: Right; now, some of the transients  
8 that were studied in the previous study were a hot zero  
9 power type transients. So, you're already at some low decay  
10 power.

11 MR. WALLIS: The whole thing is depressurized,  
12 isn't it? Maybe not; it depends on the break size.

13 MR. REYES: Right; and there were so many  
14 assumptions, conservative assumptions that were made that it  
15 was --

16 MR. WALLIS: For small breaks.

17 MR. REYES: And then, of course, at 1 percent  
18 decay power, we expect to see a -- if the positive HPI  
19 ranges is at these pressures, it would be stratified.

20 The other thing, as far as the stratification  
21 criteria, and this does show a lot of data; I didn't point  
22 that out, but this is the Palisades; this is the APEX, so  
23 it's the blue and white thing. They just fell right on top  
24 of each other.

25 MR. WALLIS: Palisades isn't data, is it?

1 MR. REYES: No, no, I'm sorry, yes; well, neither  
2 is the APEX. Right now, these are just calculations. So,  
3 for the Palisades calculations and for the APEX  
4 calculations, it's one on top of the other.

5 MR. ZUBER: For the REMIX calculations?

6 MR. REYES: Right; now, so, this was for  
7 stratification criteria. Now, to look at the behavior in  
8 the plume or in the down comer, we did two cases, and at two  
9 different pressure conditions and different cold leg  
10 conditions, and what we're doing is relating a pressure in  
11 APEX to a pressure in Palisades, and we're looking at a  
12 corresponding flow rate,  $Q_{HPI}$  flow rate that would go with  
13 those corresponding pressures, okay? So these are injection  
14 temperatures.

15 Their injection temperature is 87 degrees is their  
16 nominal requirement. So that's higher than -- we actually  
17 did more cases where we looked at in the case of APEX  
18 injecting at 87 degrees and Palisades at 87 degrees as well  
19 as 60 degrees. Sixty degrees is easier for us to operate at  
20 that condition, but we could go to 87 degrees with a little  
21 bit of effort.

22 So, REMIX calculations, so there are two cases.  
23 Here's case number one, and we're looking at the Palisades.  
24 We're looking at the temperature in the plume at different  
25 elevations in the down comer. The two blue lines, this is

1 the temperature at the cold leg line for APEX. This is the  
2 temperature at the cold leg line for Palisades. Now, this  
3 is in terms of dimension of temperature, and this  
4 temperature comes out of the top down scaling analysis, and  
5 versus the dimensionless time, and that's the same time  
6 constant that came out of the top down scaling analysis and  
7 versus dimensionless time, and that's the same time constant  
8 that came out of the top down scaling analysis.

9 MR. ZUBER: Are they the same?

10 MR. REYES: They're slightly different, so I've  
11 turned out -- if you took the ratio of our time constants,  
12 ours was about 0.8 something, so it's not quite one-to-one.

13 So, now, this is basically taking and predicting  
14 temperatures inside the plume, and this is the cold leg  
15 center line; the orange -- it's a little hard to see --  
16 orange and orange. It's two diameters down, and then, the  
17 brown is five cold leg diameters into the down comer. So  
18 what we're seeing is that they don't exactly match, but to  
19 give you a feel for the time constant, this is about 7,000  
20 seconds, 8,000 seconds in real time, so it goes fairly far  
21 out.

22 So there are some differences here, but in  
23 general, they match reasonably well for this case number  
24 one. As you get to the higher pressure, this is a lower  
25 pressure case. As you get to the higher pressure, we saw

1 better agreement. So case two was done at a higher  
2 pressure, and if you see it starting to narrow down quite a  
3 bit; this is about 7,000 seconds.

4 So, when you plot them in dimensionless terms, you  
5 can actually collapse the data pretty well. Some of the  
6 distortions, well, one of the things that we were expecting  
7 to see was -- we were expecting to see more of a distortion  
8 because of the wall effect, and so, that's something that  
9 needs to be analyzed more carefully.

10 MR. WALLIS: It's very difficult to see  
11 comparisons between APEX 2D --

12 MR. REYES: Yes.

13 MR. WALLIS: -- from there. I don't know where  
14 they are.

15 MR. REYES: Okay.

16 MR. WALLIS: Are they on top of each other or  
17 something? It's so close.

18 MR. REYES: Here, they're pretty much on top of  
19 each other, and then, they start to deviate here. This  
20 is --

21 MR. WALLIS: Okay; so, the 2Ds and the 5Ds are  
22 both there.

23 MR. REYES: Yes; unfortunately, the colors are a  
24 little bit -- well, I would say this is going to be the 5D  
25 up here, because you expect it to be higher up.

1 MR. WALLIS: I see two lines instead of four  
2 lines, so presumably --

3 MR. REYES: So, two of them --

4 MR. WALLIS: Are on top of each other.

5 MR. REYES: This is --

6 MR. WALLIS: I see four lines instead of six  
7 lines. I see four reddish-colored lines.

8 MR. REYES: Right.

9 MR. WALLIS: I see two reddish-colored lines,  
10 although there are four --

11 MR. REYES: Let me explain; these two that match  
12 here, these are the two Palisades at five and two.

13 MR. WALLIS: Oh, so --

14 MR. REYES: Yes, five and two. So, what's  
15 happened there is that you've gotten out to a certain  
16 distance.

17 MR. WALLIS: This is like what Dave was saying.

18 MR. REYES: This is what Dave was saying.

19 MR. WALLIS: Out to two; the five is the --

20 MR. REYES: Yes; and then, these are five and two  
21 for APEX.

22 MR. WALLIS: Oh, okay.

23 MR. REYES: Okay? And then, these are the two  
24 blue with the cold leg center lines.

25 MR. WALLIS: Zero and --

1 MR. REYES: Right.

2 MR. WALLIS: -- zero.

3 MR. REYES: So that's the type of behavior that  
4 we're seeing based on REMIX calculations.

5 MR. WALLIS: So, let's see now. This is saying  
6 that the cold leg centered temperature is not so different  
7 from the temperature in the down comer.

8 MR. REYES: Right; yes, for these cases, that's  
9 right. So, what REMIX does is you have an injection  
10 temperature, and then, you have mixing occurring --

11 MR. WALLIS: I thought the whole problem was --

12 MR. REYES: -- in the cold legs.

13 MR. WALLIS: -- that the temperatures were  
14 supposedly very different if there was a plume.

15 MR. REYES: Well, they're different, but you have  
16 quite a bit of mixing.

17 Now, this was, in this case, REMIX allows flow in  
18 both directions. So we would have to set up our problem so  
19 that we have the -- we have that weir wall on one side.  
20 We'd have to set it up so that we can --

21 MR. WALLIS: Doesn't the vessel still have -- why  
22 aren't the red curves starting out hot with the other one  
23 cold? Or am I somehow confused?

24 MR. REYES: So, these are just fluid temperatures,  
25 and I'm -- that's a good -- timewise --

1 MR. WALLIS: I was expecting to see a cold  
2 temperature and a hot temperature, and they all seem to be  
3 sort of close to each other.

4 MR. REYES: They're very tight, yes.

5 MR. KRESS: These don't include heat transfer to  
6 the walls.

7 MR. REYES: They do. They're --

8 MR. KRESS: But the mixing is -- sort of  
9 overwhelms that?

10 MR. REYES: That's right; when I mentioned earlier  
11 on that I was expecting to see more of an effect on the  
12 wall.

13 MR. WALLIS: The dimensionless -- the way you  
14 dimensionalize them, nondimensionalize them different for  
15 the blues and the reds, which is why they look the same.  
16 They're both sort of forced to go up in 01. So, the actual  
17 temperatures themselves are quite different.

18 MR. REYES: Right.

19 MR. WALLIS: So it's sort of misleading.

20 MR. SCHROCK: What is this dimensionless time  
21 scale? I wasn't able to find that.

22 MR. REYES: That comes in the back of the top down  
23 scaling.

24 [Pause.]

25 MR. REYES: So, this is the time constant. Oh,

1 that's a good point. This volume here, that's going to be  
2 the active volume of the control volume, so in REMIX, they  
3 give you a specific formula.

4 MR. SCHROCK: Fluid volume.

5 MR. REYES: Fluid volume, right; they give you a  
6 specific formula that says you take the cold leg length of  
7 the portion of the loop seal and one-quarter of the down  
8 comer.

9 MR. WALLIS: This is sort of a mixed reactor with  
10 a volume of the vessel and the flow rate of the --

11 MR. REYES: Exactly right. And so, they use that,  
12 then, as a -- if you did a perfect mixing, of course, you  
13 would just have an exponential decay kind of a thing and in  
14 terms of the same time constant.

15 MR. WALLIS: I was sort of puzzled by the last --  
16 the one with the temperatures.

17 MR. REYES: Oh.

18 MR. WALLIS: I thought the convection water had to  
19 be colder than that.

20 MR. REYES: Oh, I see.

21 MR. WALLIS: You fixed CL center; what is that?

22 MR. REYES: That's the cold leg center line.

23 MR. WALLIS: Well, does that mean that you've  
24 actually got hot water off there by now, and the cold water  
25 is below it?

1 MR. REYES: That's a good question; that's a good  
2 question.

3 MR. WALLIS: If you looked at the cold leg  
4 bottom --

5 MR. REYES: It seems to be -- yes.

6 MR. WALLIS: Quite different, wouldn't it?

7 Anyway --

8 MR. REYES: Well, that's a good question, and I  
9 agree with you. That should have been more.

10 MR. WALLIS: Well, the message is that APEX is  
11 like Palisades.

12 MR. REYES: Correct.

13 MR. WALLIS: Whatever we're looking at.

14 MR. KRESS: I was guessing that APEX cold leg  
15 center was just the point that the cold leg, where it goes  
16 in, that little point right at the bottom, just as you first  
17 go in and meet the wall.

18 MR. REYES: The wall.

19 MR. KRESS: That's what I thought you meant.

20 MR. REYES: Oh; I think it's --

21 MR. KRESS: So, it would be zero height there or  
22 zero depth.

23 MR. REYES: I think in the code, 0.0 is actually  
24 the center of the --

25 MR. KRESS: It's actually the center?

1 MR. REYES: The center of the cold leg.

2 MR. SCHROCK: It seems to me there are two  
3 features that don't come in here. One is the fact that the  
4 reactor has this massive wall, and therefore, the start  
5 energy in that vessel is really big compared to anything  
6 that you have in APEX.

7 MR. REYES: Right.

8 MR. SCHROCK: Does it show up in this  
9 dimensionless time? And I don't see how it factored into  
10 the dimensionless temperatures --

11 MR. REYES: Right.

12 MR. SCHROCK: -- either.

13 The other thing is that your APEX is designed for  
14 saturation temperature at 300 psi compared to -- what is the  
15 temperature difference there is about 150 degrees or --

16 MR. REYES: Yes, it would correspond to --

17 MR. SCHROCK: So, the delta-t driving the heat  
18 transfer is like twice as great in the reactor as compared  
19 to APEX.

20 MR. REYES: Right; the difference is in the  
21 fraction, in looking at the -- so, I looked at it both ways,  
22 including the time constant which includes the effect, the  
23 volume of the mass. It turns out that that volume of that  
24 mass is very small, because what you're looking at is just  
25 the volume of mass directly under the plume as opposed to

1 the -- that the way this is modeled, one-fourth the down  
2 comer fluid volume, all the cold leg volume and the loop  
3 seal volume. So that number actually turns out to be  
4 physically small. I can show you the -- I don't have them  
5 with me, but I can send them, of course, to you.

6 Now, my gut feeling was that I should see more of  
7 an effect, but these are just code calculations right now,  
8 so fluent might -- or one of the CFD codes might predict  
9 something different, but it's got to depend on the H that  
10 you pick.

11 MR. ZUBER: Does REMIX really calculate the  
12 conductions?

13 MR. REYES: It's one of the claims is that you  
14 input all of your metal mass according to their --

15 MR. ZUBER: Okay; you can see what the --

16 MR. REYES: Yes; they use an H which is based on  
17 Feuster-Jackson, and they come up with a temperature --

18 MR. ZUBER: They do 1D calculations.

19 MR. REYES: 1D calculations.

20 MR. ZUBER: Conduction?

21 MR. REYES: Right.

22 MR. ZUBER: In the metal.

23 MR. REYES: Correct, yes.

24 MR. ZUBER: You don't see the effect on the wall.  
25 The difference in the --

1 MR. REYES: Right; and I agree. So that's  
2 something we could look into, of course, much further, but  
3 we'd like to use maybe one of the CFD codes to try to do  
4 that.

5 MR. ZUBER: CFD codes will not address -- they  
6 will not calculate the --

7 MR. REYES: Yes, they have that. The new ones  
8 have that, yes.

9 Okay; so, let's conclude this part of it here.  
10 So, let me summarize the results here.

11 MR. SCHROCK: I guess another way of looking at  
12 it, Jose, is penetration depth for the conduction problem is  
13 the same -- that the metal is the same.

14 MR. REYES: Well, let's see.

15 MR. SCHROCK: So, the penetration depth compared  
16 to the wall thickness at any point in time would be much  
17 greater in APEX than it is in the reactor.

18 MR. REYES: Right; now, we do have -- our vessel  
19 is all stainless, and the conductivity is pretty low on  
20 that.

21 MR. WALLIS: I mean, it doesn't penetrate further  
22 than a certain distance. As long as the wall is much  
23 thicker than that, it doesn't matter.

24 MR. REYES: It's in here.

25 MR. WALLIS: Anyway, you're going to sum it all

1 up.

2 MR. REYES: Right; that's one of the goals.  
3 That's something that I identified already and said that  
4 this something is not quite --

5 MR. WALLIS: So you're going to address, then,  
6 these two questions: can you predict the overall sort of  
7 transient and the flow rates in the whole loop well enough  
8 to know when you get stagnations, and the other thing is can  
9 you model the boom in the down comer accurately enough for  
10 whatever purposes. Those are the sort of the two key goals.

11 MR. REYES: Those are the key goals.

12 As far as my personal concerns of how well the  
13 experiments will go, the measurement points, you can never  
14 get enough measurement points in a down comer, especially  
15 things like velocity. It's very difficult to come up with  
16 velocities when you're at pressure, and we looked at some of  
17 the probes that are available commercially, and they won't  
18 -- unfortunately, they won't do the temperatures that we  
19 wanted to look at, so we're still looking to see what's a  
20 good way to measure the velocity.

21 MR. WALLIS: I think your CFD people ought to  
22 consider different turbulence models, because this doesn't  
23 do a good job on this kind of lines of flows.

24 MR. REYES: Well --

25 MR. WALLIS: Confined jets, and this is a kind of

1 confined jet as well.

2 MR. REYES: Right.

3 MR. WALLIS: So there are certain situations where  
4 Kay-Epson is not -- there are other models which are -- this  
5 shouldn't be so difficult; it is, after all, a single phase  
6 flow.

7 MR. REYES: Well, it's a single phase flow. It  
8 should -- well, that's what these codes were developed for,  
9 I mean, these CFD codes.

10 MR. WALLIS: Well, I think as far as the down  
11 comer goes.

12 MR. REYES: Right.

13 MR. WALLIS: Because the whole loop thing has  
14 to --

15 MR. REYES: Right, that's the difference, right.

16 Well, I'm going to conclude there. I can't find  
17 my conclusion slides. They got mixed in with this stuff, so  
18 you can read through there. We've modified the facility to  
19 include the loop seals. Now, it's just based on geometric  
20 similarity and trying to meet this stratification criteria  
21 as far as the h-dry nozzle. We believe we can model the  
22 onset of h-dry back flow. We can model the thermal  
23 stratification in the cold legs.

24 We have a new criterion which I'd like to get some  
25 test data on the other end to see if that works or not.

1 We've got our time constants for the mixing behavior, and I  
2 have a note here that I should check the effect of the  
3 conduction volumes.

4 And as far as remaining scaling, I still need to  
5 complete the documentation on the secondary side blow-downs,  
6 the main steam breaks and then produce one large table with  
7 all of the pi groups so that I can evaluate them and present  
8 the distortions in kind of a unified way. So that's still  
9 something that's lacking with regards to this analysis.

10 Any questions?

11 MR. WALLIS: Well, my impression from both  
12 presentations is that we've given you a bit of feedback, but  
13 really, you're so much at the beginning of this that I'm not  
14 sure we can help you much until you start to get the  
15 results, and this looks like a good way to proceed generally  
16 speaking. We have to get some results.

17 MR. REYES: Okay; well, I'm open to any turbulence  
18 models you might have or any other analysis ideas.

19 MR. ZUBER: I think better about the -- now  
20 than --

21 MR. REYES: Okay; good.

22 MR. WALLIS: Well, we still need some good feeling  
23 that when these guys do their academic jobs that it's going  
24 to be well-integrated into whatever is done here.

25 MR. ZUBER: It depends on how they're going to use

1 it and for what purpose.

2 MR. WALLIS: So, what does the committee want to  
3 do? Any more questions? Any more presentations from the  
4 staff?

5 MR. BOEHNERT: That's it?

6 MR. ELTAWILA: I'd like just to close. I want to  
7 thank Jose and Dave for their presentation. I think, before  
8 I get into that, Paul pass on an integrated schedule for the  
9 PTS issue resolution and rulemaking process. I just want to  
10 let you know that we are part of an integral team that's  
11 working on the PTS, and there is a cooperation from the  
12 industry at work to provide the staff with the information  
13 to be able to come up with the resolution of that issue.

14 We were asked to provide pressure, temperature and  
15 heat transfer calculations, a very simple request that was  
16 requested from us from the team that's working on PTS. We  
17 thought that if we come here to you and provide you with  
18 RELAP5 or a TRAC calculation, we're going to be harassed  
19 about the applicability of this code to this transient. So  
20 we took a different approach. We said let's try to use some  
21 of the facility that we have here to try to understand some  
22 of the physics that's happening in the facility and use the  
23 experimental data, the scaling rationale and the codes and  
24 try to put a story together about the actual behavior of the  
25 plant.

1           If we fail to make that message clear, I hope by  
2 the time that Jose finished, I think it's clearer right now;  
3 we would have been much better prepared if we had a few  
4 weeks to digest the information that's coming out of Jose  
5 and things like that, but we're trying to do the best with  
6 what we have right now.

7           So, the -- again, the emphasis of the program is  
8 just to provide them with this information so they will be  
9 able to do an integral assessment of the PTS. Another thing  
10 that's different from the original analysis that was done in  
11 1985 that we are going to have an integral assessment of the  
12 uncertainty, talking about the thermal hydraulic uncertainty  
13 fracture mechanics and PRA and integrated together. So  
14 that's why some of the experiment work is being pursued  
15 right now.

16           Thank you.

17           MR. WALLIS: Thank you.

18           And now, I think it's been very useful that we've  
19 learned what you're doing. We're going to keep in touch as  
20 you work on this problem, which seemed to me too early for  
21 us to recommend that any presentation be made to the full  
22 ACRS. We're not ready for anything like that, are we?

23           MR. ELTAWILA: We've -- yes, I think all the  
24 presentation about PTS is coordinated as one presentation.  
25 There will be no single presentation of thermal hydraulics.

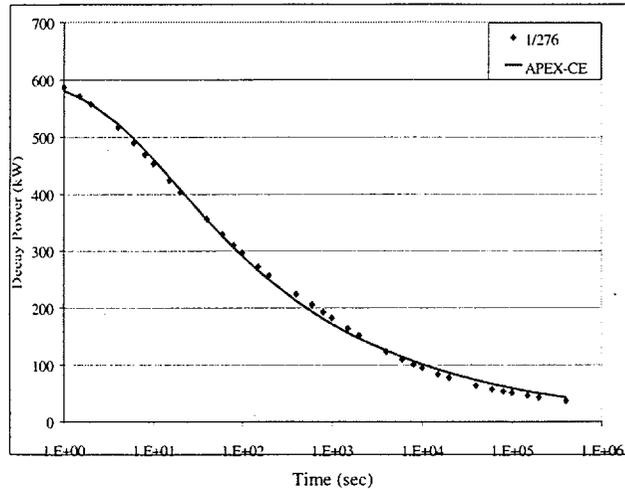
1 It's an overall project. And there are some milestones  
2 here; you can see them that we are supposed to continue.

3 MR. WALLIS: Right. Well, maybe we could go off  
4 the record, and then, we could have a discussion among  
5 ourselves about what we've learned today. Would that be  
6 appropriate to do that now? Just caucus before we disappear  
7 for the day? So, let's close the record. I'll close the  
8 meeting. Thank you very much.

9 [Whereupon, at 4:15 p.m., the recorded portion of  
10 the meeting was concluded.]

11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25

## APEX-CE Decay Power



Nuclear Engineering & Radiation Health Physics  
Oregon State University

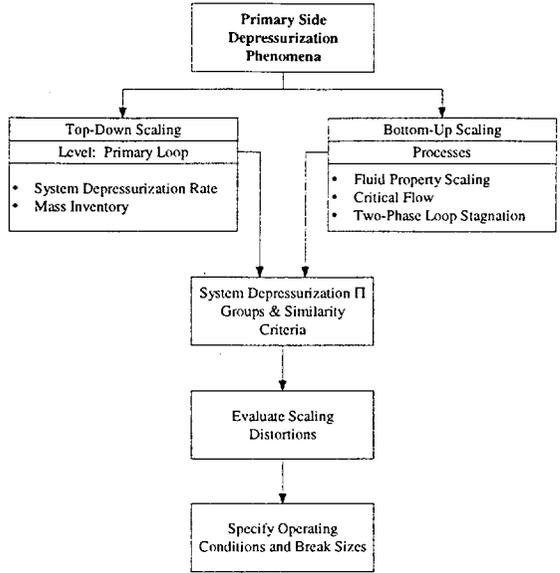
## Single Phase Loop Stagnation

- Asymmetric MSLB may cause loop stagnation on “intact” side of plant .
- Loop stagnation has two potential PTS implications:
  - Reduces volume of primary fluid available for mixing. Hence local cooling is more severe.
  - HPI operation during loop stagnation results in cold leg fluid thermal stratification and cold plumes in the downcomer.
- **Scaling Analysis of Secondary Side Blowdowns**
- **Include realistic modeling of Steam Generator Control System logic in APEX-CE.**



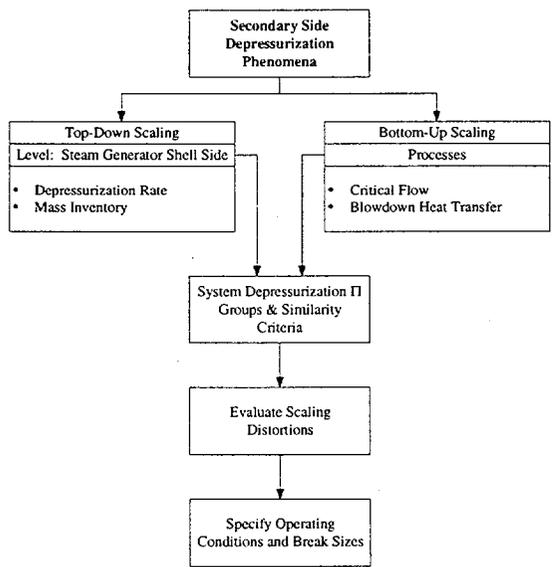
Nuclear Engineering & Radiation Health Physics  
Oregon State University

# System Depressurization Scaling



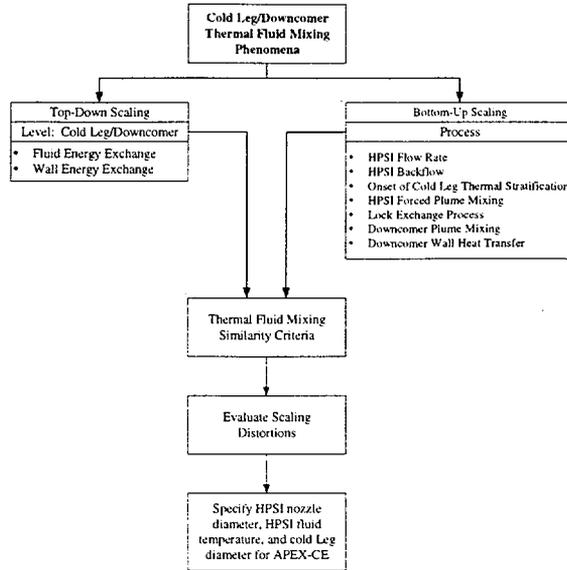
Nuclear Engineering & Radiation Health Physics  
Oregon State University

# System Depressurization Scaling



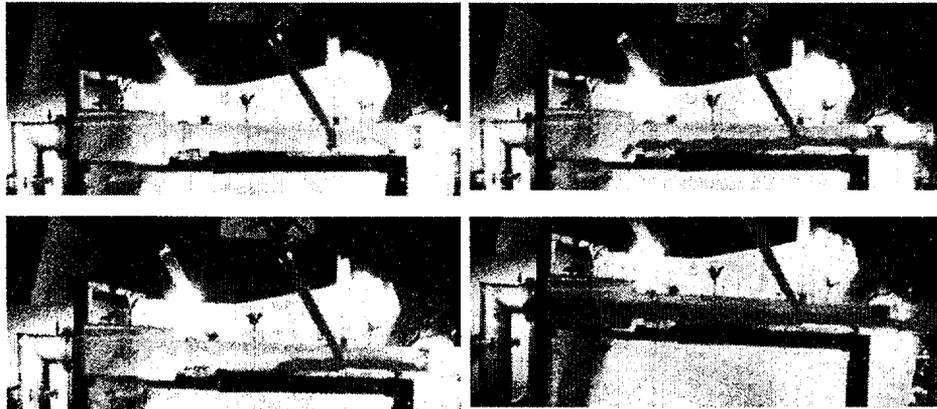
Nuclear Engineering & Radiation Health Physics  
Oregon State University

# Thermal Mixing Scaling Analysis



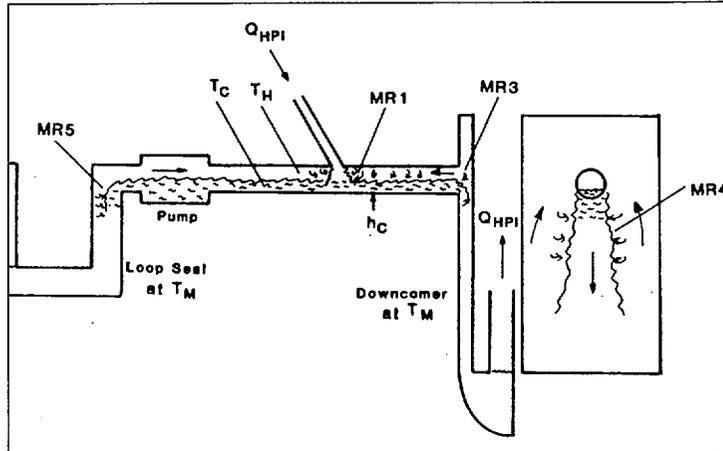
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## CREARE 1/5 Scale Mixing Tests



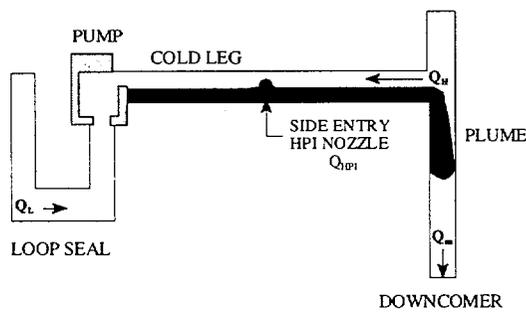
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Thermal Stratification in Cold Leg and Downcomer



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Thermal Mixing Control Volume



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Balance Equations for Thermal Mixing

- **Mass Balance:**

$$V \frac{d\rho_m}{dt} = Q_{HPI} \rho_{HPI} + Q_L \rho_L - Q_m \rho_m \quad (6.1)$$

- **Energy Balance:**

$$V \frac{d\Theta}{dt} = \frac{q_{bc}}{\rho_m C_p (T_{LO} - T_{HPI})} - Q_{HPI} \frac{\rho_{HPI}}{\rho_m} \Theta - Q_L \frac{\rho_L (T_m - T_L)}{\rho_m (T_{LO} - T_{HPI})} \quad (6.7)$$

- **where**

$$\Theta = \frac{(T_m - T_{HPI})}{(T_{LO} - T_{HPI})} \quad (6.6)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Dimensionless Balance Equations

- **Mass Balance:**

$$\tau_{HPI} \frac{d\rho_m^*}{dt} = \Pi_p Q_{HPI}^* + \Pi_L Q_L^* \rho_L^* - \Pi_m Q_m^* \rho_m^* \quad (6.16)$$

- **Energy Balance:**

$$\tau_{HPI} \frac{d\Theta^*}{dt} = \Pi_q \frac{q_{bc}^*}{\rho_m^*} - \Pi_p \frac{Q_{HPI}^* \Theta^*}{\rho_m^*} - \Pi_L \Pi_T \frac{\rho_L^* Q_L^* (T_m - T_L)^*}{\rho_m^*} \quad (6.21)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Characteristic Time Scale & $\Pi$ Groups

- **Mixing Time Constant:**

$$\tau_{\text{HPI}} = \frac{V}{Q_{\text{HPI},\text{O}}} \quad (6.17)$$

- **Density Ratio:**

$$\Pi_{\rho} = \frac{\rho_{\text{HPI}}}{\rho_{\text{m},\text{O}}} \quad (6.18)$$

- **Loop Flow Rate Ratio:**

$$\Pi_L = \frac{Q_{\text{L},\text{O}} \rho_{\text{L},\text{O}}}{Q_{\text{HPI},\text{O}} \rho_{\text{m},\text{O}}} \quad (6.19)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Characteristic Time Scale & $\Pi$ Groups

- **Mixture Flow Ratio:**

$$\Pi_m = \frac{Q_{\text{m},\text{O}}}{Q_{\text{HPI},\text{O}}} \quad (6.20)$$

- **Downcomer Heat Transfer:**

$$\Pi_q = \frac{q_{\text{DC},\text{O}}}{\rho_{\text{m},\text{O}} Q_{\text{HPI},\text{O}} C_p (T_{\text{m},\text{O}} - T_{\text{HPI}})} \quad (6.22)$$

- **Mixture Temperature Ratio:**

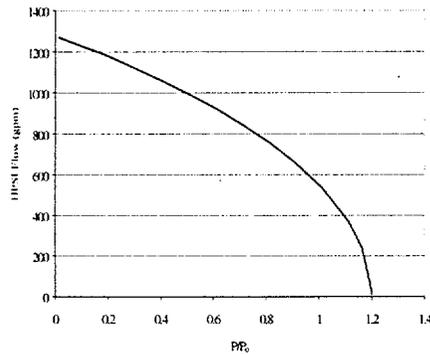
$$\Pi_T = \frac{(T_m - T_{L'})_o}{(T_{\text{m},\text{O}} - T_{\text{HPI}})} \quad (6.23)$$



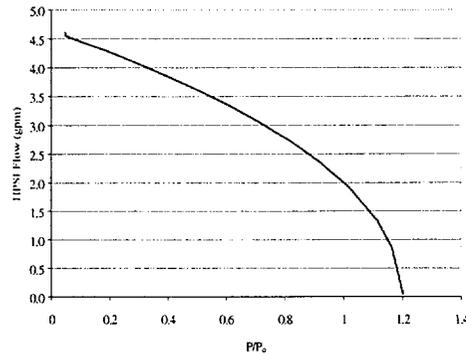
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Bottom-Up Scaling

### HPSI Flow Rate



Palisades



APEX-CE



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Buoyant Backflow into the Horizontal HPSI Line

- HPI Froude Number:

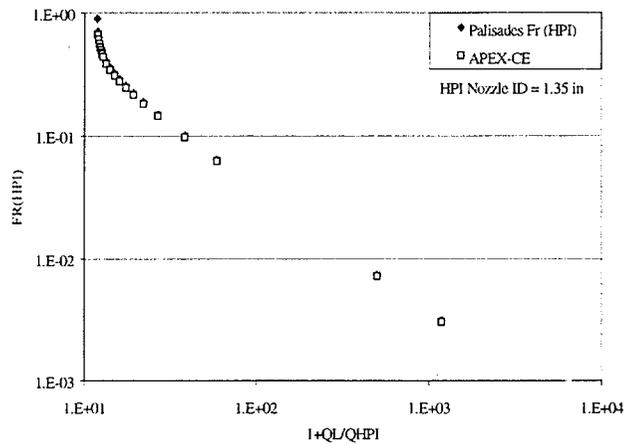
$$(Fr_{HPI})_R = 1 \quad (6.24)$$

$$Fr_{HPI} = \frac{Q_{HPI}}{a_{HPI} \left[ gD_{HPI} \frac{(\rho_{HPI} - \rho_{CL})}{\rho_{HPI}} \right]^{1/2}} \quad (6.25)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Buoyant Backflow into the Horizontal HPSI Line



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Onset of Cold Leg Thermal Stratification

- Theofanous (et al.):

$$Fr_{HP/CL} = \left[ \frac{\beta_m}{\beta_{HPI}} \right]^{-1/2} \left[ 1 + \frac{Q_L}{Q_{HPI}} \right]^{-3/2} \quad (6.27)$$

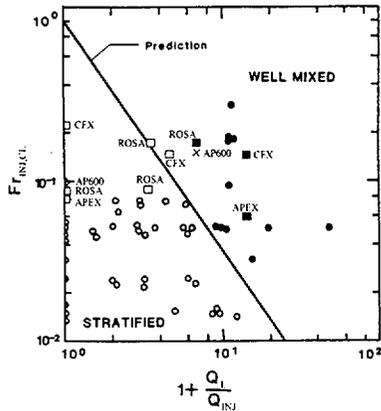
- which was approximated by:

$$Fr_{HP/CL} = \left[ 1 + \frac{Q_L}{Q_{HPI}} \right]^{-7/5} \quad (6.28)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Thermal Stratification Criterion



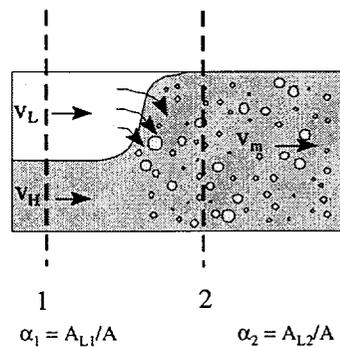
$$F_{\text{HMICL}} = \frac{Q_{\text{HI}}}{a_{\text{CL}} \left[ g D_{\text{CL}} \frac{\rho_{\text{HI}} - \rho_{\text{CL}}}{\rho_{\text{HI}}} \right]^{1/2}} \quad (6.29)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Hydraulic Jump Analysis

- Concern regarding appropriate length scale for onset of thermal mixing motivated a new analysis.
- A new stratification criterion has been developed based on a hydraulic jump analysis.



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Hydraulic Jump Analysis

- Continuity Equation for Heavy Fluid:

$$\rho_H v_H (1-\alpha_1) A = \rho_H v_m (1-\alpha_2) A \quad (6.35)$$

- Bernoulli's Equation for each fluid:

Heavy Fluid  $\rightarrow P_1 + \frac{\rho_H v_H^2}{2} + \rho_H g D (1-\alpha_1) = P_2 + \frac{\rho_H v_m^2}{2} + \rho_H g D (1-\alpha_2) \quad (6.37)$

Light Fluid  $\rightarrow P_1 + \frac{\rho_L v_L^2}{2} - \rho_L g D \alpha_1 = P_2 + \frac{\rho_L v_m^2}{2} - \rho_L g D \alpha_2 \quad (6.38)$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Hydraulic Jump Analysis

- Governing Equation:

$$\frac{\rho_H Q_H^2}{g \Delta \rho D A^2 (1-\alpha_1)^2} \left[ \frac{2 - (\alpha_1 + \alpha_2)}{2(1-\alpha_2)^2} \right] + \frac{\rho_L Q_L^2}{g \Delta \rho D A^2 \alpha_1^2} \left[ \frac{(\alpha_1 + \alpha_2)}{2\alpha_2^2} \right] = 1 \quad (6.39)$$

- Critical Condition:

$$\alpha_2 = \alpha_1 \quad (6.40)$$

- Maximum relative velocity that can occur without a change in area fraction.



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Hydraulic Jump Analysis

- Stratification Criterion:

$$\frac{\rho_H Q_H^2}{g \Delta \rho D A^2 (1 - \alpha_1)^3} + \frac{\rho_L Q_L^2}{g \Delta \rho D A^2 \alpha_1^3} = 1 \quad (6.41)$$

$$\frac{\rho_H v_H^2}{g \Delta \rho D (1 - \alpha_1)} + \frac{\rho_L v_L^2}{g \Delta \rho D \alpha_1} = 1 \quad (6.42)$$

$$Fr_H^2 + Fr_L^2 = 1 \quad (6.44)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Wallis Slugging Criterion

- Changing coordinates for the hydraulic jump such that  $v_H = 0$  in rectangular geometry yields the following result:

$$Fr_\Delta = \left( 1 - \frac{h_L}{H} \right)^{\frac{1}{2}}$$

- which can be compared to Wallis and Dobson (1973)

$$Fr_\Delta = 0.5 \left( 1 - \frac{h_L}{H} \right)^{\frac{1}{2}}$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Hydraulic Jump Analysis

- New stratification criterion:

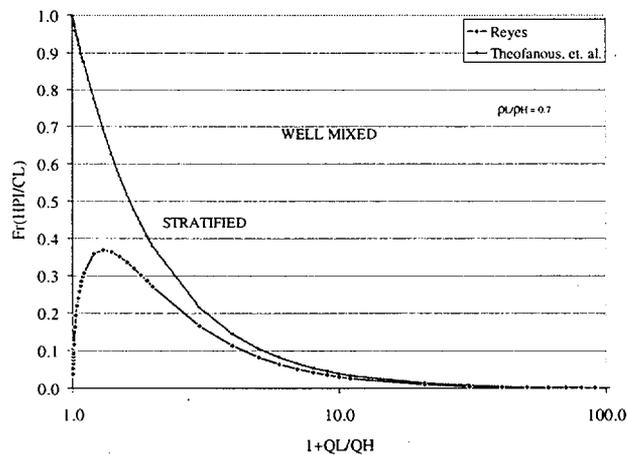
Reyes  $\rightarrow$  
$$Fr_{HP/CL} = \left[ 1 + \frac{\rho_L Q_H}{\rho_H Q_L} \right]^{-1/2} \left[ 1 + \frac{Q_L}{Q_{HPI}} \right]^{-3/2} \quad (6.46)$$

Theofanous (et al.)  $\rightarrow$  
$$Fr_{HP/CL} = \left[ \frac{\beta_m}{\beta_{HPI}} \right]^{-1/2} \left[ 1 + \frac{Q_L}{Q_{HPI}} \right]^{-3/2} \quad (6.27)$$



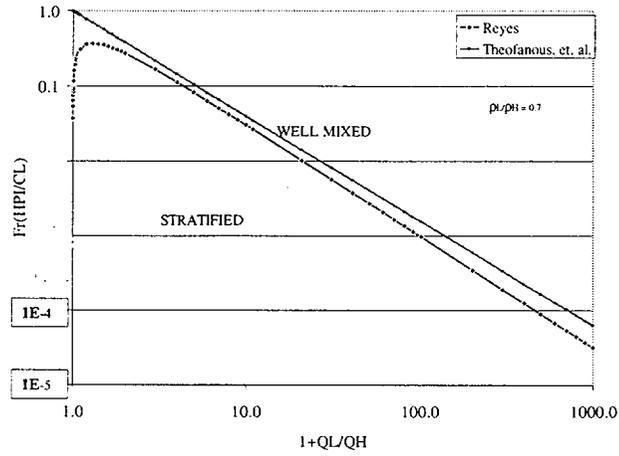
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Comparison of Criteria



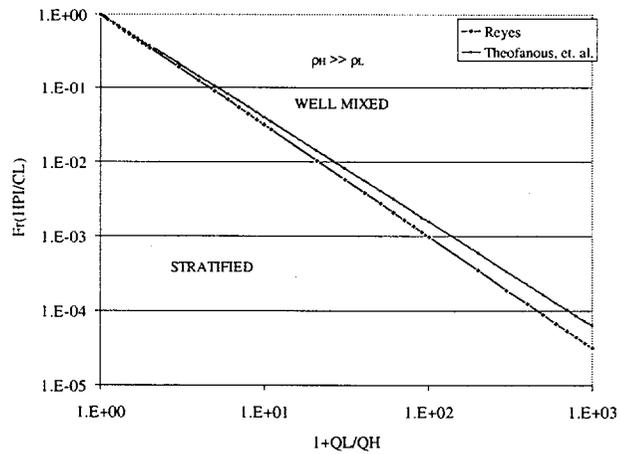
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Comparison of Criteria



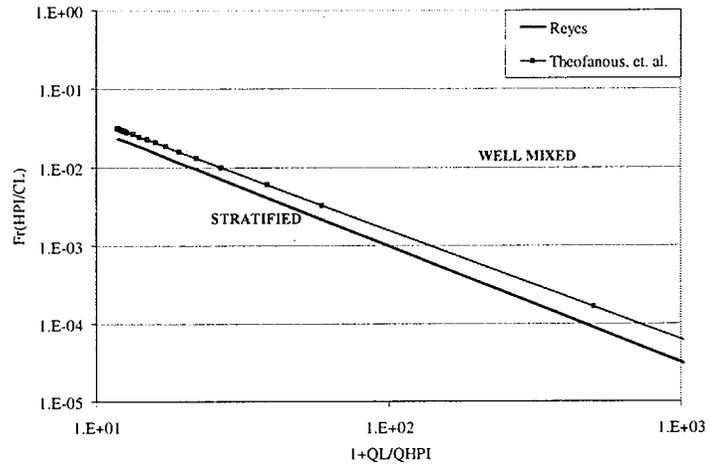
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Comparison of Criteria



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Range Applicable to Palisades



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Thermal Stratification Scaling Criteria

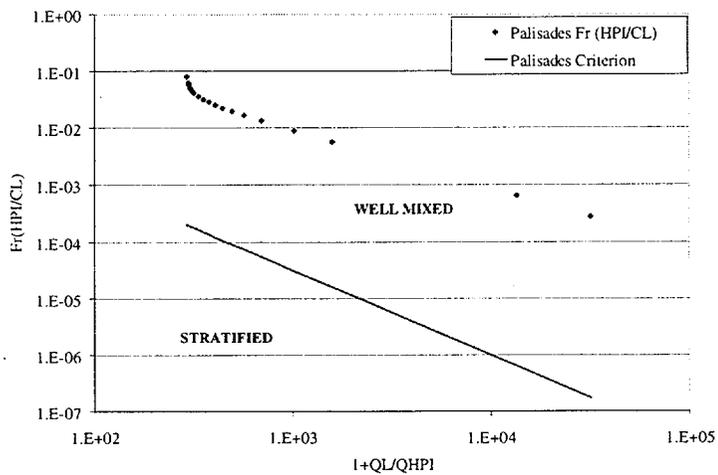
- **Thermal Mixing in the Cold Leg:**
  - To preserve the onset of thermal stratification in the cold leg, requires:
 
$$(Fr_{HP/CL})_R = 1$$

$$(Q_L/Q_{HPI})_R = 1$$
  - where  $Q_L$  is the primary loop natural circulation flow rate.



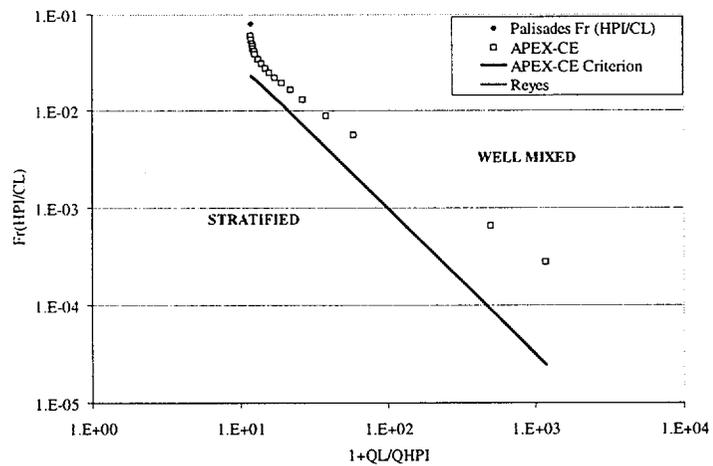
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Forced Flow Conditions for Palisades



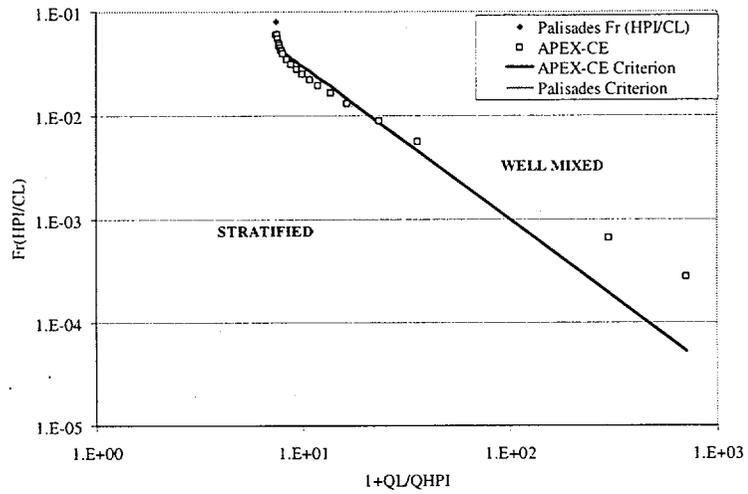
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Natural Circulation at 2.5% Decay Power



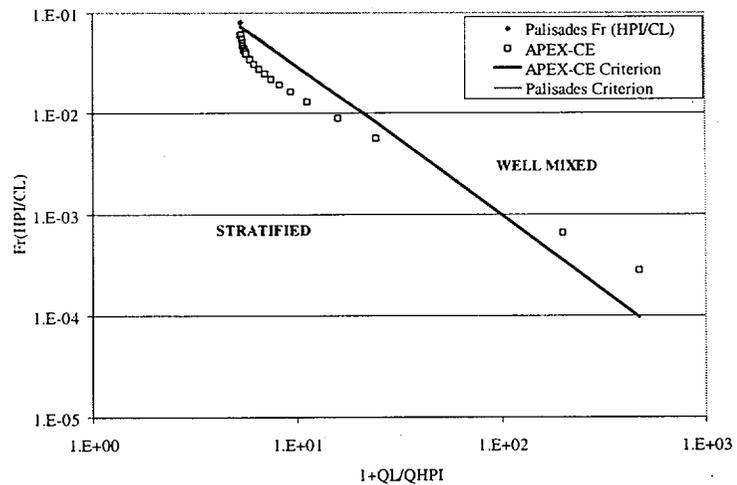
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Natural Circulation at 1.5% Decay Power



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Natural Circulation at 1.0% Decay Power



Nuclear Engineering & Radiation Health Physics  
Oregon State University

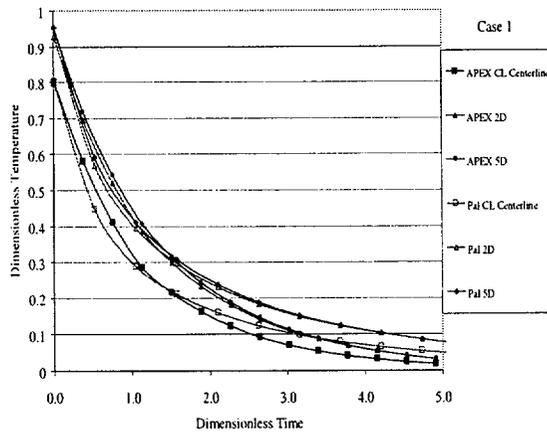
## REMIX Calculations

|               | Pressure (psia) | Cold Leg Temperature (°F) | Injection Temperature (°F) | Injection Flow Rate (ft <sup>3</sup> /s) |
|---------------|-----------------|---------------------------|----------------------------|--|
| <b>Case 1</b> |                 |                           |                            |  |
| APEX-CE       | 90              | 320                       | 60                         | $2.25 \times 10^{-3}$                    |
| Palisades     | 315             | 421.8                     | 87                         | 0.62                                     |
| <b>Case 2</b> |                 |                           |                            |  |
| APEX-CE       | 290             | 414                       | 60                         | $1.07 \times 10^{-3}$                    |
| Palisades     | 1020            | 546.4                     | 87                         | 0.297                                    |



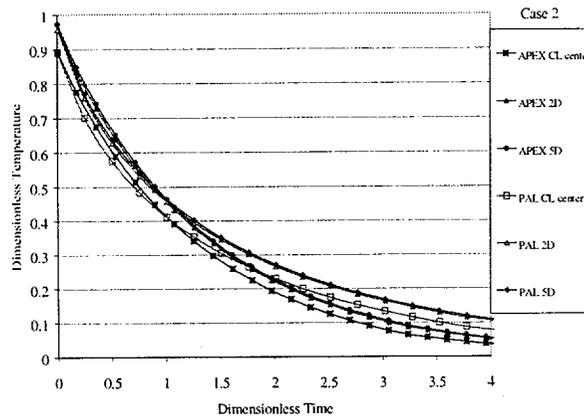
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## REMIX Plume Temperature Calculation



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## REMIX Plume Temperature Calculation



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Conclusions

- OSU has modified APEX to simulate the Palisade's 2x4 PWR. This includes the addition of an HPI line on each cold leg, cold leg loop seals, and additional T/C rakes.
- APEX-CE is geometrically similar to Palisades.
- APEX-CE operations will match the range of  $Fr_{HPI}$ ,  $Fr_{HPI/CL}$  and  $Q_L/Q_{HPI}$  values for Palisades to simulate:
  - The onset of HPI buoyant backflow
  - The onset of thermal stratification in the cold legs.
- A new thermal stratification criterion has been developed.



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Conclusions (*continued*)

- Detailed Downcomer mixing behavior can be studied using separate effects tests in APEX-CE.
- Time constants and characteristic  $\Pi$  groups have been obtained for the natural circulation, primary system depressurization, and thermal mixing scaling analyses.



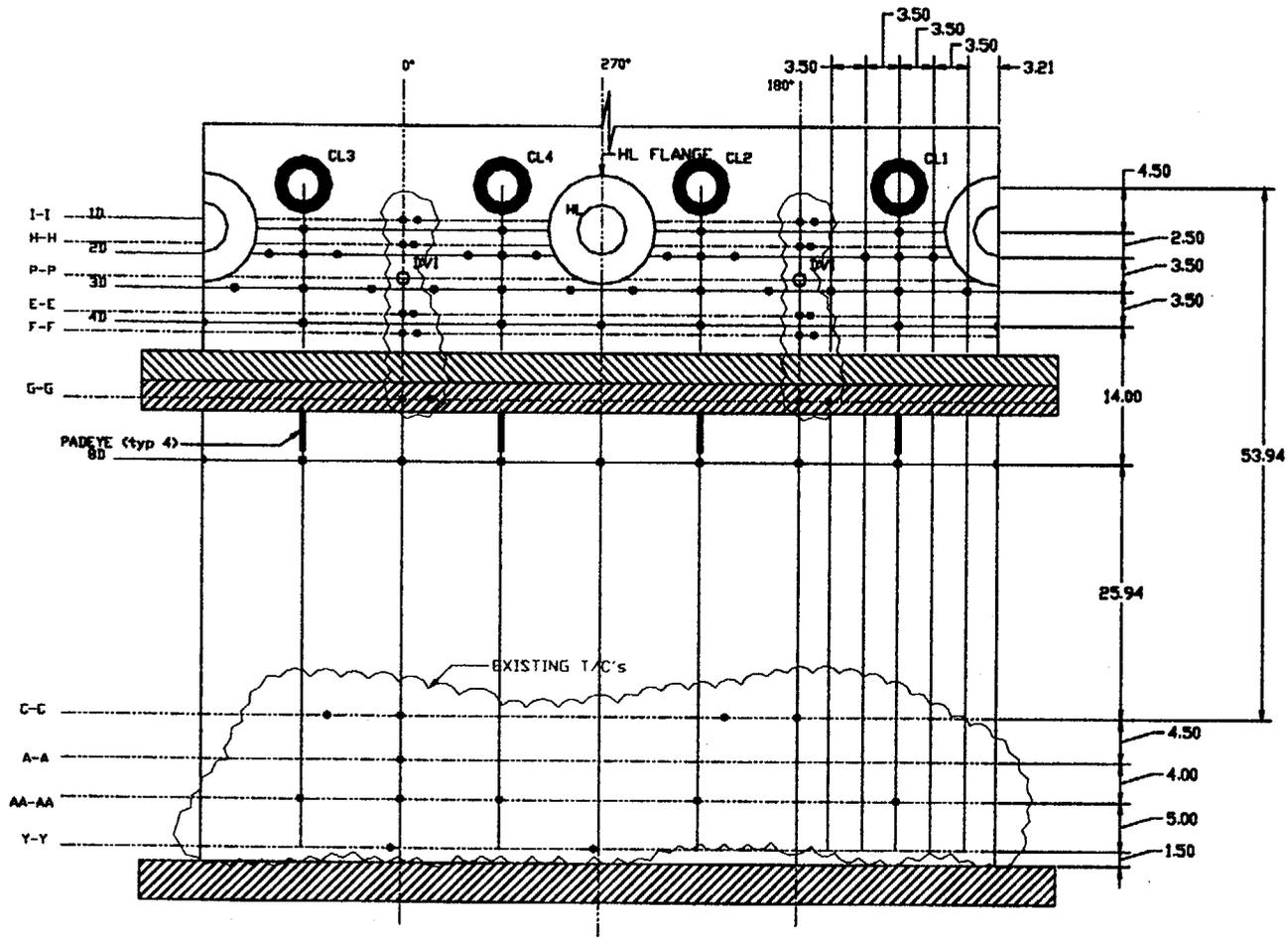
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Remaining Scaling Effort

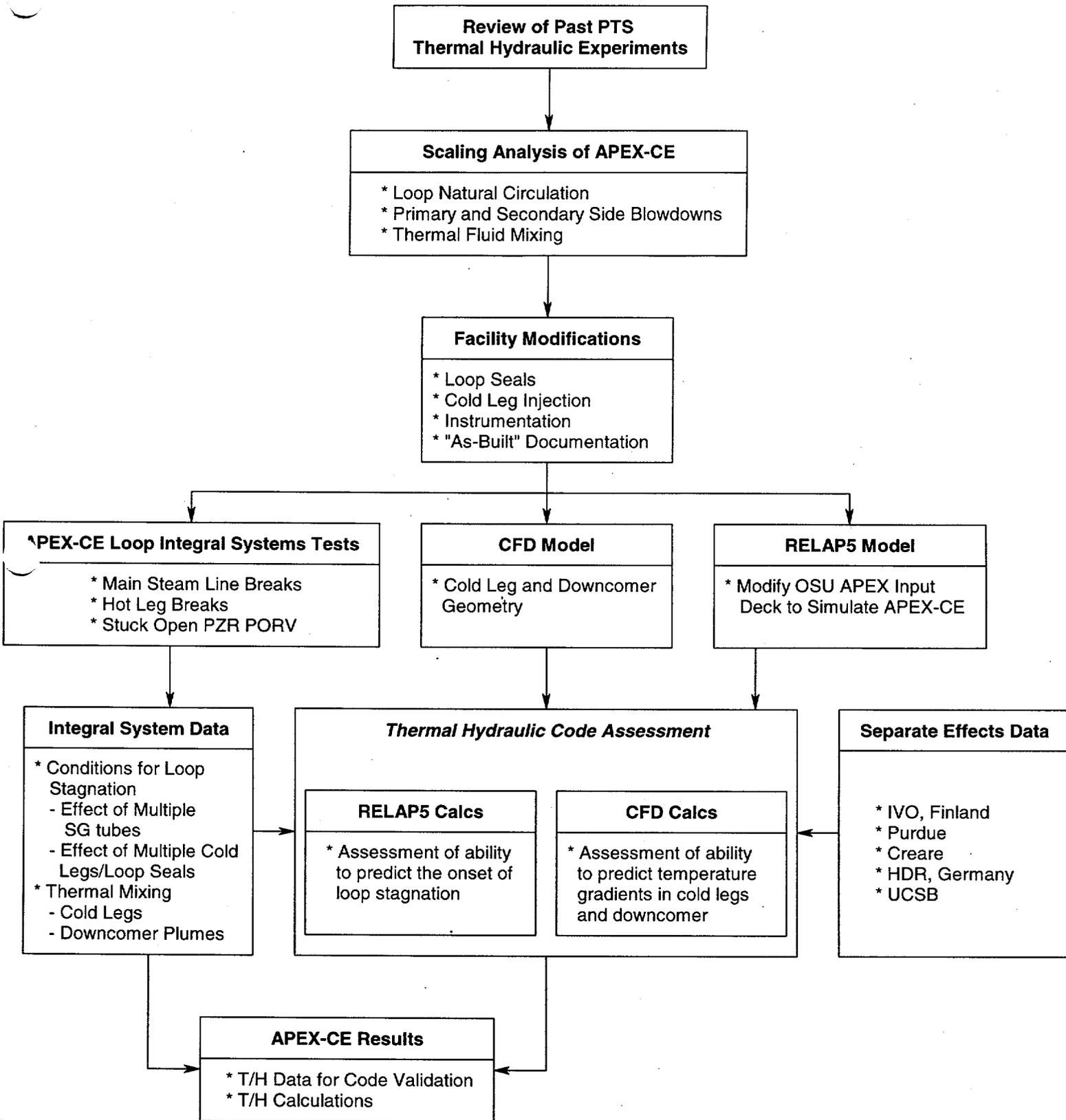
- Complete secondary side blowdown scaling analysis.
- Complete evaluation of all  $\Pi$  groups.
- Complete documentation.



Nuclear Engineering & Radiation Health Physics  
Oregon State University



| Layer | Tag #  | Degree |
|-------|--------|--------|
| E-E   | TF-131 | 186.2  |
|       | TF-152 | 180    |
|       | TF-134 | 0      |
| F-F   | TF-135 | 6.2    |
|       | TF-153 | 180    |
|       | TF-154 | 188    |
|       | TF-132 | 0      |
| H-H   | TF-133 | 8      |
|       | TF-149 | 180    |
| I-I   | TF-150 | 186.2  |
|       | TF-164 | 0      |
|       | TF-165 | 6.2    |
|       | TF-147 | 180    |
|       | TF-148 | 188    |
|       | TF-166 | 0      |
| G-G'  | TF-167 | 8      |
|       | TF-155 | 180    |
|       | TF-156 | 191.3  |
| C-C   | TF-130 | 0      |
|       | TF-131 | 11.3   |
|       | TF-157 | 212    |
|       | TF-158 | 180    |
|       | TF-128 | 0      |
| A-A   | TF-129 | 32     |
|       | TF-126 | 225    |
|       | TF-127 | 315    |
|       | TF-162 | 45     |
| AA-AA | TF-163 | 135    |
|       | TF-172 | 0      |
| Y-Y   | TF-173 | 270    |
|       | TF-118 | 22.5   |



REPORTER'S CERTIFICATE

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

NAME OF PROCEEDING: MEETING: THERMAL-HYDRAULIC  
PHENOMENA

CASE NUMBER:

PLACE OF PROCEEDING: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.



Mike Paulus

Official Reporter

Ann Riley & Associates, Ltd.

71  
INTRODUCTORY STATEMENT BY THE CHAIRMAN OF THE  
SUBCOMMITTEE ON THERMAL-HYDRAULIC PHENOMENA  
11545 ROCKVILLE PIKE, ROOM T-2B3  
ROCKVILLE, MARYLAND  
MARCH 15, 2000

The meeting will now come to order. This is a meeting of the ACRS Subcommittee on Thermal-Hydraulic Phenomena. I am Graham Wallis, Chairman of the Subcommittee.

ACRS Members in attendance are: Thomas Kress, and Dana Powers. ACRS Consultants in attendance are Virgil Schrock and Novak Zuber.

The purpose of this meeting is to (1) begin review of the thermal-hydraulic issues associated with the pressurized thermal shock (PTS) Screening Criterion Reevaluation Project being conducted by NRC Office of Nuclear Regulatory Research (RES); (2) discuss the status of the NRC staff acceptance review of the Siemens S-RELAP5 and GE Nuclear Energy TRACG codes; and, (3) discuss the status of the NRC staff's review of the EPRI RETRAN-3D code. The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Paul Boehmert is the Cognizant ACRS Staff Engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the *Federal Register* on February 25 and March 7, 2000.

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

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

**(Chairman's Comments - if any)**

We will now proceed with the meeting and I call upon Mr. Ralph Caruso of the Office of Nuclear Reactor Regulation to begin.

**STATUS OF COMPUTER CODE REVIEWS**

**RETRAN - 3D  
S-RELAP5  
TRACG**

**ACRS THERMAL-HYDRAULIC PHENOMENA  
SUBCOMMITTEE**

**MARCH 15, 2000**

**RALPH R. LANDRY  
REACTOR SYSTEMS BRANCH, DSSA/NRR**

## **PRESENTATION TOPICS**

- **STATUS OF RETRAN - 3D REVIEW**
- **STATUS OF S-RELAP5 REVIEW**
- **STATUS OF TRACG REVIEW**

## **STATUS OF RETRAN - 3D REVIEW**

- **DOCUMENTATION AND CODE SUBMITTED FOR REVIEW**
- **TIMELINE OVERVIEW**
- **CODE PROBLEM AREAS**
- **REVIEW CURRENTLY ON HOLD**
- **ADDITIONAL MATERIAL WAS TO BE SENT ON MARCH 6, 2000**

## Timeline

- **September 1998 RETRAN-3D submitted for review**
- **December 1998 meeting with ACRS T/H Subcommittee on code**
- **December 1998 code accepted for review**
- **RAIs and draft responses exchanged informally**
- **Official RAI release April 27, 1999**
- **Official RAI response May 21, 1999**
- **Telecon with EPRI, et al, April 19, 1999 (RETRAN-02 limitations addressed by RETRAN-3D)**
- **April 1999 EPRI provided:**
  - ▶ **RETRAN Bibliography - June 10, 1999**
  - ▶ **Paper by Agee at RELAP5 Seminar - June 1989**
  - ▶ **Reactor Analysis Support Document, Vol 2 - 1986**
  - ▶ **Reactor Analysis Support Document, Vol 3 - 1986**
  - ▶ **Qualification of RETRAN for Simulator Applications - 1988**
- **May 26, 1999 ACRS T/H Subcommittee Mtg:**
  - ▶ **5-equation flow field model not adequate, new model coming**
  - ▶ **June 1998 9<sup>th</sup> International RETRAN Conf discussed model problems**

- **June 29, 1999 meeting with EPRI, et al**
  - ▶ **New development areas (new cross-section model, etc.)**
  - ▶ **5-equation model**
- **July 14, 1999 Graham Wallis presentation to ACRS on quality of RETRAN momentum equation, Staff presentation on status of review**
- **August 16-20, 1999 RETRAN-3D training in Idaho Falls**
- **August 19, 1999 CD-ROM RETRAN-3D, MOD003 delivered**
- **Week of August 16, 1999 telecom with EPRI, et al, discussing responses to Graham Wallis's concerns**
- **July-August 1999 staff assessed 3-D kinetics; instructed EPRI on what to do and provided data and cross-sections for EPRI**

## **Code Version**

- **Code version submitted for review differs from that being distributed**
  - ▶ **Different 3-D kinetics**
  - ▶ **Different flow field equations**
- **What is to be reviewed?**
- **SE will apply only to version reviewed**

### **3-D Kinetics**

- **SPERT benchmarks coupled with other work in LTR provide good basis for acceptance of existing code**
- **Have not reviewed “new material” because we have not been provided with the documentation**
  - **New Material refers to new kinetics model and new cross section formulation**
- **Expect to be able to give approval for reactivity controlled events (PWR and BWR RIA) only**
- **Cannot approve events which require hydraulic feedback such as BWR stability, PWR MSLB, etc. due to lack of assessment**

### **Assessment**

- **Pointed out in first round RAls that assessment is incomplete**
- **Pointed out again during April 1999 telecon that problems with assessment still exist**
- **New models added (5-eqn) and assessments that had been done were not rerun**
- **Individual user will be required to fully assess code for each application**

## **User Guidelines**

- **Pointed out in first round RAIs that user guidelines are needed**
- **EPRI responded that they will provide user guidelines 2-5 years in the future, after more experience is gained**
- **August 1999 training reemphasized need for adequate user guidelines**
- **Each applicant will be required to provide and justify every assumption, option, model and correlation chosen**
- **Each applicant will be required to demonstrate code has been used within range of applicability of each model and correlation chosen**

## **Conclusions**

- **Staff has been reviewing a moving target**
- **Assessment is incomplete**
- **If approval to use as RETRAN-02 replacement is granted:**
  - ▶ **Applicant must verify only those models and correlations in RETRAN-02 have been used**
  - ▶ **Applicant must verify results are identical with those obtained with RETRAN-02**
- **In absence of user guidelines, user must:**
  - ▶ **Justify each and every model and correlation option used**
  - ▶ **Verify each and every model and correlation is used within range of applicability**
  - ▶ **Verify adequate training and experience of user**

## **STATUS OF S-RELAP5 REVIEW**

- ▶ **DOCUMENTATION AND CODE SUBMITTED FOR REVIEW**
- ▶ **STAFF ACCEPTANCE LETTER IN CONCURRENCE**
- ▶ **CODE IS HYBRID - NOT RELAP5/MOD2 NOR RELAP5/MOD3**

## **S-RELAP5 REVIEW**

- ▶ **NOVEMBER 22, 1999 REQUEST FOR CHAPTER 15 NON-LOCA APPLICATION REVIEW OF S-RELAP5**
- ▶ **JANUARY 10, 2000 REQUEST FOR SMALL BREAK LOCA APPLICATION REVIEW OF S-RELAP5**
- ▶ **FEBRUARY 3, 2000 SUBMITTAL OF FULL CODE DOCUMENTATION AND SOURCE CODE**
- ▶ **MARCH 1, 2000 MEETING WITH SIEMENS TO EXPLAIN CODE, DOCUMENTATION, REVIEW OBJECTIVES AND SCHEDULE**

## **S-RELAP5 REVIEW**

### **DOCUMENTATION:**

- ▶ **EMF-2100(P), REV 2, "S-RELAP5 MODELS AND CORRELATIONS CODE MANUAL"**
- ▶ **EMF-2101(P), REV 1, "S-RELAP5 PROGRAMMERS GUIDE"**
- ▶ **EMF-CC-097(P), REV 4, "S-RELAP5 INPUT DATA REQUIREMENTS"**
- ▶ **EMF-2310(P), REV 0, "SRP CHAPTER 15 NON-LOCA METHODOLOGY FOR PRESSURIZED WATER REACTORS"**
- ▶ **EMF-2328(P), REV 0, "PWR SMALL BREAK LOCA EVALUATION MODEL, S-RELAP5 BASED"**

## **S-RELAP5 REVIEW**

### **ACCEPTANCE:**

- ▶ **ACCEPTANCE LETTER IS IN CONCURRENCE**
- ▶ **DOCUMENTATION APPEARS TO BE THOROUGH**
- ▶ **THERE ARE SHORTCOMINGS, HOWEVER**
- ▶ **CODE HAS BEEN INSTALLED AND BUILT ON OUR SYSTEM**

## **S-RELAP5 REVIEW**

### **SCHEDULE:**

- ▶ **ACCEPTANCE REVIEW - COMPLETE**
- ▶ **RAIs - EARLY TO MID MAY 2000**
- ▶ **RESPONSES - MID JULY 2000**
- ▶ **SER - SBLOCA - END OF SEPTEMBER 2000**
- ▶ **SER - TRANSIENTS - DECEMBER 2000**

## **STATUS OF TRACG REVIEW**

- ▶ **DOCUMENTATION SUBMITTED FOR REVIEW**
- ▶ **ACCEPTANCE REVIEW WILL NOT PROCEED UNTIL CODE IS SUBMITTED**

## **TRACG REVIEW**

- ▶ **JULY 15, 1999 - MEETING TO DISCUSS TRACG REVIEW FOR BWR TRANSIENT APPLICATIONS**
- ▶ **JANUARY 31, FEBRUARY 28, FEBRUARY 29, 2000 - TRANSMITTAL OF TOPICAL REPORTS FOR REVIEW**

## **TRACG REVIEW**

### **DOCUMENTATION:**

- ▶ **NEDC-32900P, "TRACG LICENSING APPLICATION FRAMEWORK FOR AOO TRANSIENT ANALYSES**
- ▶ **NEDE-32176P, REV 2, "TRACG MODEL DESCRIPTION"**
- ▶ **NEDE-32906P, "TRACG APPLICATION FOR ANTICIPATED OPERATIONAL OCCURRENCES TRANSIENT ANALYSES"**
- ▶ **NEDE-32177P, REV 2, "TRACG QUALIFICATION"**
- ▶ **NEDC-32956P, REV 0, "TRACG02A USER'S MANUAL"**

## **TRACG REVIEW**

### **ACCEPTANCE:**

- ▶ **DOCUMENTATION APPEARS TO BE THOROUGH**
- ▶ **CODE RECEIVED EXTENSIVE REVIEW DURING SBWR REVIEW**
- ▶ **CODE HAS NOT BEEN SUBMITTED**

## **TRACG REVIEW**

### **SCHEDULE:**

- ▶ **ONCE CODE IS SUBMITTED, ACCEPTANCE REVIEW WILL START WITH APPROXIMATELY ONE MONTH TO COMPLETE**

**RETRAN Maintenance Group Comments  
Regarding NRC Review of RETRAN-3D**

**ACRS Subcommittee on Thermal-Hydraulic Phenomena  
March 15, 2000 Meeting**

**Gregg B. Swindlehurst  
Duke Power Company  
Chairman – RETRAN Maintenance Group**

## **Review Milestones**

- |                 |  |
|-----------------|--|
| <b>7/8/98</b>   | <b>RETRAN-3D submitted for review</b>  |
| <b>12/4/98</b>  | <b>NRC accepts RETRAN-3D for review</b>  |
| <b>4/27/99</b>  | <b>First round RAI</b>   |
| <b>5/21/99</b>  | <b>Response to first round RAI</b>   |
| <b>8/25/99</b>  | <b>Second round RAI</b>  |
| <b>10/22/99</b> | <b>Response to second round RAI</b>  |
| <b>3/6/00</b>   | <b>Submittal of additional information</b> <ul style="list-style-type: none"><li>- Follow up on 12/16/99 meeting</li><li>- Respond to all known issues</li><li>- Withdraw certain code options</li></ul> |

## **Perspectives on Review Status**

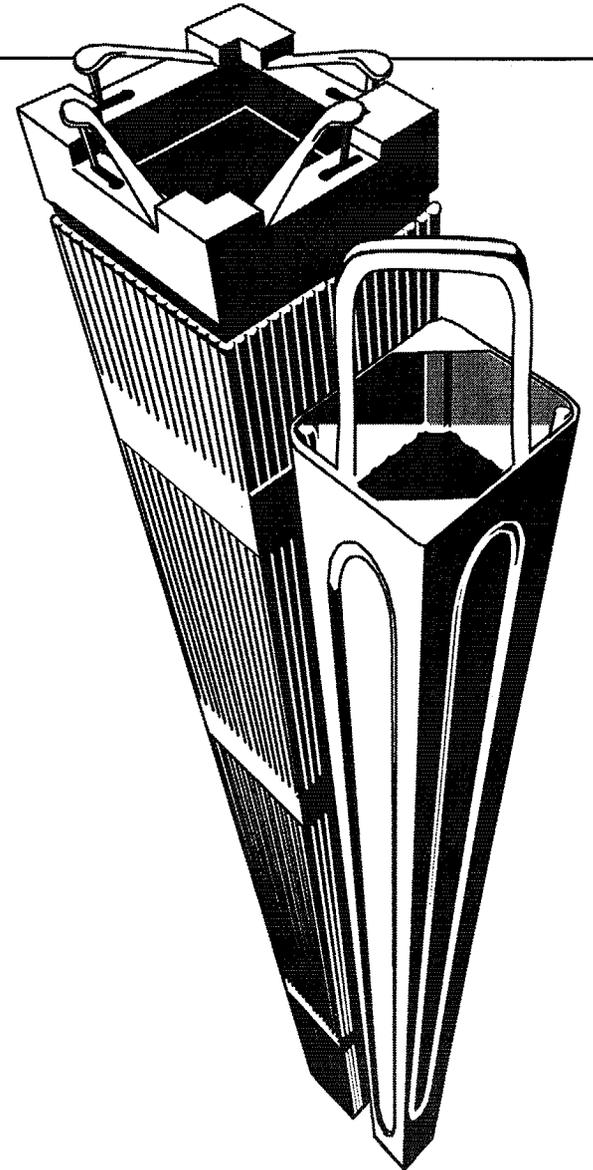
- **The staff has conducted a very thorough review**
- **We have attempted to be responsive to all issues raised**
- **Two code errors identified by the staff were corrected**
- **Certain new code models have been withdrawn from review**
- **The new RETRAN-3D models will improve the capability of the users to accurately simulate non-LOCA plant transients. This will enhance safety**
- **The standards for review should be consistent with the risk-significance of the intended applications of the code (i.e. non-LOCA events)**
- **Use of plant transient analysis simulation codes by licensees should be encouraged as an enhancement to safety**

## **Future Goals**

- **Continue to work with the NRC staff to resolve all issues**
- **Obtain an SER that will enable users to upgrade to RETRAN-3D, which is an improvement over the widely used RETRAN-02**
- **Maintain licensee option to simulate plant transients and enhance safety with modern software**

Presented by: James F. Mallay  
Director, Regulatory Affairs

ACRS Subcommittee  
March 15, 2000



## Siemens' Representatives

---

Robin Feuerbacher, Vice President  
Engineering

Larry O'Dell, Manager  
Research & Technology

Jerry S. Holm, Manager  
PWR Product Licensing

Jim Mallay, Director  
Regulatory Affairs

## Siemens' Objectives

---

- Introduce a few key personnel
- Summarize Siemens' strategy for the application of S-RELAP5
- Understand the expectations of the ACRS subcommittee on Thermal Hydraulics

# Application of S-RELAP5

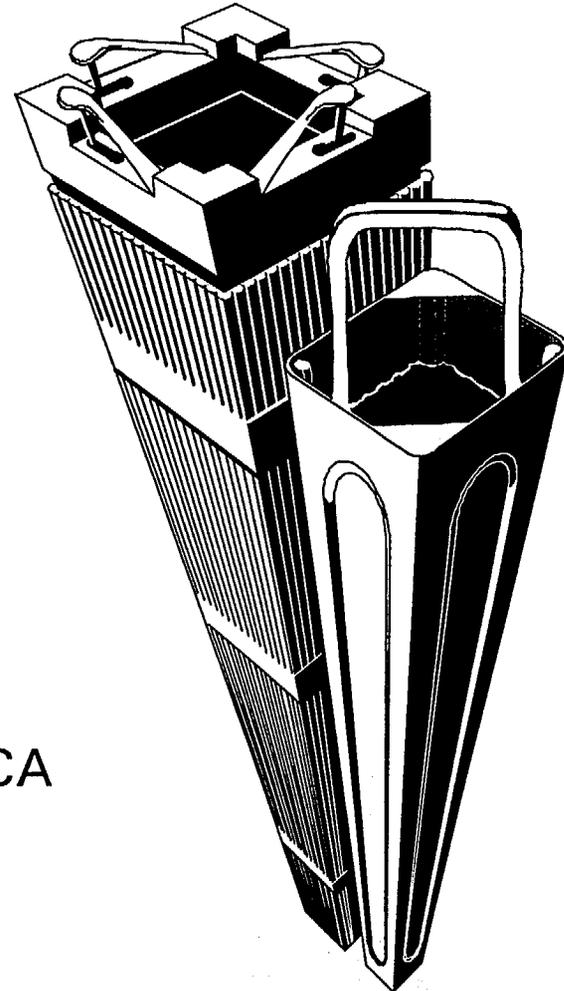
---

L. D. O'Dell, Manager

U.S. & Far East Research & Technology

Project Manager Realistic Large Break LOCA

Siemens Power Corporation



## Application of S-RELAP5

---

- Objective of Today's Discussion
  - Introduce Siemens' overall strategy for the application of the S-RELAP5 code in the performance of safety analysis
    - PWR application (near-term)
    - BWR application (longer term)

## Application of S-RELAP5

---

- S-RELAP5 Code
  - Original basis: RELAP5/MOD2 (INEL Cycle 36.02)
  - Siemens modifications to support use for SRP Chapter 15 LOCA and Non-LOCA licensing analyses and to improve code predictions of assessments
    - Addition of 2D thermal hydraulic capabilities
  - Addition of RELAP5/MOD3 features/models
    - S-RELAP5 code structure modified for portability
    - Reactor kinetics
    - Control systems
    - Trip systems

## Application of S-RELAP5

---

- PWR Applications
  - Code currently being used by our Siemens KWU counterparts to support European and South American plants
  - Current U.S. submittals
    - SRP Chapter 15 Non-LOCA transient analyses
    - Appendix K Small Break LOCA analysis
  - Planned submittal (June to November 2000)
    - Realistic Large Break LOCA analyses
      - Drivers are support for H. B. Robinson and Shearon Harris plants

## Application of S-RELAP5

---

- Longer Term BWR Applications
  - Code currently being used by our Siemens KWU counterparts to support European plants
  - Development projects for U.S. application to be initiated next fiscal year
    - SRP Chapter 15 Non-LOCA transient analyses
    - Small Break LOCA
    - Large Break LOCA

## Application of S-RELAP5

---

- Realistic Large Break LOCA
  - Methodology development following CSAU approach
    - Supporting information obtained from review of ACRS minutes published on the internet
    - Code and documentation verification performed
      - Siemens, INEEL, and DE&S personnel
    - PIRT developed in-house
      - Peer review conducted with Siemens personnel, consultants, and customer participation
        - M. J. Thurgood, J. M. Kelly, Dr. L. E. Hochreiter
    - Nuclear Power Plant model developed
      - Numerous sensitivity studies
      - Peer review conducted

## Application of S-RELAP5

---

- Realistic Large Break LOCA
  - Assessment matrix established
    - Based on PIRT and results of sensitivity studies
    - Addresses scalability and compensating error issues
    - Peer review conducted
  - Current efforts
    - Final assessments being performed and associated uncertainties and biases developed
      - Peer review of assessment results will be performed
    - Software for performance of statistical plant analyses under development
      - Statistical support provided by Dr. John Jaech

## Application of S-RELAP5

---

- Realistic Large Break LOCA
  - Siemens striving to meet documentation requirements
    - Detailed methodology document
      - Methodology roadmap
      - Follows CSAU outline
    - Code documentation
      - Models and correlations
      - Programmers manual
      - User input manual
      - Verification and validation
  - Siemens objective is to work closely with the NRC staff on this project
  - Siemens will work with the ACRS at the appropriate times in the review process

**STATUS OF COMPUTER CODE REVIEWS**

**RETRAN - 3D  
S-RELAP5  
TRACG**

**ACRS THERMAL-HYDRAULIC PHENOMENA  
SUBCOMMITTEE**

**MARCH 15, 2000**

**RALPH R. LANDRY  
REACTOR SYSTEMS BRANCH, DSSA/NRR**

## **PRESENTATION TOPICS**

- **STATUS OF RETRAN - 3D REVIEW**
- **STATUS OF S-RELAP5 REVIEW**
- **STATUS OF TRACG REVIEW**

## **STATUS OF RETRAN - 3D REVIEW**

- **DOCUMENTATION AND CODE SUBMITTED FOR REVIEW**
- **TIMELINE OVERVIEW**
- **CODE PROBLEM AREAS**
- **REVIEW CURRENTLY ON HOLD**
- **ADDITIONAL MATERIAL WAS TO BE SENT ON MARCH 6, 2000**

## Timeline

- **September 1998 RETRAN-3D submitted for review**
- **December 1998 meeting with ACRS T/H Subcommittee on code**
- **December 1998 code accepted for review**
- **RAIs and draft responses exchanged informally**
- **Official RAI release April 27, 1999**
- **Official RAI response May 21, 1999**
- **Telecon with EPRI, et al, April 19, 1999 (RETRAN-02 limitations addressed by RETRAN-3D)**
- **April 1999 EPRI provided:**
  - ▶ **RETRAN Bibliography - June 10, 1999**
  - ▶ **Paper by Agee at RELAP5 Seminar - June 1989**
  - ▶ **Reactor Analysis Support Document, Vol 2 - 1986**
  - ▶ **Reactor Analysis Support Document, Vol 3 - 1986**
  - ▶ **Qualification of RETRAN for Simulator Applications - 1988**
- **May 26, 1999 ACRS T/H Subcommittee Mtg:**
  - ▶ **5-equation flow field model not adequate, new model coming**
  - ▶ **June 1998 9<sup>th</sup> International RETRAN Conf discussed model problems**

- **June 29, 1999 meeting with EPRI, et al**
  - ▶ **New development areas (new cross-section model, etc.)**
  - ▶ **5-equation model**
- **July 14, 1999 Graham Wallis presentation to ACRS on quality of RETRAN momentum equation, Staff presentation on status of review**
- **August 16-20, 1999 RETRAN-3D training in Idaho Falls**
- **August 19, 1999 CD-ROM RETRAN-3D, MOD003 delivered**
- **Week of August 16, 1999 telecom with EPRI, et al, discussing responses to Graham Wallis's concerns**
- **July-August 1999 staff assessed 3-D kinetics; instructed EPRI on what to do and provided data and cross-sections for EPRI**

## Code Version

- Code version submitted for review differs from that being distributed
  - ▶ Different 3-D kinetics
  - ▶ Different flow field equations
- What is to be reviewed?
- SE will apply only to version reviewed

### **3-D Kinetics**

- **SPERT benchmarks coupled with other work in LTR provide good basis for acceptance of existing code**
- **Have not reviewed “new material” because we have not been provided with the documentation**
  - ▶ **New Material refers to new kinetics model and new cross section formulation**
- **Expect to be able to give approval for reactivity controlled events (PWR and BWR RIA) only**
- **Cannot approve events which require hydraulic feedback such as BWR stability, PWR MSLB, etc. due to lack of assessment**

### **Assessment**

- **Pointed out in first round RAs that assessment is incomplete**
- **Pointed out again during April 1999 telecon that problems with assessment still exist**
- **New models added (5-eqn) and assessments that had been done were not rerun**
- **Individual user will be required to fully assess code for each application**

## **User Guidelines**

- **Pointed out in first round RAIs that user guidelines are needed**
- **EPRI responded that they will provide user guidelines 2-5 years in the future, after more experience is gained**
- **August 1999 training reemphasized need for adequate user guidelines**
- **Each applicant will be required to provide and justify every assumption, option, model and correlation chosen**
- **Each applicant will be required to demonstrate code has been used within range of applicability of each model and correlation chosen**

## **Conclusions**

- **Staff has been reviewing a moving target**
- **Assessment is incomplete**
- **If approval to use as RETRAN-02 replacement is granted:**
  - ▶ **Applicant must verify only those models and correlations in RETRAN-02 have been used**
  - ▶ **Applicant must verify results are identical with those obtained with RETRAN-02**
- **In absence of user guidelines, user must:**
  - ▶ **Justify each and every model and correlation option used**
  - ▶ **Verify each and every model and correlation is used within range of applicability**
  - ▶ **Verify adequate training and experience of user**

## **STATUS OF S-RELAP5 REVIEW**

- ▶ **DOCUMENTATION AND CODE SUBMITTED FOR REVIEW**
- ▶ **STAFF ACCEPTANCE LETTER IN CONCURRENCE**
- ▶ **CODE IS HYBRID - NOT RELAP5/MOD2 NOR RELAP5/MOD3**

## **S-RELAP5 REVIEW**

- ▶ **NOVEMBER 22, 1999 REQUEST FOR CHAPTER 15 NON-LOCA APPLICATION REVIEW OF S-RELAP5**
- ▶ **JANUARY 10, 2000 REQUEST FOR SMALL BREAK LOCA APPLICATION REVIEW OF S-RELAP5**
- ▶ **FEBRUARY 3, 2000 SUBMITTAL OF FULL CODE DOCUMENTATION AND SOURCE CODE**
- ▶ **MARCH 1, 2000 MEETING WITH SIEMENS TO EXPLAIN CODE, DOCUMENTATION, REVIEW OBJECTIVES AND SCHEDULE**

## **S-RELAP5 REVIEW**

### **DOCUMENTATION:**

- ▶ **EMF-2100(P), REV 2, "S-RELAP5 MODELS AND CORRELATIONS CODE MANUAL"**
- ▶ **EMF-2101(P), REV 1, "S-RELAP5 PROGRAMMERS GUIDE"**
- ▶ **EMF-CC-097(P), REV 4, "S-RELAP5 INPUT DATA REQUIREMENTS"**
- ▶ **EMF-2310(P), REV 0, "SRP CHAPTER 15 NON-LOCA METHODOLOGY FOR PRESSURIZED WATER REACTORS"**
- ▶ **EMF-2328(P), REV 0, "PWR SMALL BREAK LOCA EVALUATION MODEL, S-RELAP5 BASED"**

## **S-RELAP5 REVIEW**

### **ACCEPTANCE:**

- ▶ **ACCEPTANCE LETTER IS IN CONCURRENCE**
- ▶ **DOCUMENTATION APPEARS TO BE THOROUGH**
- ▶ **THERE ARE SHORTCOMINGS, HOWEVER**
- ▶ **CODE HAS BEEN INSTALLED AND BUILT ON OUR SYSTEM**

## **S-RELAP5 REVIEW**

### **SCHEDULE:**

- ▶ **ACCEPTANCE REVIEW - COMPLETE**
- ▶ **RAIs - EARLY TO MID MAY 2000**
- ▶ **RESPONSES - MID JULY 2000**
- ▶ **SER - SBLOCA - END OF SEPTEMBER 2000**
- ▶ **SER - TRANSIENTS - DECEMBER 2000**

## **STATUS OF TRACG REVIEW**

- ▶ **DOCUMENTATION SUBMITTED FOR REVIEW**
- ▶ **ACCEPTANCE REVIEW WILL NOT PROCEED UNTIL CODE IS SUBMITTED**

## **TRACG REVIEW**

- ▶ **JULY 15, 1999 - MEETING TO DISCUSS TRACG REVIEW FOR BWR TRANSIENT APPLICATIONS**
- ▶ **JANUARY 31, FEBRUARY 28, FEBRUARY 29, 2000 - TRANSMITTAL OF TOPICAL REPORTS FOR REVIEW**

## **TRACG REVIEW**

### **DOCUMENTATION:**

- ▶ **NEDC-32900P, "TRACG LICENSING APPLICATION FRAMEWORK FOR AOO TRANSIENT ANALYSES"**
- ▶ **NEDE-32176P, REV 2, "TRACG MODEL DESCRIPTION"**
- ▶ **NEDE-32906P, "TRACG APPLICATION FOR ANTICIPATED OPERATIONAL OCCURRENCES TRANSIENT ANALYSES"**
- ▶ **NEDE-32177P, REV 2, "TRACG QUALIFICATION"**
- ▶ **NEDC-32956P, REV 0, "TRACG02A USER'S MANUAL"**

## **TRACG REVIEW**

### **ACCEPTANCE:**

- ▶ **DOCUMENTATION APPEARS TO BE THOROUGH**
- ▶ **CODE RECEIVED EXTENSIVE REVIEW DURING SBWR REVIEW**
- ▶ **CODE HAS NOT BEEN SUBMITTED**

## **TRACG REVIEW**

### **SCHEDULE:**

- ▶ **ONCE CODE IS SUBMITTED, ACCEPTANCE REVIEW WILL START WITH APPROXIMATELY ONE MONTH TO COMPLETE**

*GE Nuclear Energy*

---

**TRACG Application  
For BWR Transients**

**Presentation to ACRS  
J. G. M. Andersen**

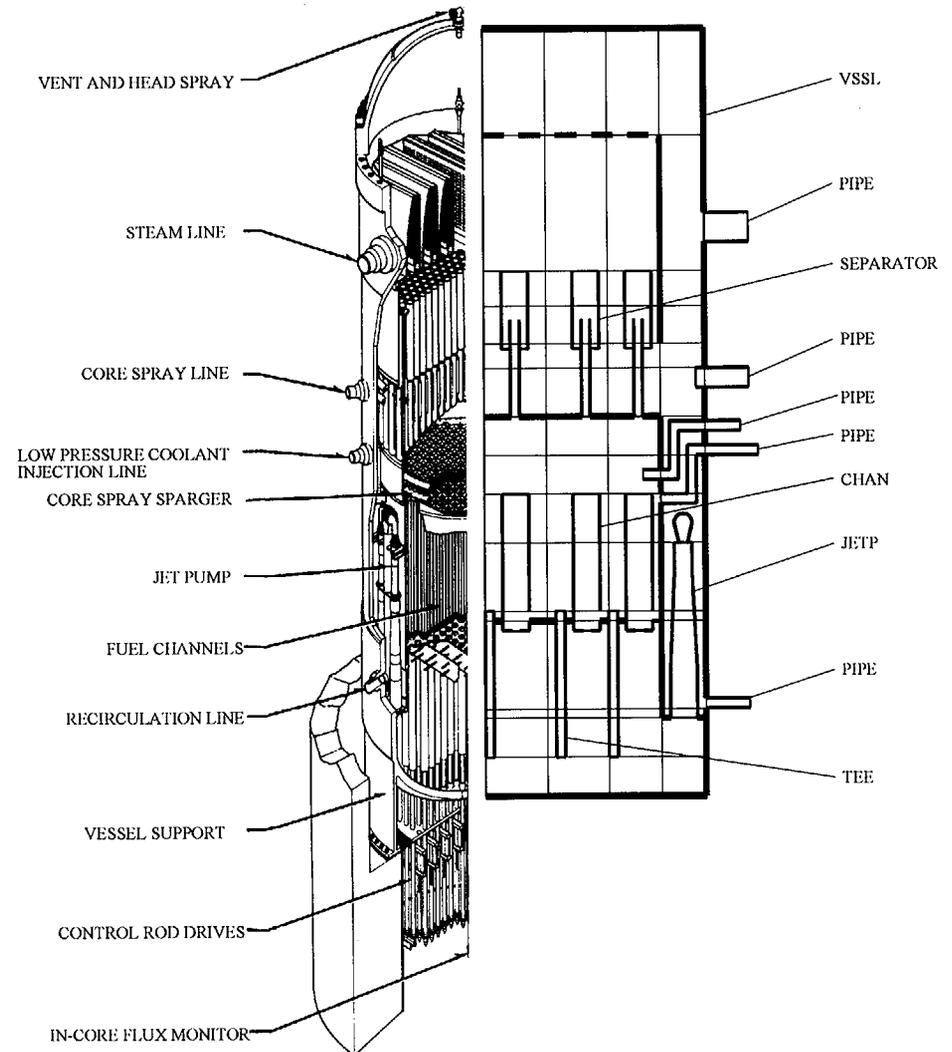
**March 15, 2000**



# TRACG

## Realistic Code for BWR Transients

- Transients, ← Focus of submittal  
LOCA, ATWS, Stability, RIA, RIPD
- Multi-dimensional vessel
- Flexible modular structure with control system capability
- Proven 3D nuclear kinetics consistent with PANACEA
- Steam, liquid, boron and non-condensable gases
- Flow regime map covering all hydraulic conditions
- Consistent use of constitutive correlations
  - Shear and heat transfer
- BWR component models
  - Pump, Jet Pump, Separator, Fuel Channel
- Extensive qualification
  - Separate effects tests
  - BWR component performance data
  - Integral system effects
  - Full scale plant data



# Past TRACG Applications

---

- **LOCA - Benchmark tool for qualification of SAFER**
- **Transients - Time varying axial power shape**
- **Stability -  $\Delta$ CPR for BWROG option III**
- **ATWS stability for BWROG and ABWR**
- **Forsmark time-temperature criterion**
- **Rod drop accident analysis, reactivity insertion accidents**
- **Containment annulus pressurization**
- **Acoustic loads**
- **Reactor internal pressure differences**
- **Dodewaard re-licensing (transients, LOCA, ATWS, etc.)**
- **SBWR safety analysis**
- **K6 Startup testing**
- **Nordic Applications - ATWS, RIA, Transient, LOCA**

**Numerous TRACG Applications in the Past  
Many Applications Reviewed and Accepted by NRC  
Current Submittal Focus on AOO Transients**

# **Scope: Application of TRACG for BWR Transients**

---

- **Plants:**                    **BWR/2/3/4/5/6**
- **Events:**                    **Anticipated Operational Occurrences (Transients)**
  - Increase / Decrease in Reactor Pressure
  - Increase / Decrease in Core Flow
  - Increase / Decrease in Reactor Coolant Inventory
  - Decrease in Core Coolant Temperature
  - Same Events as Currently Approved for ODYN/TASC
- **Documentation**
  - TRACG Licensing Application Framework for AOO Transient Analyses, NEDC-32900P
  - TRACG Model Description LTR, NEDE-32176P, Revision 2
  - TRACG Qualification LTR , NEDE-32177P, Revision 2
  - TRACG Application LTR for AOO Transient Analyses, NEDE-32906P
  - TRACG02A Users Manual, NRDC-32956P
- **Review Scope**
  - SER for Application of TRACG to BWR AOO Transients
    - Applicability of TRACG for AOO Transients
    - Qualification
    - Application Methodology for AOO Transients

# Benefits

---

- **Integrated Analysis Using a Single Computer Code**
  - Eliminate potential for errors in data transfer between codes
  - Improved understanding of process by all organizations
    - **Utility / Vendor / Regulators**
  
- **More Realistic Prediction of Plant Transient Response**
  - Better operational response to AOOs
  - Improved plant safety
  - Improved Operating Limits/Plant Capacity Factors
  
- **Better Quantification of Margin and Uncertainty**
  - Application to risk-based decision making

# Comparison to Current Approved Methodology

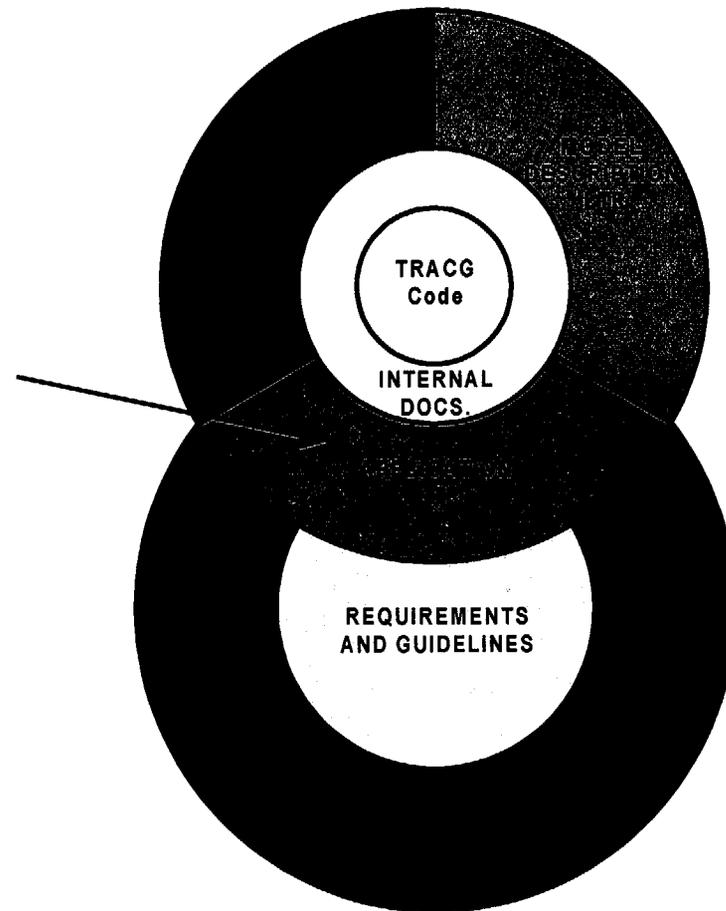
|  | ODYN / TASC   | TRACG   |
|--|---|---|
| Scope  | <ul style="list-style-type: none"> <li>• Calculation of operating limit minimum critical power ratio</li> </ul>   | <ul style="list-style-type: none"> <li>• Calculation of operating limit minimum critical power ratio</li> </ul>   |
| Model  | <ul style="list-style-type: none"> <li>• ODYN – Simulation of core average power response.                             <ul style="list-style-type: none"> <li>- One dimensional kinetics and hydraulic model for reactor core</li> <li>- Collapsed nuclear data from GE 3D core simulator (PANACEA)</li> </ul> </li> <li>• TASC – Simulation of hot channel transient CPR response.                             <ul style="list-style-type: none"> <li>- One dimensional thermal hydraulic model</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>• TRACG – Three-dimensional simulation of core power and CPR response.                             <ul style="list-style-type: none"> <li>- Three dimensional kinetics consistent with GE 3D core simulator (PANACEA)</li> <li>- Parallel channel hydraulic model for core including hot channel</li> </ul> </li> </ul>                                  |
| Data and Model Uncertainty                       | <ul style="list-style-type: none"> <li>• Model uncertainty determined from comparison to plant data</li> <li>• Model uncertainty verified by statistical methodology (propagation of errors)</li> </ul>   | <ul style="list-style-type: none"> <li>• Model uncertainty determined by statistical methodology (ANOVA or Order Statistics)</li> <li>• Model uncertainty verified by comparison to data using statistical methodology</li> </ul>   |
| Application Methodology for Combined Uncertainty | <ul style="list-style-type: none"> <li>• Nominal calculation                             <ul style="list-style-type: none"> <li>- Best estimate models</li> <li>- Tech. spec. for most plant parameters</li> </ul> </li> <li>• Combined uncertainty                             <ul style="list-style-type: none"> <li>- Model uncertainty, Power and Scram speed</li> </ul> </li> </ul>  | <ul style="list-style-type: none"> <li>• Nominal calculation                             <ul style="list-style-type: none"> <li>- Best estimate models</li> <li>- Best estimate or tech. spec. plant parameters</li> </ul> </li> <li>• Combined uncertainty                             <ul style="list-style-type: none"> <li>- Model and plant parameter uncertainties</li> </ul> </li> </ul> |

**Statistical Methodology Similar to Current Approved Method**

# TRACG Application Methodology - Major Elements

---

- **Plant and Event Definition**
- **Identification of Important Phenomena**
  - All Identified Event Categories
  - Ranking by Impact on Critical Safety Parameters  
CPR, Pressure, Water Level, Fuel T/M response
  - All high and Medium ranked parameters included
- **Determination of Code Applicability**
  - Structure, Basic Equations, Models and Correlations, Numerics
  - Cross reference to PIRT
- **Qualification and Determination of Code Uncertainty**
  - Separate Effects Tests, Component Tests, Integral Effects Tests, Full Scale Plant Data
  - Cross reference to PIRT
- **Determination of Effect of Reactor Input Parameters and State**
- **Determination of Total Uncertainty**
  - Plant sensitivity studies
  - One Sided Upper Statistical Limit for Critical Safety Parameters

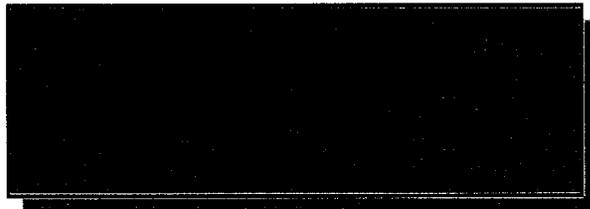


**Structured Approach Consistent with CSAU Methodology**

# Approach

---

## Submittal



### Rev. 0

Transient application methodology

CSAU Approach

Model & Qualification data included

## Supporting Documents

Model Description  
NEDE-32176P

### Rev. 1

*Reviewed by NRC*

### Rev. 2

Incorporates RAIs  
Deletes SBWR Models

Qualification  
NEDE-32177P

### Rev. 1

*Reviewed by NRC*

### Rev. 2

Incorporates RAIs  
Deletes SBWR  
Qualification Studies

Requested Review is Application Methodology

# **TRACG Application to BWR AOO Transients**

---

## **Summary**

- **Scope: BWR/2-6 AOO Transients**
- **Meets All Regulatory Requirements**
- **Demonstration of Model Capability and Applicability**
- **Extensive Prior Reviews and Acceptance of TRACG**
- **Rigorous and Sound Statistical Methodology**
  - Model Uncertainty
  - Initial Conditions and Plant Parameter Uncertainties
  - One Sided Upper Statistical Limit for Critical Safety Parameters
- **Application Methodology Demonstrated for All Event Types**

**Obtain SER for TRACG Application to BWR AOOs**

David Bessette  
Office of Nuclear Regulatory Research  
US Nuclear Regulatory Commission

**THERMAL HYDRAULIC INPUT TO  
PTS SCREENING REVALUATION PROGRAM**

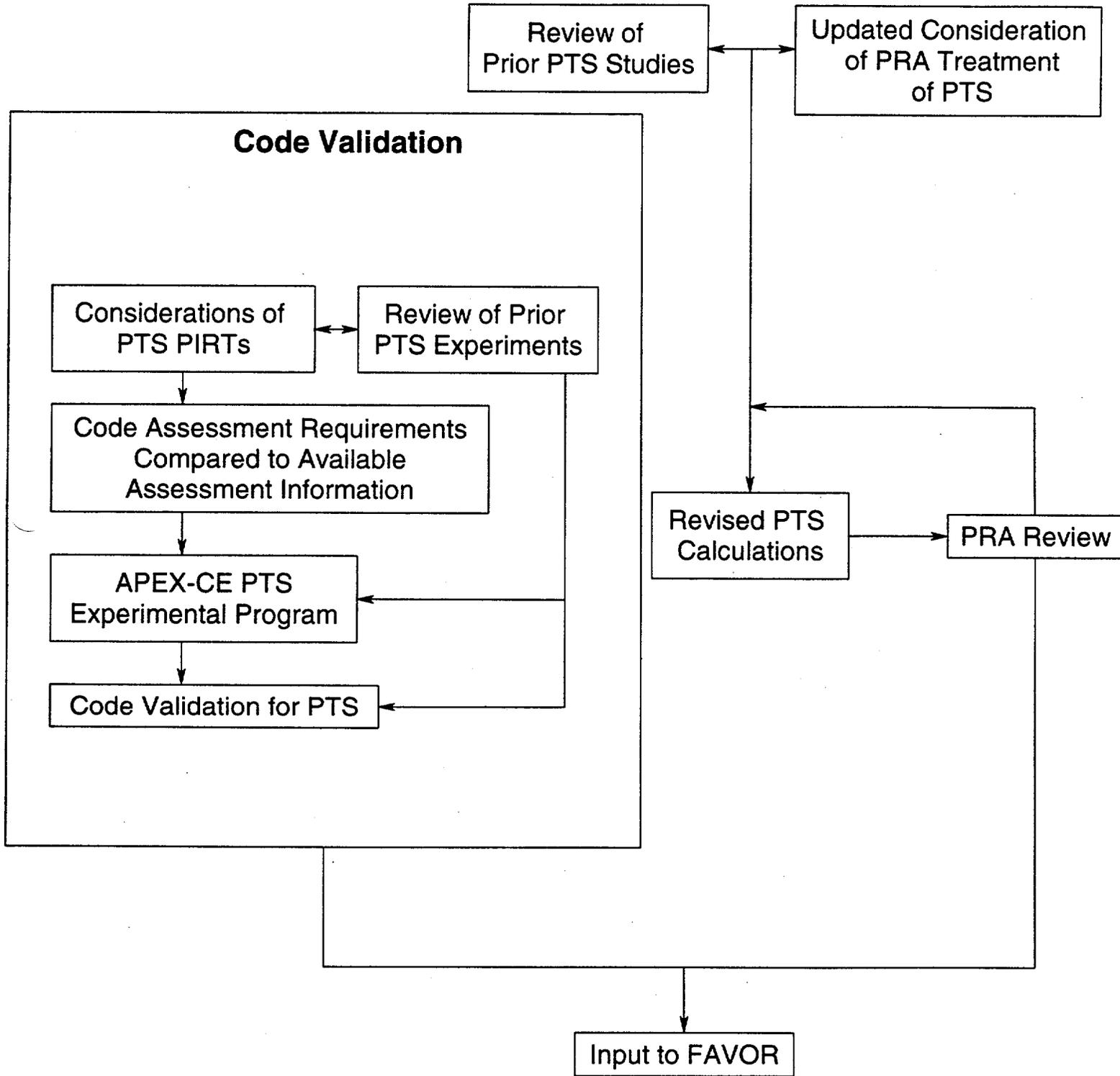
Thermal Hydraulic Phenomena Subcommittee  
Advisory Committee on Reactor Safeguards

March 15, 2000  
Rockville, MD

## **Purpose**

- Give overview of the thermal hydraulics input into the PTS screening reevaluation program
- Briefly review existing fluid-fluid mixing data base in the reactor geometry of interest
- Discuss some results from prior PTS studies
- Plans for calculations

# Thermal Hydraulic Input to PTS Re-evaluation



## **Background**

- One of the key governing principles of reactor safety is that the reactor vessel must not fail, since should such an event occur, core coolability is questionable.
- The recognition of this principal by around 1966 led to the establishment of the Heavy Section Steel Technology program and the continuing efforts over the years to assure that such an event remains at an extremely low probability.
- Before 1978 it was postulated the most severe thermal shock a reactor vessel could experience would be during a large break loss-of-coolant (LOCA) accident.

Ambient temperature emergency core coolant would flood the downcomer following a thirty second blowdown that would leave the reactor coolant system essentially empty of liquid. Initially the accumulators would fill the downcomer in about twenty seconds injecting water approximately 27C (80F). This would be followed by low pressure injection (Much of this water would be preheated before entering the downcomer to near saturation from steam flowing from the core). During this time, however, the reactor vessel would be under no pressure stress. The downcomer temperature would be in the range 235F to 270F.

## **Background (cont'd)**

- The issue of pressurized thermal shock has its origins in the Rancho Seco event of 1978. This event led to an actuation of high pressure injection for an extended period of time, resulting in the primary system going water solid and discharging liquid out the safety valves on the pressurizer (2450 psi).
- Following the Rancho Seco event, pressurized thermal shock was designated as Unresolved Safety Issue A-49.
- Should overcooling events occur in conjunction with high pressure and an embrittled vessel, the potential exists for an existing flaw in the vessel wall to propagate.

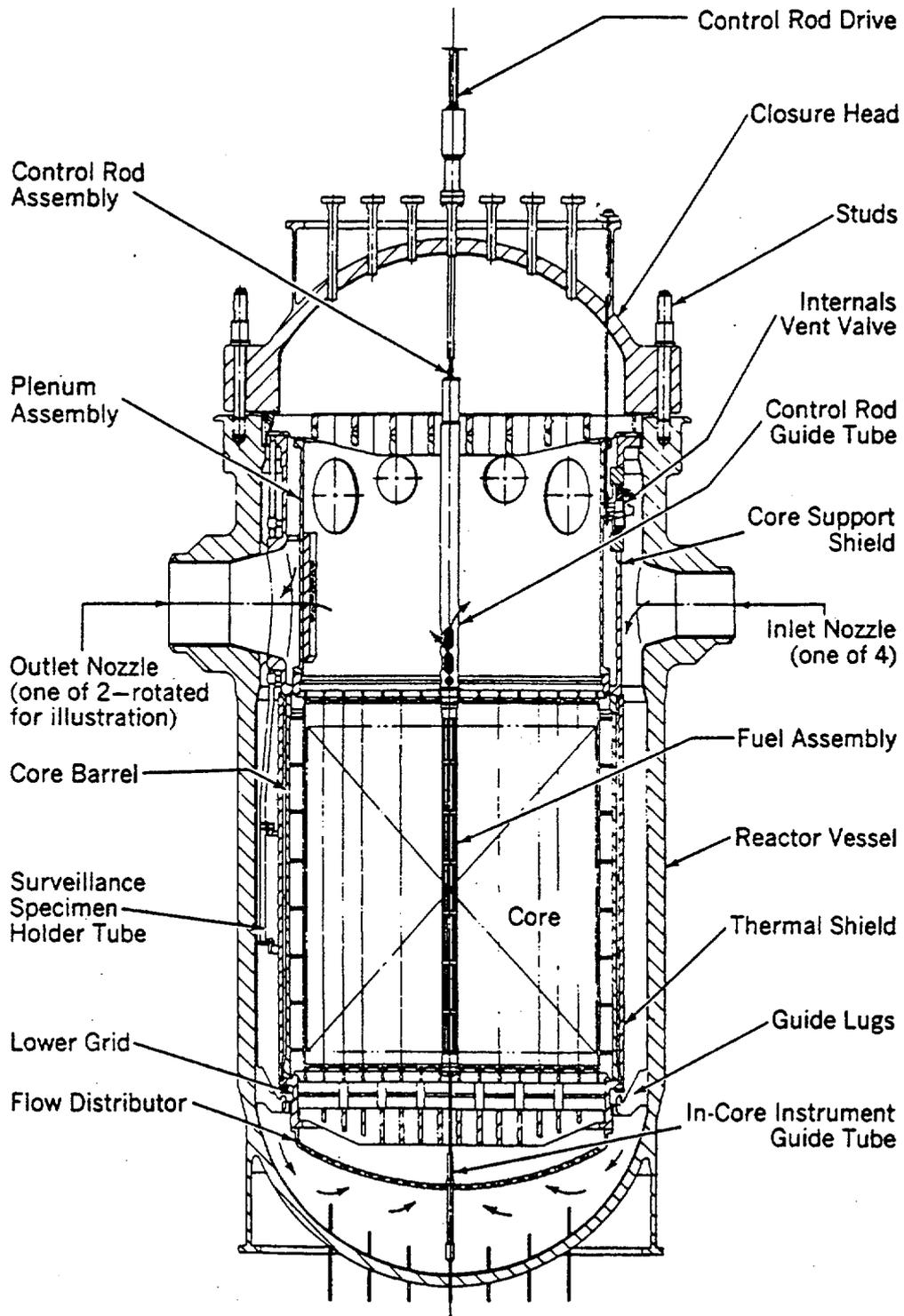
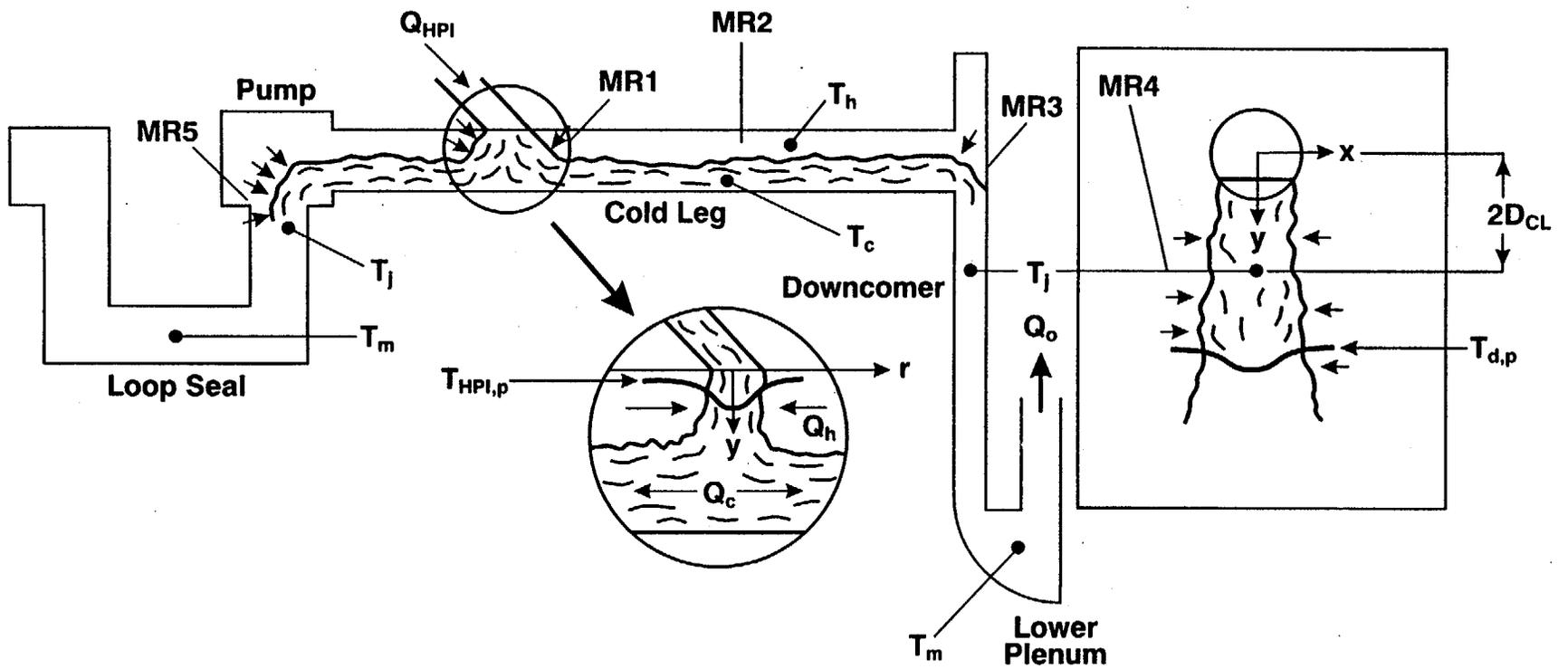


Figure 2.2 Detail of Oconee-1 PWR vessel.



Conceptual definition of flow regime and the regional mixing model.

## **The IPTS Study**

- A research program was initiated to develop the technical basis for a pressurized thermal shock rule and to aid in the development of guidance for plant-specific analyses, as well as acceptance criteria for proposed corrective actions.
- The objectives were to:
  1. Provide an estimate of the probability of a crack propagating through the wall of the reactor vessel due to PTS;
  2. Determine the dominant overcooling transients, including effects of plant features and operator actions; and
  3. Determine the effectiveness of potential corrective measures.

## **The IPTS Study (cont'd)**

- Three PWRs were selected for analysis, one from each vendor:
  1. Oconee Unit 1 (Babcock and Wilcox);
  2. Calvert Cliffs Unit 1 (Combustion Engineering); and
  3. H.B. Robinson Unit 2 (Westinghouse).
- The research became known as the Integrated Pressurized Thermal Shock (IPTS) study.
- The results were published in 1985

## **Current Regulatory Basis for PTS**

- 10 CFR 50.61, "Fracture Toughness Requirements for Protection against Pressurized Thermal Shock Events"
- Regulatory Guide 1.154, "Format and Content of Plant-Specific Pressurized Thermal Shock Safety Analysis Reports for Pressurized Water Reactors."

## **Objective of Current Thermal Hydraulic Reevaluation Effort**

- To ensure that for the risk significant classes of events, the thermal hydraulic inputs, developed at the time of the IPTS study, are still operative; or  
are otherwise corrected and updated as needed.
- Additionally, to provide an estimate of the uncertainty of these values.

## **Thermal Hydraulic Plan**

- To support this effort, the former IPTS study results obtained in the 1983-85 time frame are reviewed to determine their continued applicability. The cases that need to be updated will be recalculated.
- Industry input is utilized to ensure that the basis for the IPTS analysis in terms of plant design, control systems, and operator procedures is correct, or is otherwise updated as necessary.
- Information on loop flow stagnation will be updated to reflect current understanding. The Oregon State University APEX facility will be used to generate PTS-specific experimental data.

## Thermal Hydraulics Input to Fracture Mechanics

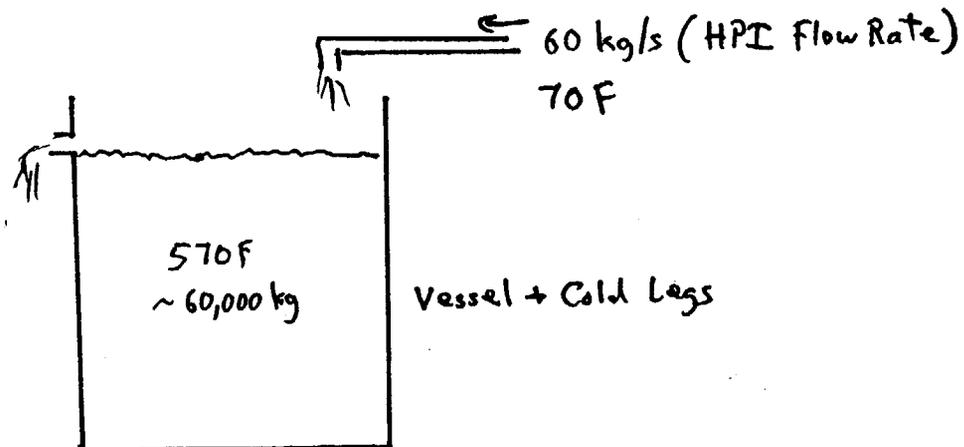
- As a function of time;
  1. System Pressure (P)
  2. Downcomer Temperature (T) (adjacent to the core)
  3. Fluid-to-Wall Convective Heat Transfer Coefficient (h)
- Uncertainty estimates for the three parameters
- P, T, and h are not independent parameters, however, their interdependence varies as a function of time during a transient.
- System pressure is generally calculated reasonable well from TRAC or RELAP.
- Downcomer temperature can also be calculated reasonably well, either using TRAC and RELAP or REMIX. Plumes are expected to have dissipated (mixed) before reaching the beltline region, based on experimental data, leaving only an axial temperature gradient (evidence must be compiled in a convincing manner).
- Over the region of interest, sensitivity of vessel fracture probability to variations in h has been shown to be small (NUREG-1667)

## Characteristic Time Scales

- Two characteristic times are important
  1. Vessel fluid cooldown rate
  2. Vessel wall cooldown rate

## Vessel Fluid Cooldown Rate

- Typical example for a mixing volume of vessel and cold legs = 70 m<sup>3</sup> and high pressure injection rate of 60 kg/s.



- To cooldown from initial conditions of 570F to 300F (the first PTS screening criteria) takes ~15 minutes (900 s)

## Vessel Wall Cooldown Rate and Effects

- Three cases will be shown for three cooldown and depressurization rates
  1. Constant rate cooldown from 550F to 150F and depressurization from 1000 psi to 600 psi over 20 minute time period
  2. Constant rate cooldown from 550F to 150F and depressurization from 1000 psi to 600 psi over 40 minute time period
  3. Constant rate cooldown from 550F to 150F and depressurization from 1000 psi to 600 psi over 60 minute time period

- For each case,

Figure 1 shows coolant temperature-time history

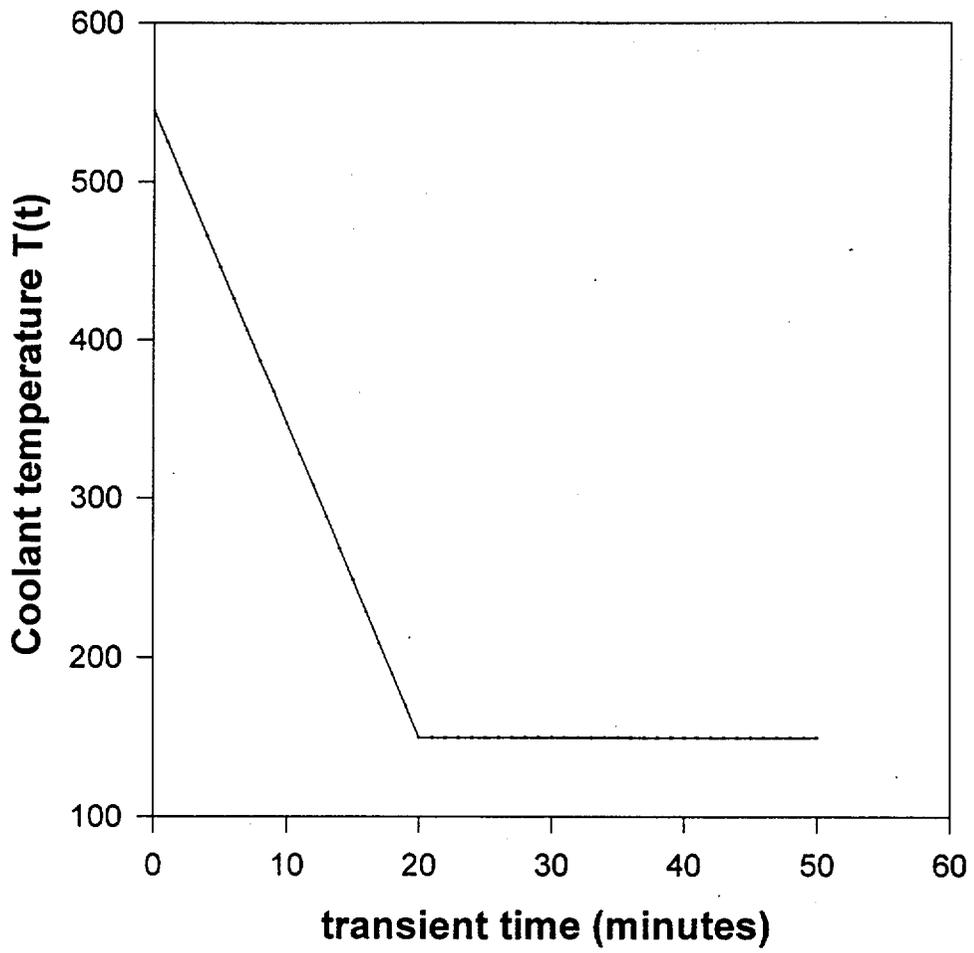
Figure 2 shows pressure-time history

Figure 3 shows time history of hoop stress, including residual stress.

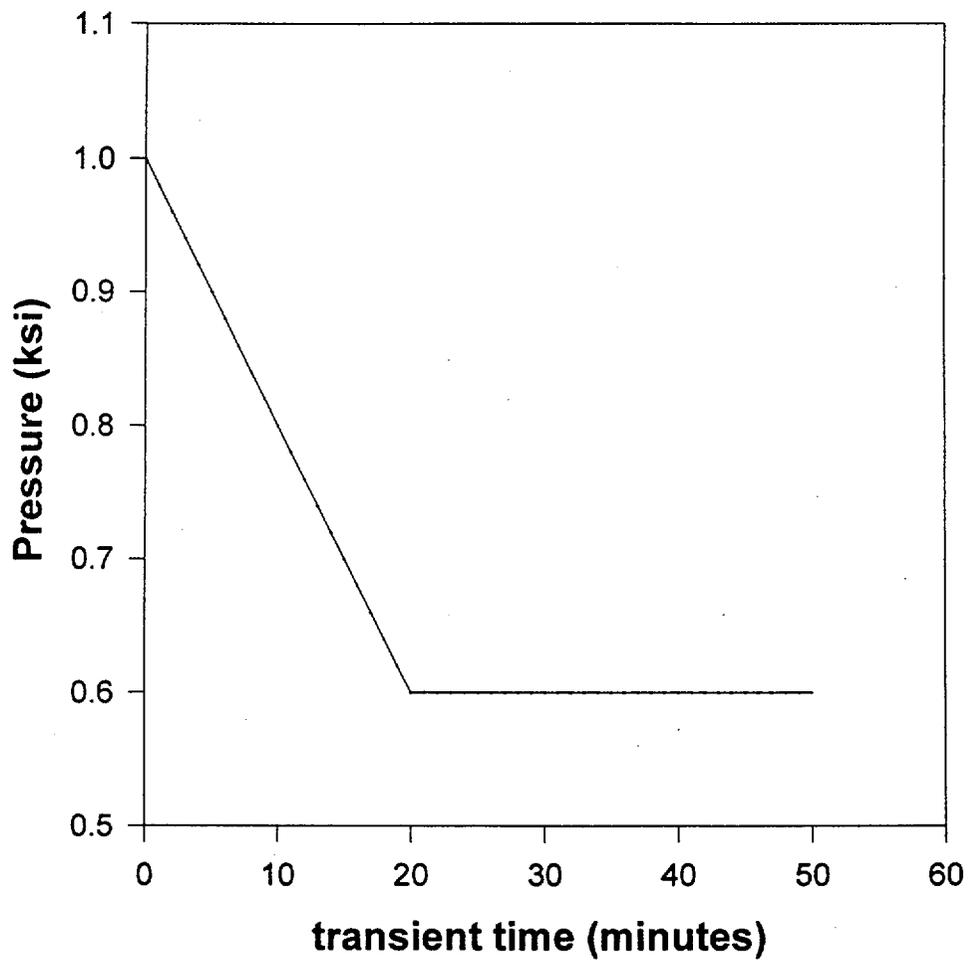
Figure 4 shows through wall temperature distribution at various transient times.

Figure 5 shows through wall total hoop stress distribution at various transient times.

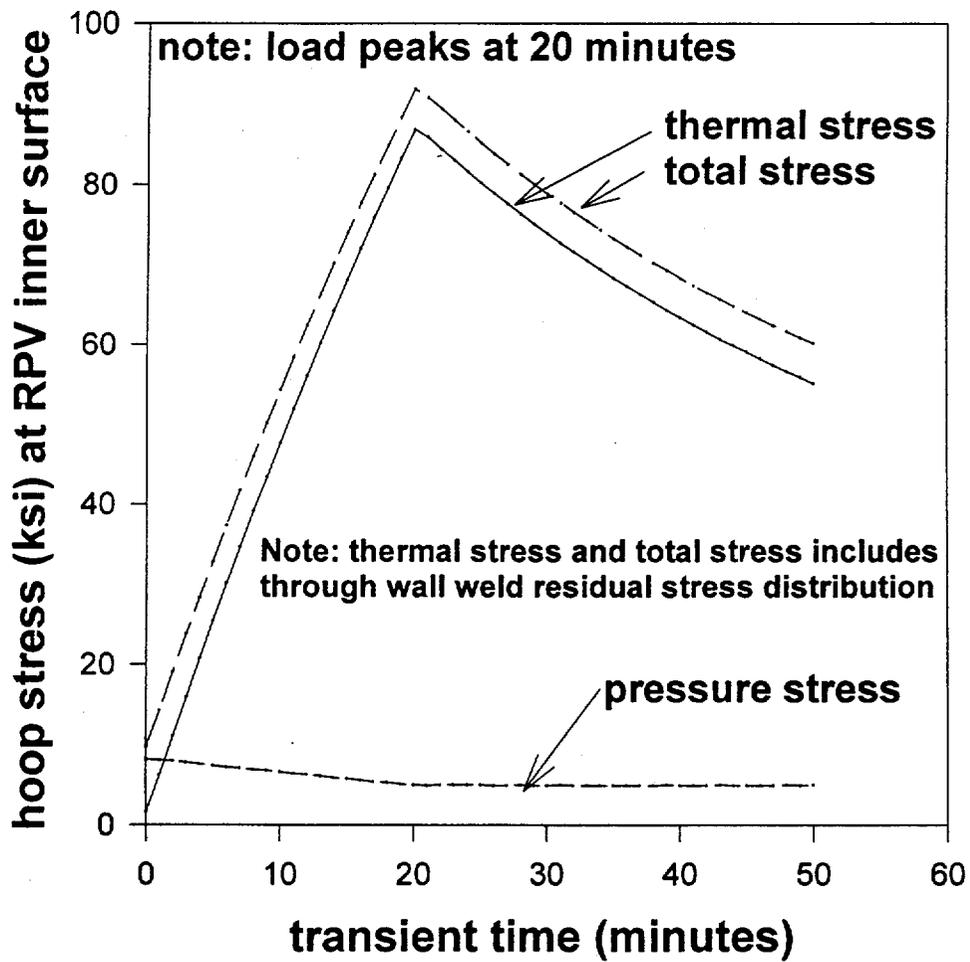
Figure 6 shows the K-ratio ( $K_I / K_{Ic}$ ) for three embedded flaw depths.



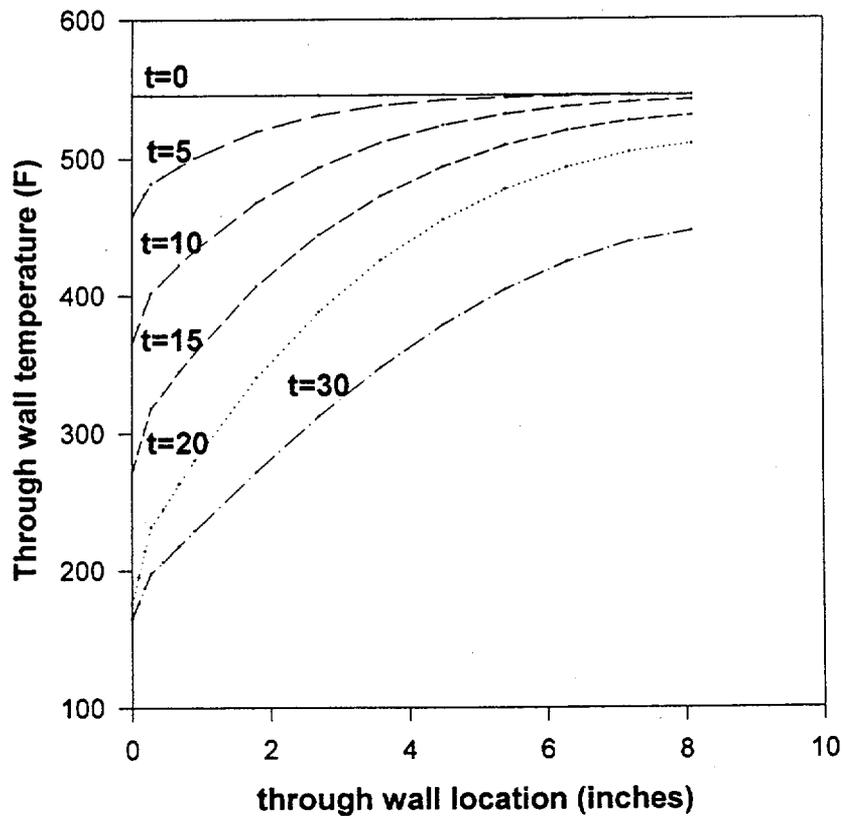
**Figure 1 - Thermal transient for case 1**



**Figure 2 - Pressure transient**



**Figure 3 - Circumferential (hoop) stress**



**Figure 4 - through wall temperature at various transient times**

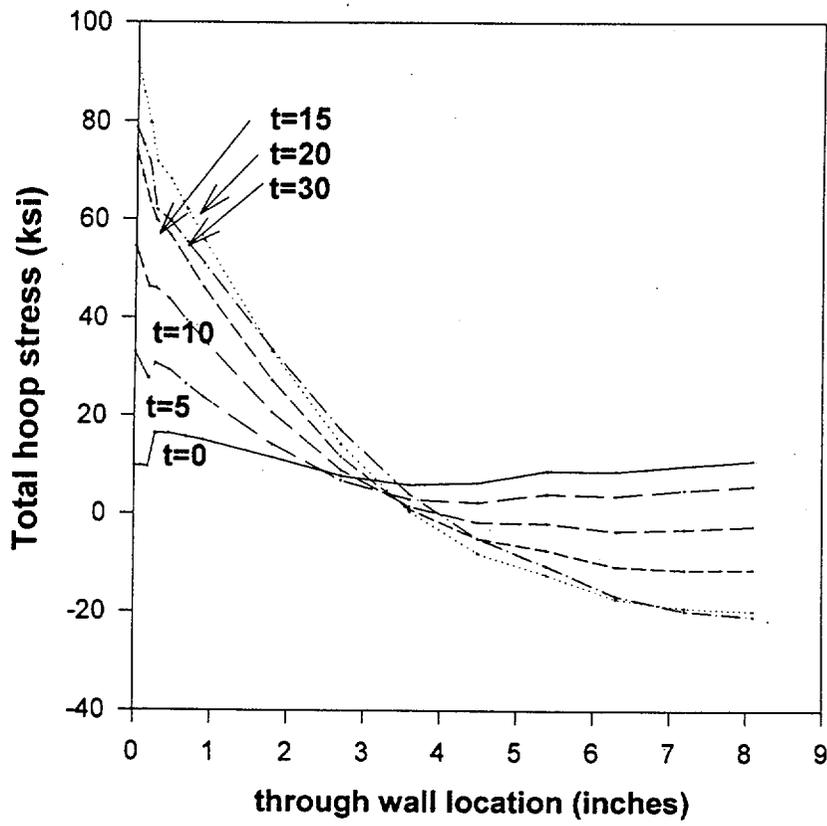


Figure 5 - through wall hoop stress at various transient times

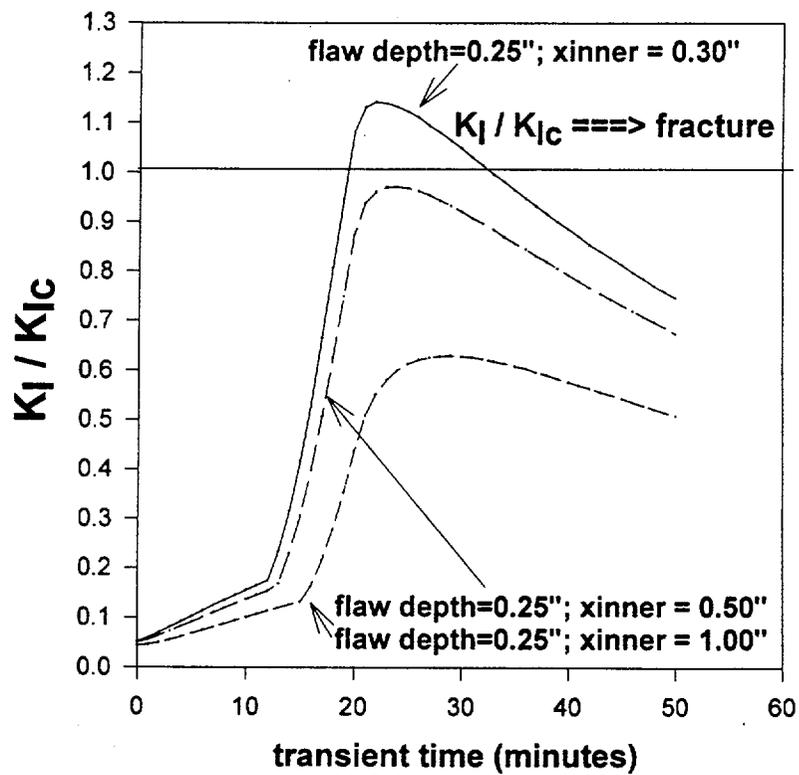
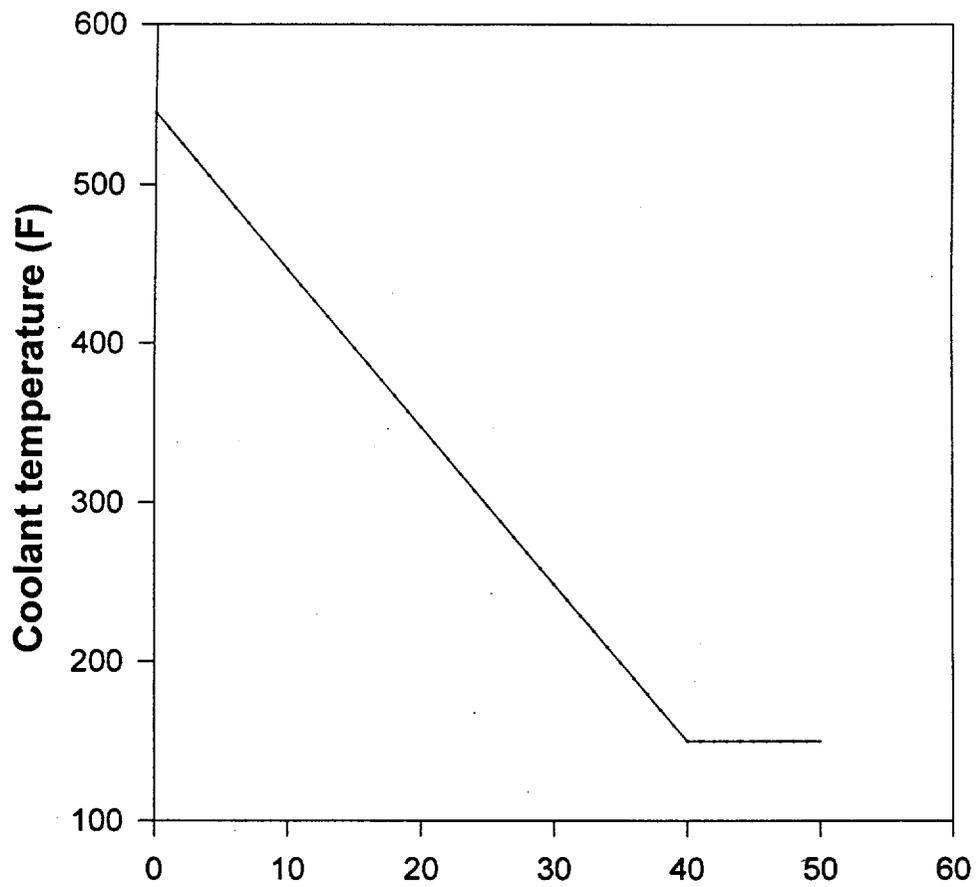
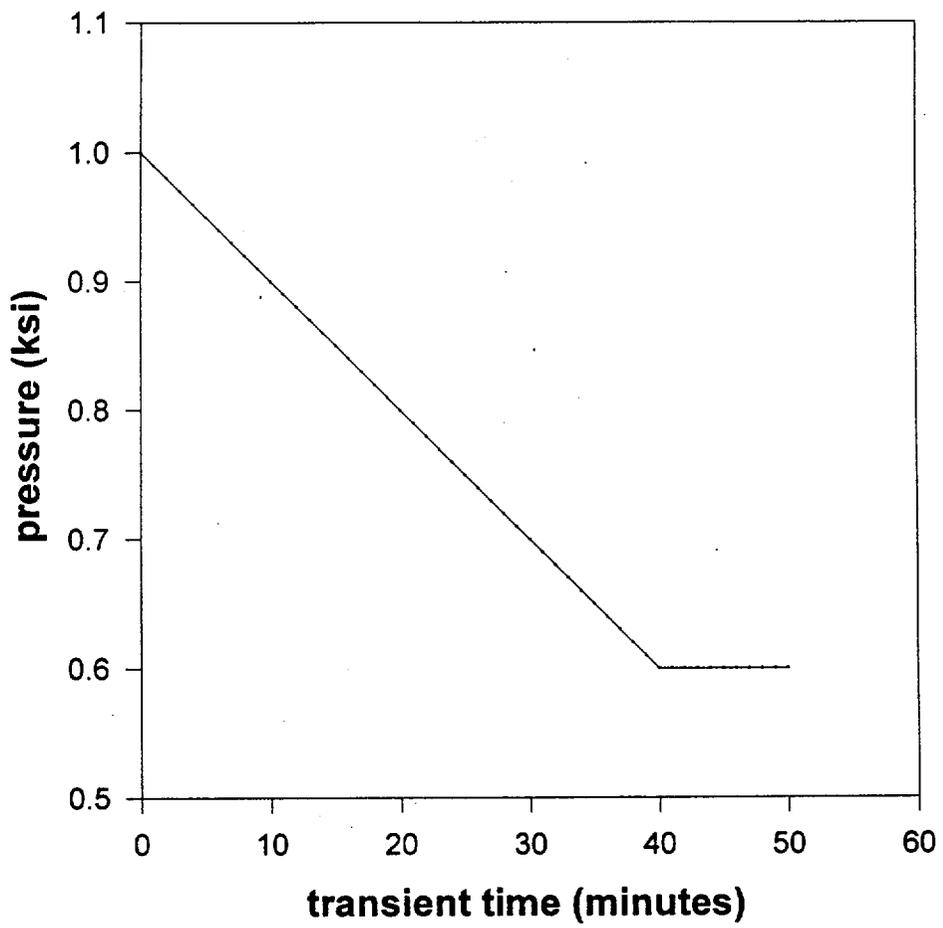


Figure 6: Kratio ( $K_I / K_{Ic}$ ) for various embedded flaw geometries evaluated at  $RT_{NDT_s} = 270$  F (PTS screening criteria for axial welds / plates)



**Figure 1 - Case 2 thermal transient**



**Figure 2 - Case 2 pressure transient**

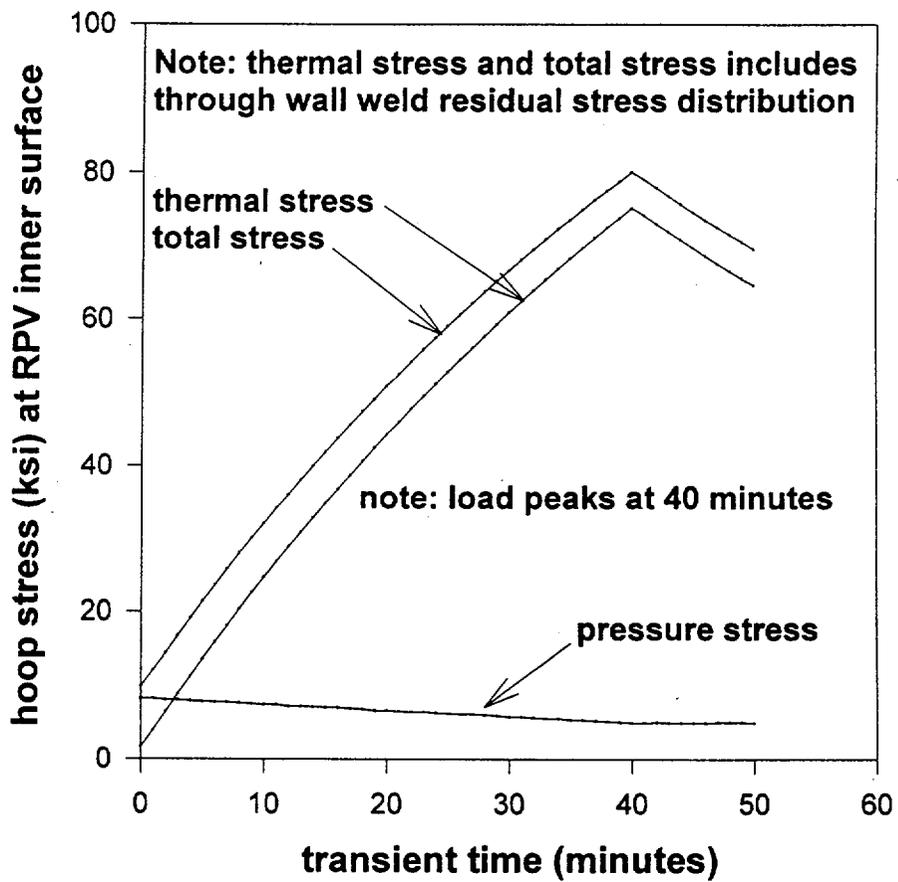


Figure 3 - Case 2 circumferential (hoop) stress

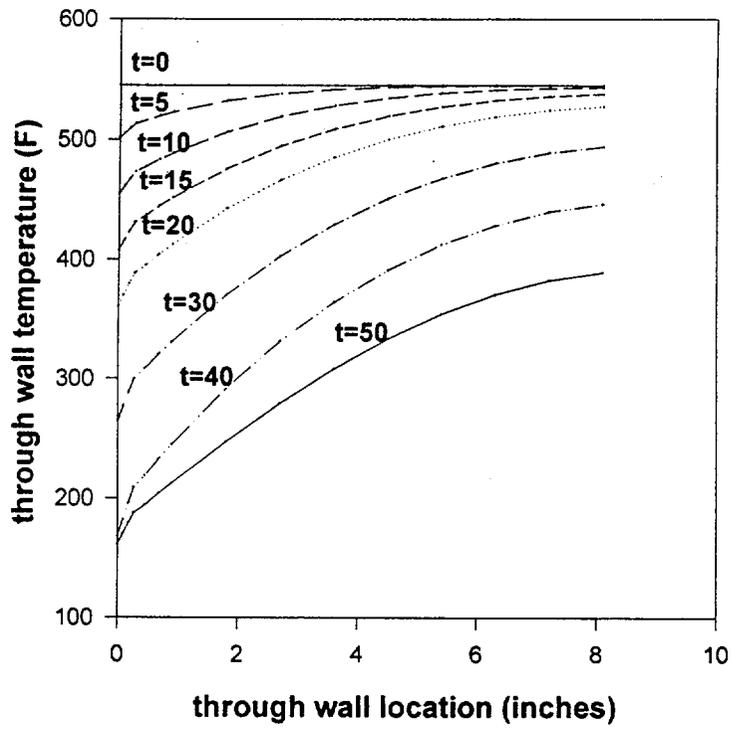


Figure 4 - Case 2 through wall temperature at various transient times

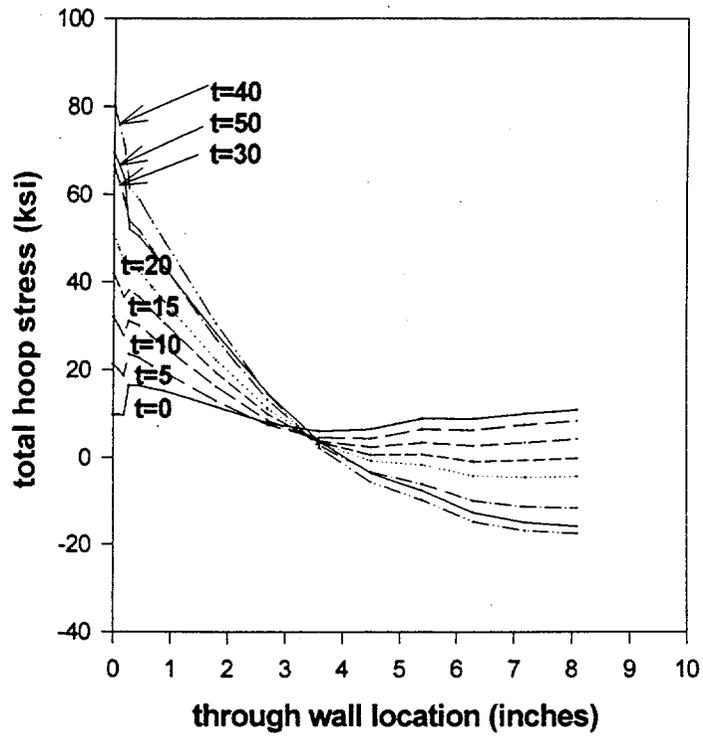


Figure 5 - Case 2 through wall hoop stress at various transient times

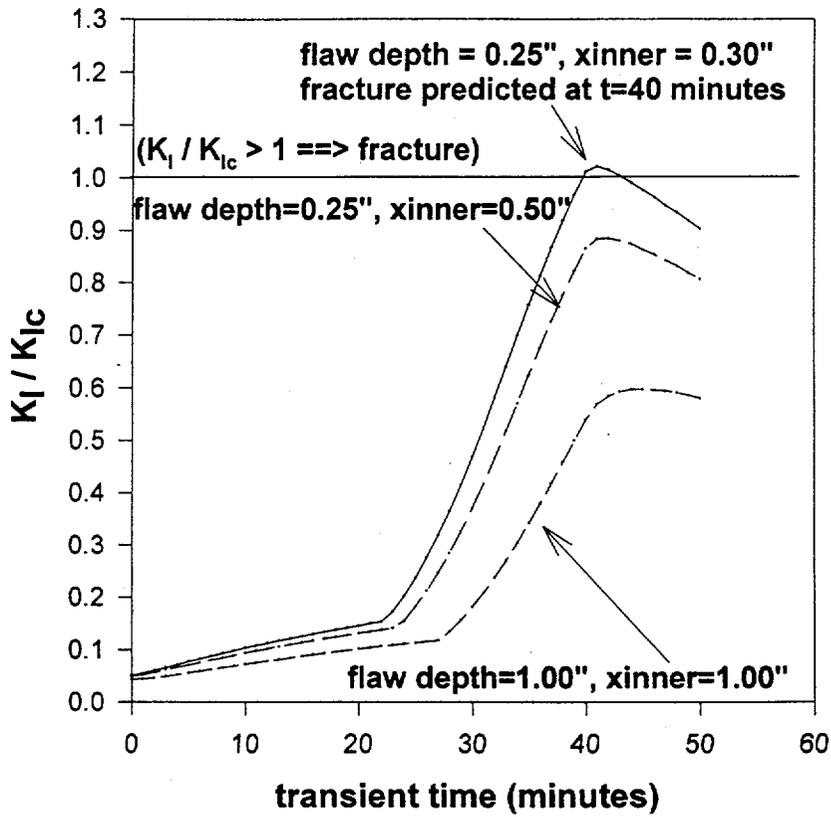
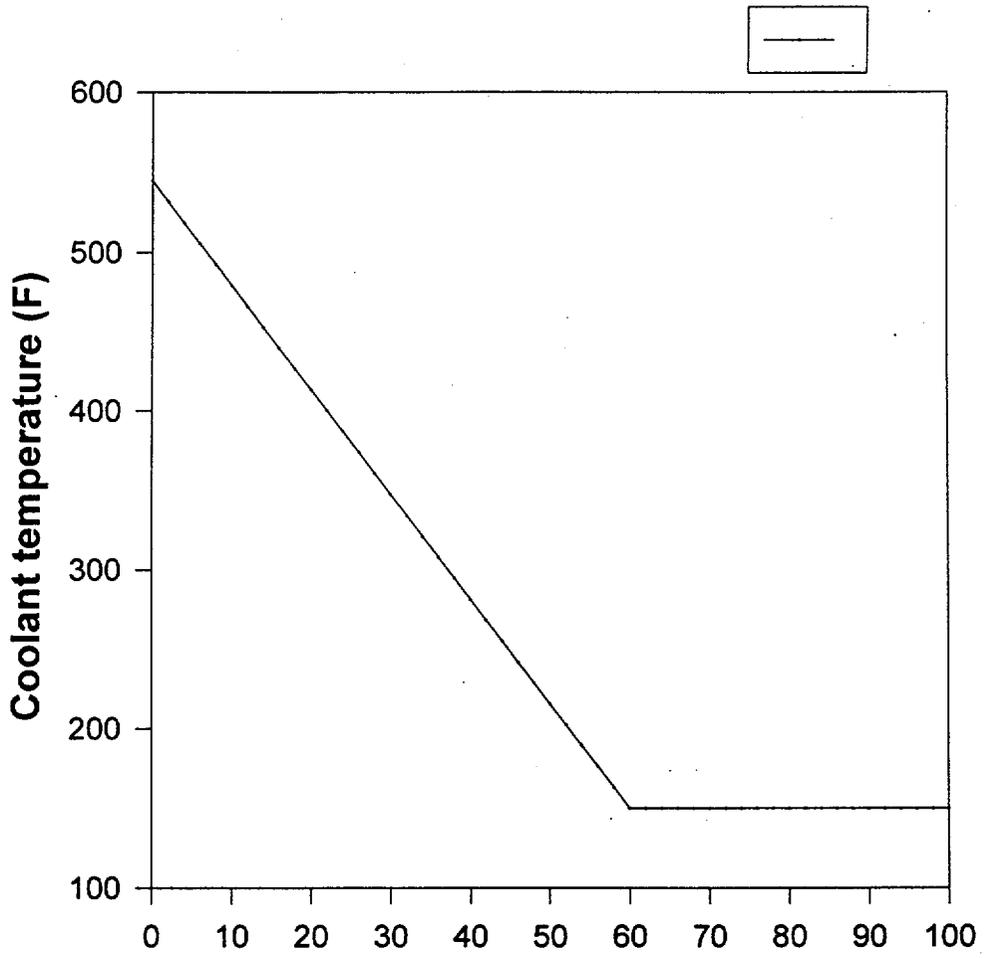
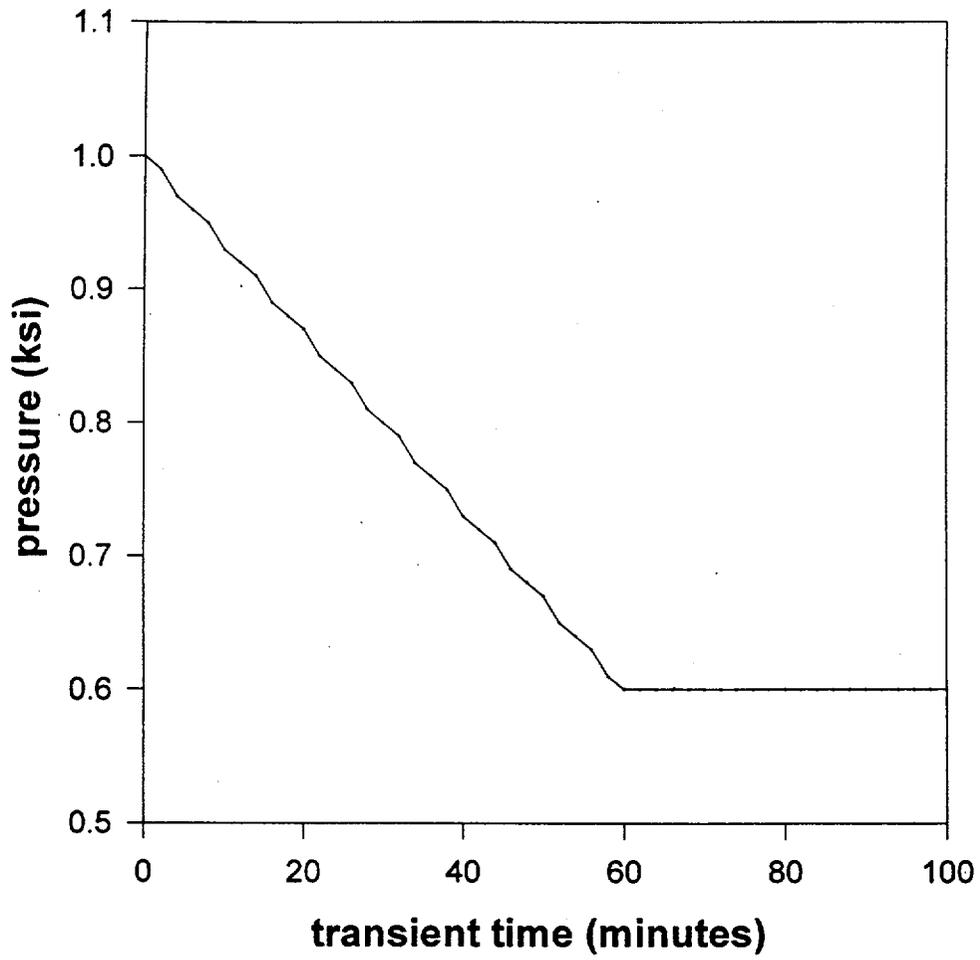


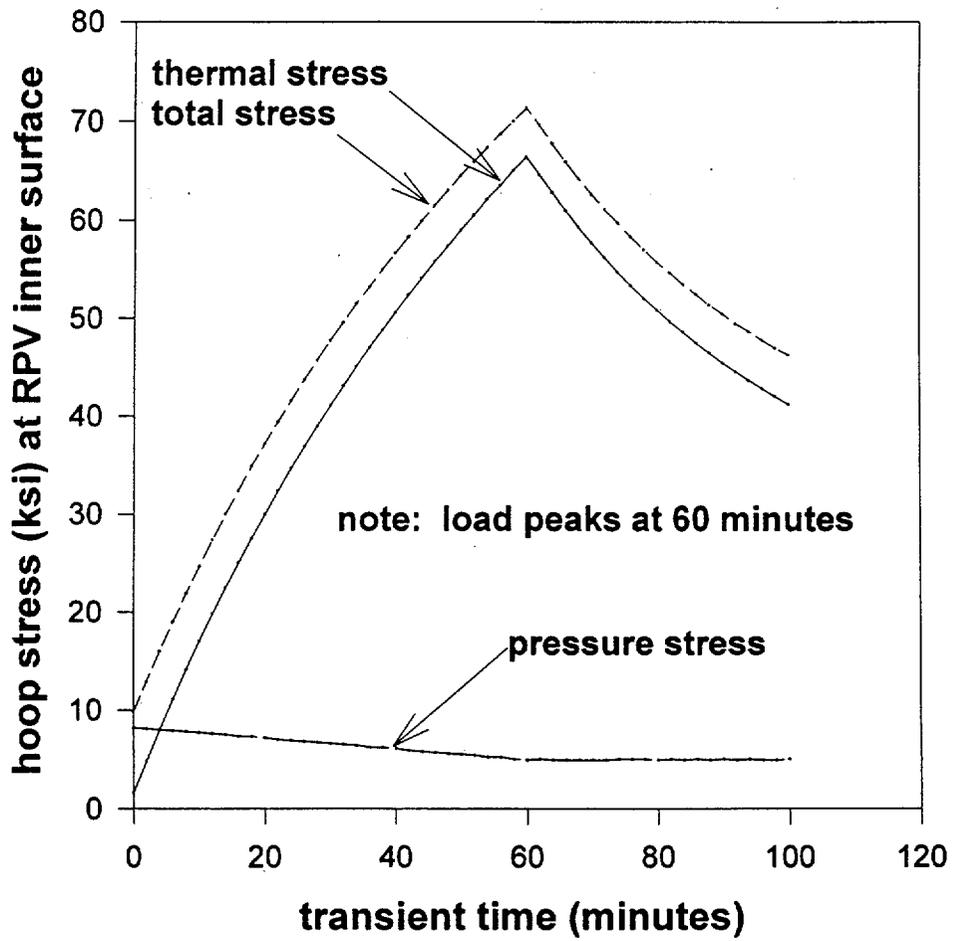
Figure 6 - Case 2 Kratio ( $K_I / K_{Ic}$ ) for various embedded flaw geometries evaluated at  $RT_{NDT_s} = 270$  F (PTS screening criteria for axial welds / plate )



**Figure 1 - Case 3 thermal transient**



**Figure 2 - Case 3 pressure transient**



**Figure 3 - transient 3 circumferential (hoop) stress**

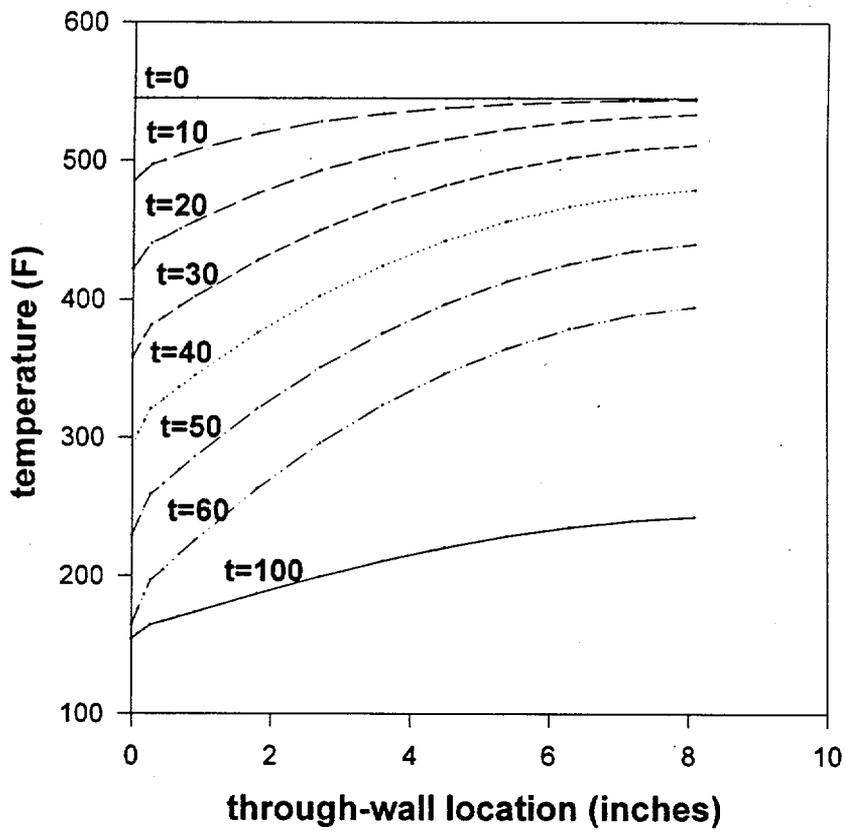


Figure 4 - Case 3 through wall temperature at various transient times

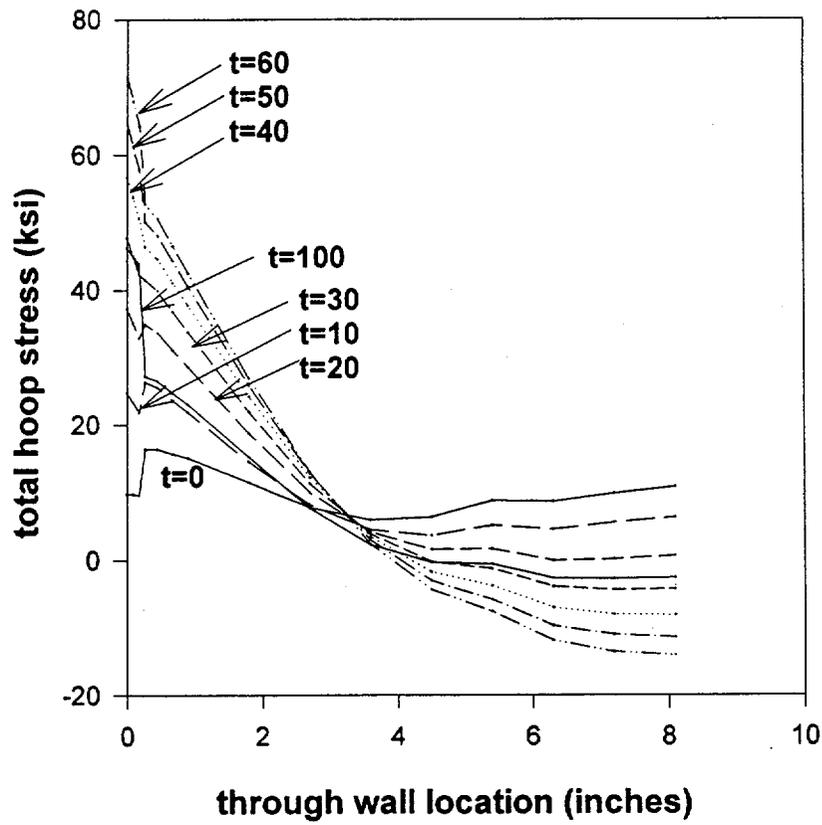


Figure 5 - Case 3 through wall hoop stress at various locations

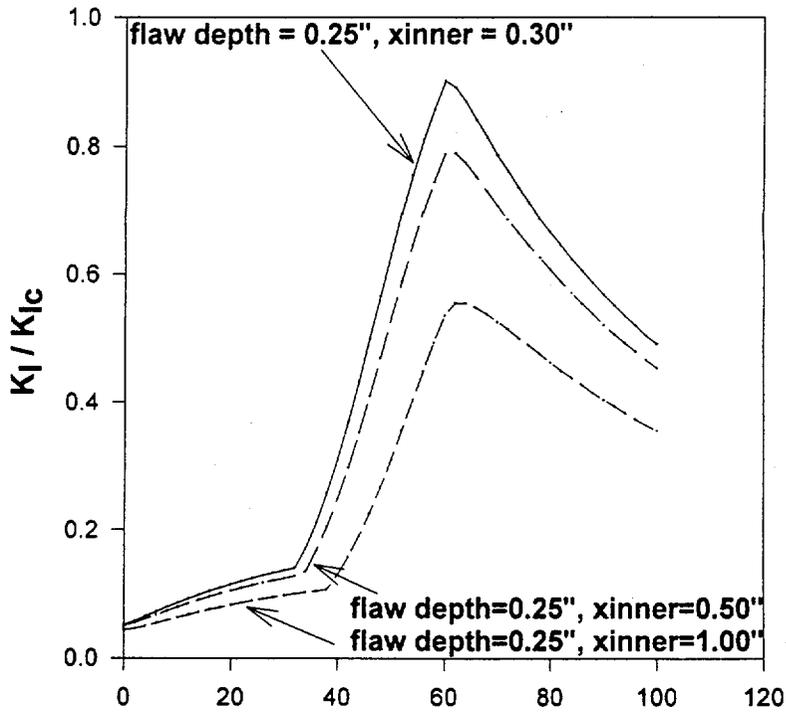


Figure 6 - Case 3 K ratio ( $K_I / K_{Ic}$ ) for various embedded flaw geometries evaluated at  $RT_{NDT_s} = 270$  F (PTS screening criteria for axial weld/plate)

## **Important PTS Phenomena**

- Three PIRTs have been performed on PTS:
  1. H.B. Robinson,
  2. Yankee Rowe,
  3. REMIX

## H.B. Robinson PIRT

- The PIRT panel consisted of

|                       |                                       |
|-----------------------|---------------------------------------|
| Cliff Davis           | Idaho National Engineering Laboratory |
| Prof. Marino di Marzo | University of Maryland                |
| Prof. Peter Griffith  | Massachusetts Institute of Technology |
| Prof. Yassin Hassan   | Texas A&M University                  |
| Prof. Barkclay Jones  | University of Illinois                |

- The PIRT considered four transients
  1. Main steam line break from hot standby;
  2. Steam generator overfeed with the initiating transient being a turbine trip from full power with delayed initiation of auxiliary feedwater,
  3. Small (2-inch) cold leg break LOCA; and
  4. Small (2-inch) hot leg break LOCA.
- The key parameters were downcomer temperature, system pressure, and convective heat transfer coefficient.

## **H.B. Robinson PIRT (cont'd)**

- The "phenomena" identified were, in rank order for the 10 highest ranked were
  1. Accumulator injection flow rate
  2. Vessel wall heat conduction (three dimensional)
  3. HPI injection flow rate
  4. Flow distribution in downcomer (plume mixing and global downcomer flows)
  5. Accumulator liquid temperature
  6. Break flow
  7. HPI injection temperature
  8. Mixing of HPI jet as it enters the cold leg and mixing of stratified cold leg flow as it enters the downcomer
  9. Decay heat
  10. Convective heat transfer in downcomer

## Yankee Rowe PIRT

- The PIRT panel consisted of

Gerald Lellouche

Prof. Marino di Marzo      University of Maryland

Prof. Peter Griffith      Massachusetts Institute of Technology

Prof. Ray Viskanta      Purdue University

Prof. Sy Ostrach      Case Western Reserve

- The PIRT transients considered a small (1.3-inch) cold leg break LOCA and a main steam line break
- The key parameters were downcomer temperature, pressure, and convective heat transfer coefficient.

## Yankee Rowe PIRT (cont'd)

- The "phenomena" identified for the small cold leg break were, in rank order for the 10 highest:
  1. Mixing of HPI jet as it enters the cold leg and mixing of stratified cold leg flow as it enters the downcomer
  2. Injection temperature and flow rate
  3. Break flow
  4. Global flow distribution in downcomer
  5. Plume mixing in downcomer
  6. Stratification and mixing in the cold legs
  7. Decay heat
  8. Convective wall heat transfer to the vessel
  9. Bypass flow between upper plenum and downcomer
  10. Vessel wall heat conduction

## REMIX PIRT

- Nourbakhsh (NUREG/CR-6658 draft)
- Pertains to period following onset of loop flow stagnation
- Phenomena ranked high (no further rank order) were
  1. Stratification and mixing in cold legs, pump, and loop seals
  2. Mixing of the HPI jet at the injection location
  3. Mixing at the junction of the cold leg and downcomer
  4. Plume mixing and dispersion
  5. Stored energy in structures
  6. Convective heat transfer to the vessel
- Phenomena ranked medium were
  1. Backflow of hot fluid from the upper downcomer to the cold legs

**Table 5.1 Comparison of the world PTS thermal mixing facilities**

| Facility<br>(Country) | Organization/Sponsor   | Scale       | Downcomer<br>Geometry | No. of<br>Cold<br>Legs | HPI<br>Location<br>(Orientation) | Loop<br>Flow |
|-----------------------|--|-------------|-----------------------|------------------------|----------------------------------|--------------|
| CREARE<br>(USA)       | CREARE, Inc./EPRI  | 1/5         | Planar                | 1                      | Top<br>(60° & 90°)               | Yes          |
| Japanese              | Mitsubishi Heavy<br>Industries, Ltd./<br>Kansai Electric Co., Inc. | 1/3         | Planar                | 1                      | Top<br>(45° & 90°)               | Yes          |
| IVO<br>(Finland)      | Imatran Volma Oy/<br>IVO   | 2/5         | Semiannular           | 3                      | Bottom                           | Yes          |
| IVO<br>(Finland)      | Imatran Volma Oy/<br>U.S. NRC                                      | 2/5         | Semiannular           | 3                      | Top                              |              |
| PURDUE<br>(USA)       | Purdue Univ./<br>U.S. NRC  | ½           | Planar                | 1                      | Top and side                     | No           |
| CREARE<br>(USA)       | CREARE, Inc./<br>U.S. NRC and EPRI                                 | ½           | Planar                | 1                      | Top (90°)                        | No           |
| UCL/TRAC<br>(Belgium) |  | ½           | Planar                | 1                      | Top and<br>downcomer             |              |
| SAI (USA)             | SAI/EPRI   | 1/1         | Planar                | 1                      | Top                              | Yes          |
| HDR<br>(Germany)      | Battelle Institute/BMTF  | 1/4-<br>1/1 | Annular               | 1                      | Top and side                     | Yes          |
| UPTF<br>(Germany)     | KWU/BMTF   | 1/1         | Annular               | 1                      | Top                              |              |

# Experimental Facility Summary

|                       | Creare 1/5                   | IVO 2/5        | Purdue 1/2  | Creare 1/2 | UPTF Full          | HDR Full  |
|-----------------------|------------------------------|----------------|-------------|------------|--------------------|-----------|
| HPI diameter (cm)     | 5.08 or 0.7                  | 2.7            | 10.8        | 11.43      | 15.9               | 5.0       |
| HPI m (kg/s)          | 0.126-0.442                  | 0.36-4.66 *    | 0.71-2.21   | 3.5-5.2    | 5-70               | 0.12-5.56 |
| $Fr_{HPI}$            | 0.22-0.68                    | 0.388-98.23    | 0.22-18     | 0.96-1.42  | 0.58-8.39          | 0.1-7.4   |
| Buoyancy              | solute/thermal               | solute/thermal | solute      | solute     | thermal            | thermal   |
| $\Delta\rho/\rho$     | 0.162-0.02                   | 0.167-0.019    | 0.158-0.088 | 0.122      | 0.119              | 0.08      |
| Stagnant or loop flow | stagnant (MIX4), flow (MIX3) | both           | stagnant    | stagnant   | stagnant           | both      |
| Multi-loop            | no                           | yes            | no          | no         | effectively 1 loop | no        |
| Thermal shield        | yes/yes                      | no             | no          | yes        | no                 | no        |

\*per injector

# Results of Experimental Facility PTS Testing

- Downcomer plumes typically reached ambient temperature by  $\sim 3$  CL diameters below CL
- Westinghouse and CE plants with low  $Fr_{\text{HPI}}$  allow backflow into HPI injection line
- B&W with high  $Fr_{\text{HPI}}$  well mixed in CL
- If RELAP or TRAC predicted loop stagnation then REMIX used to predict downcomer temperatures
- REMIX compared well with 1/5 to full scale data
- Good agreement between solute and thermal experiments

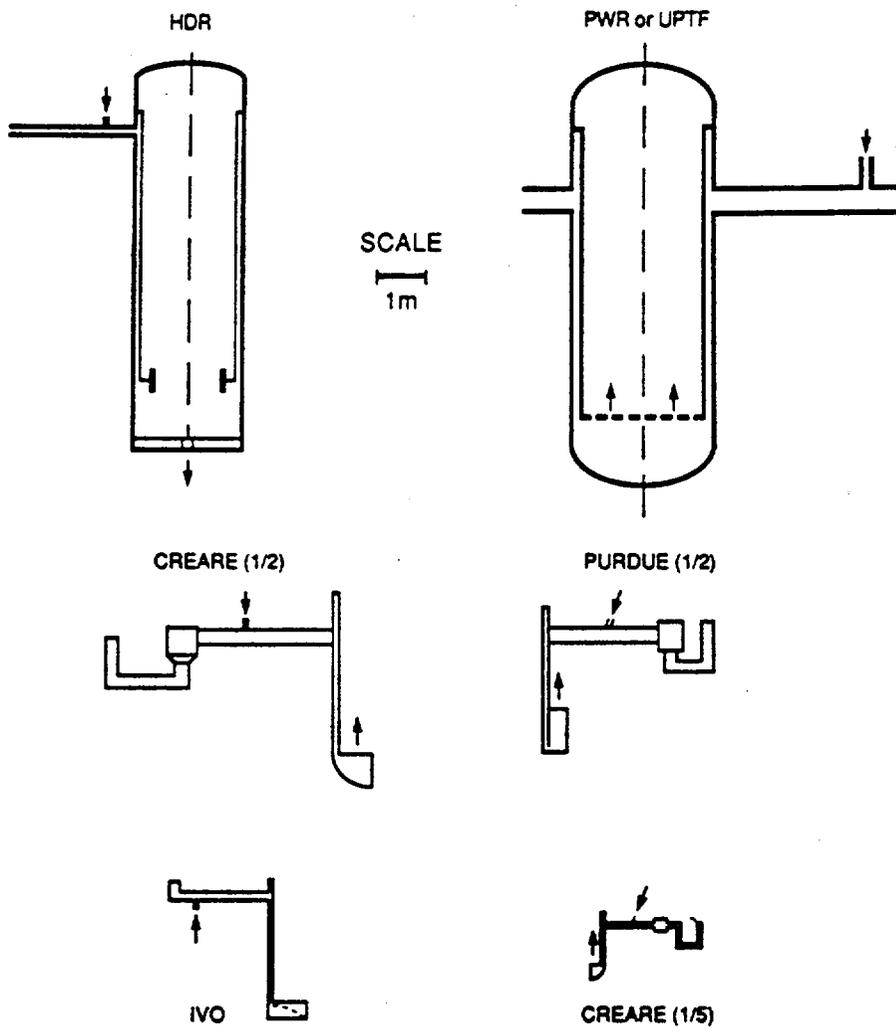


Fig. 2 Relative sizes of various integral test facilities in comparison to full scale commercial PWR.

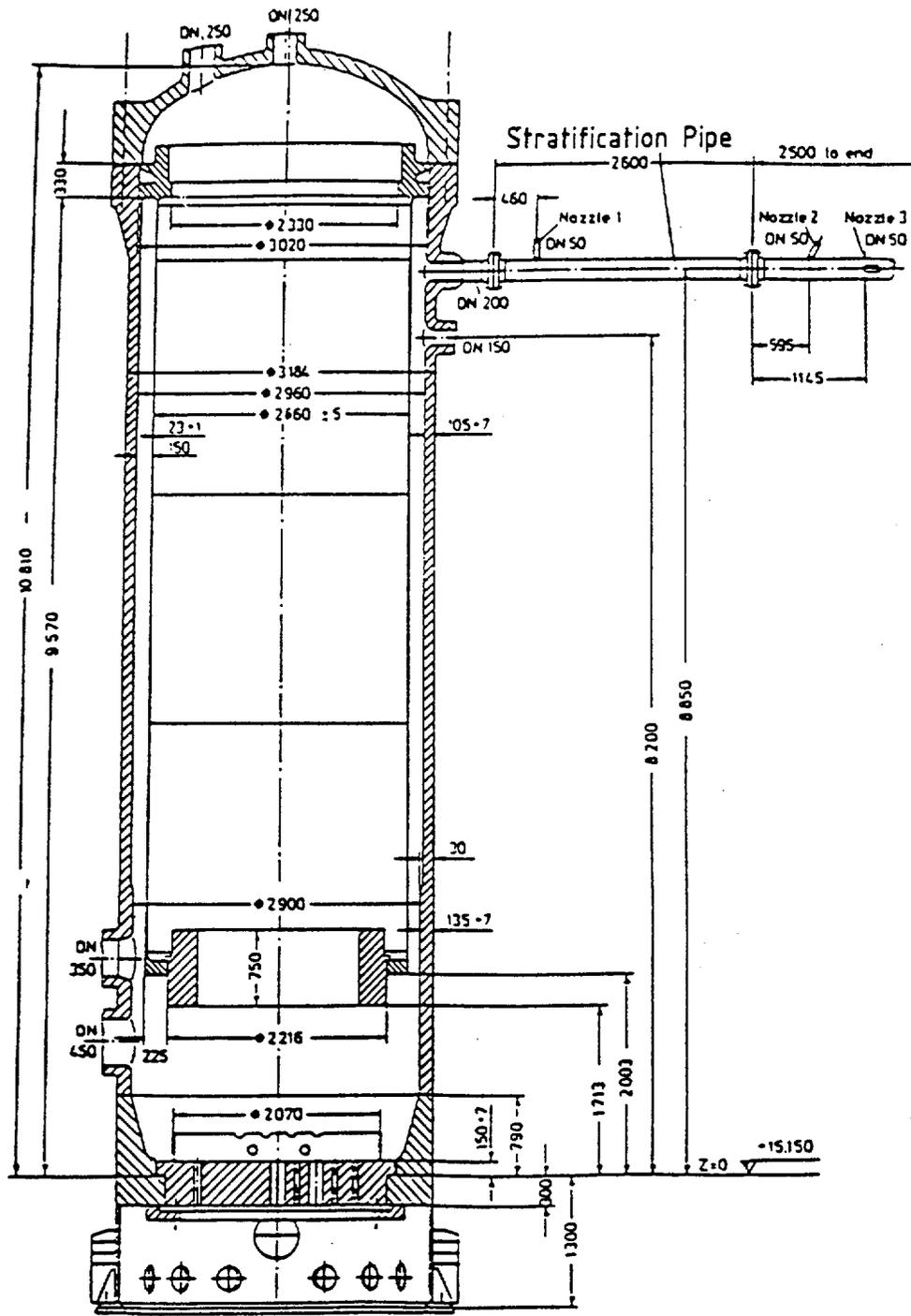


Fig. 1. Cross-section of the HDR-pressure vessel.

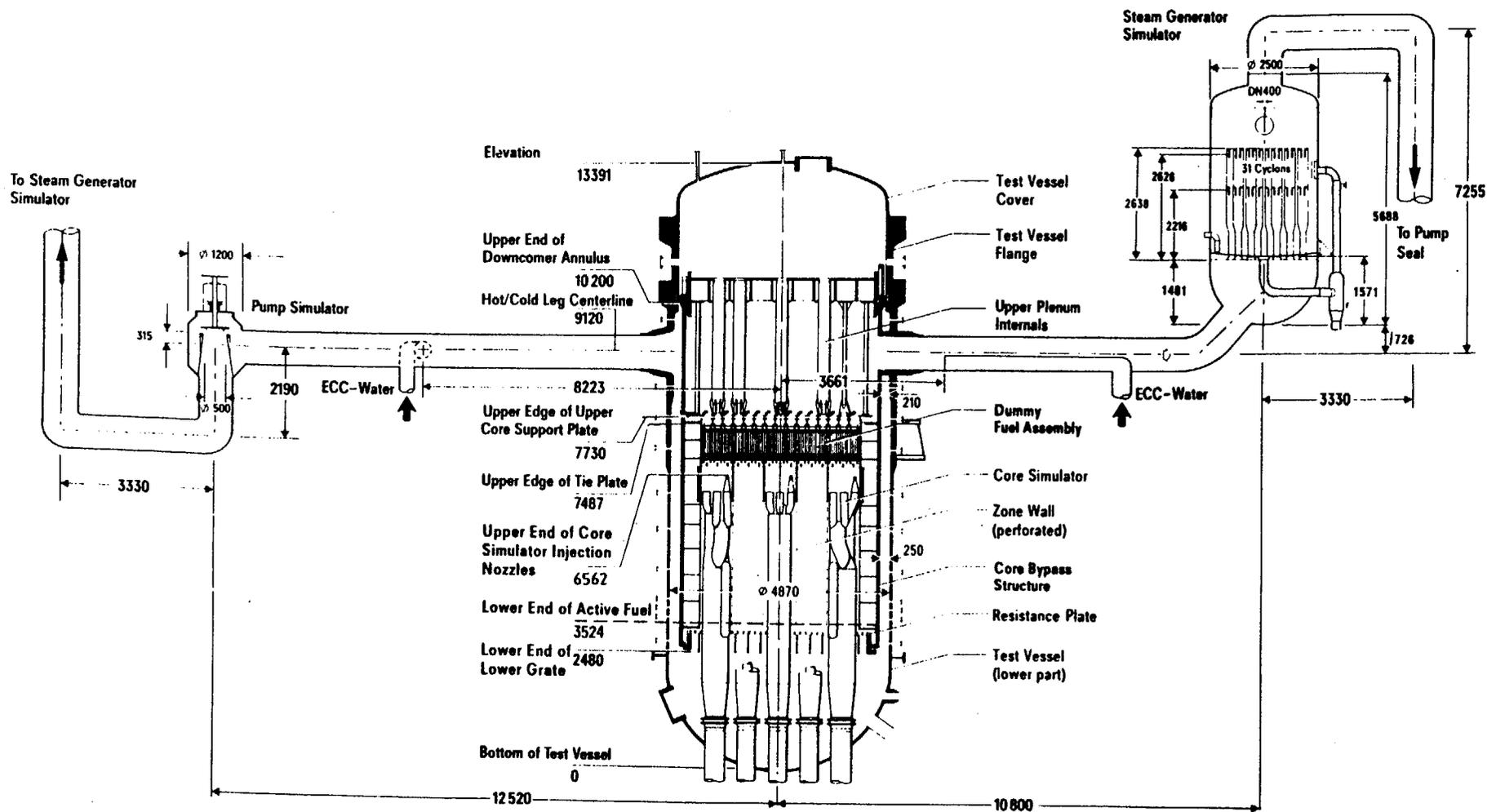


Fig. 3: Major Dimensions of UPTF - Primary System

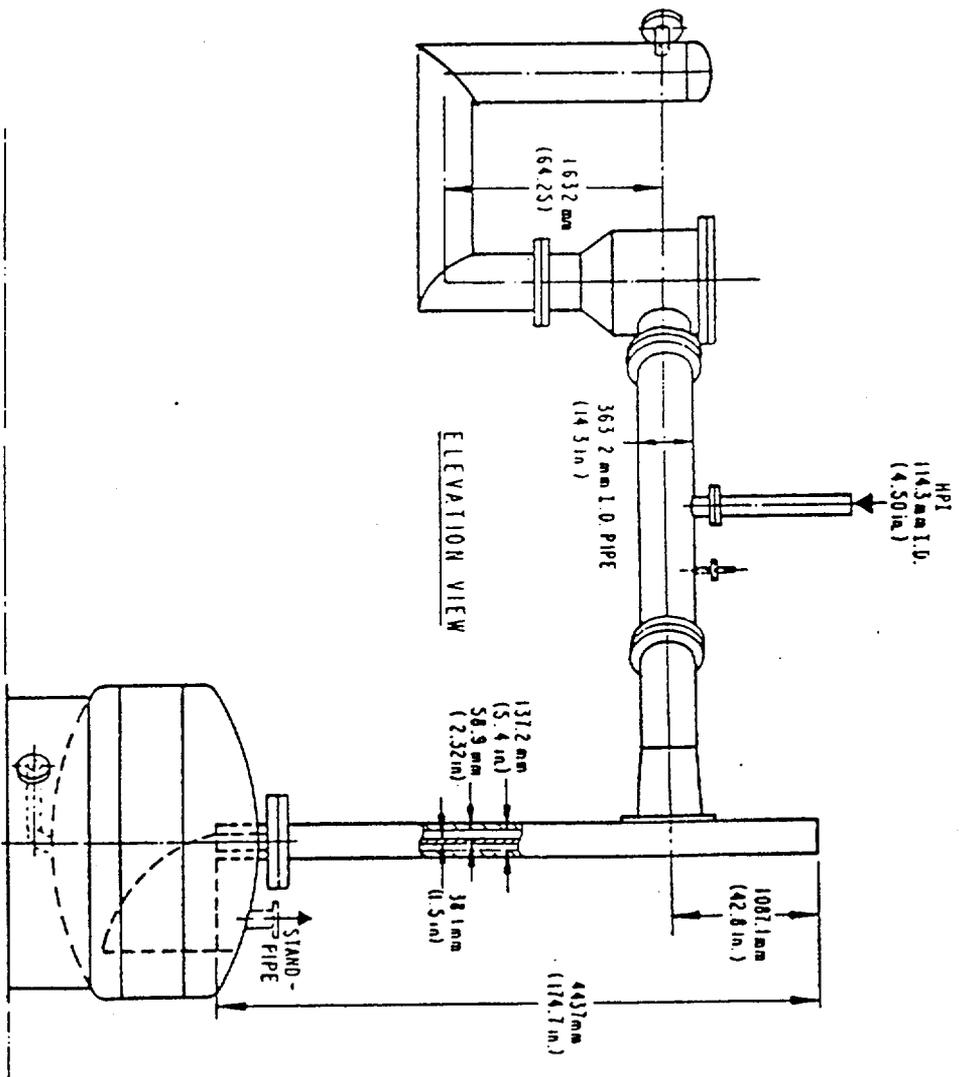


Figure 5.32 Schematic of CREARE 1/2-scale test facility

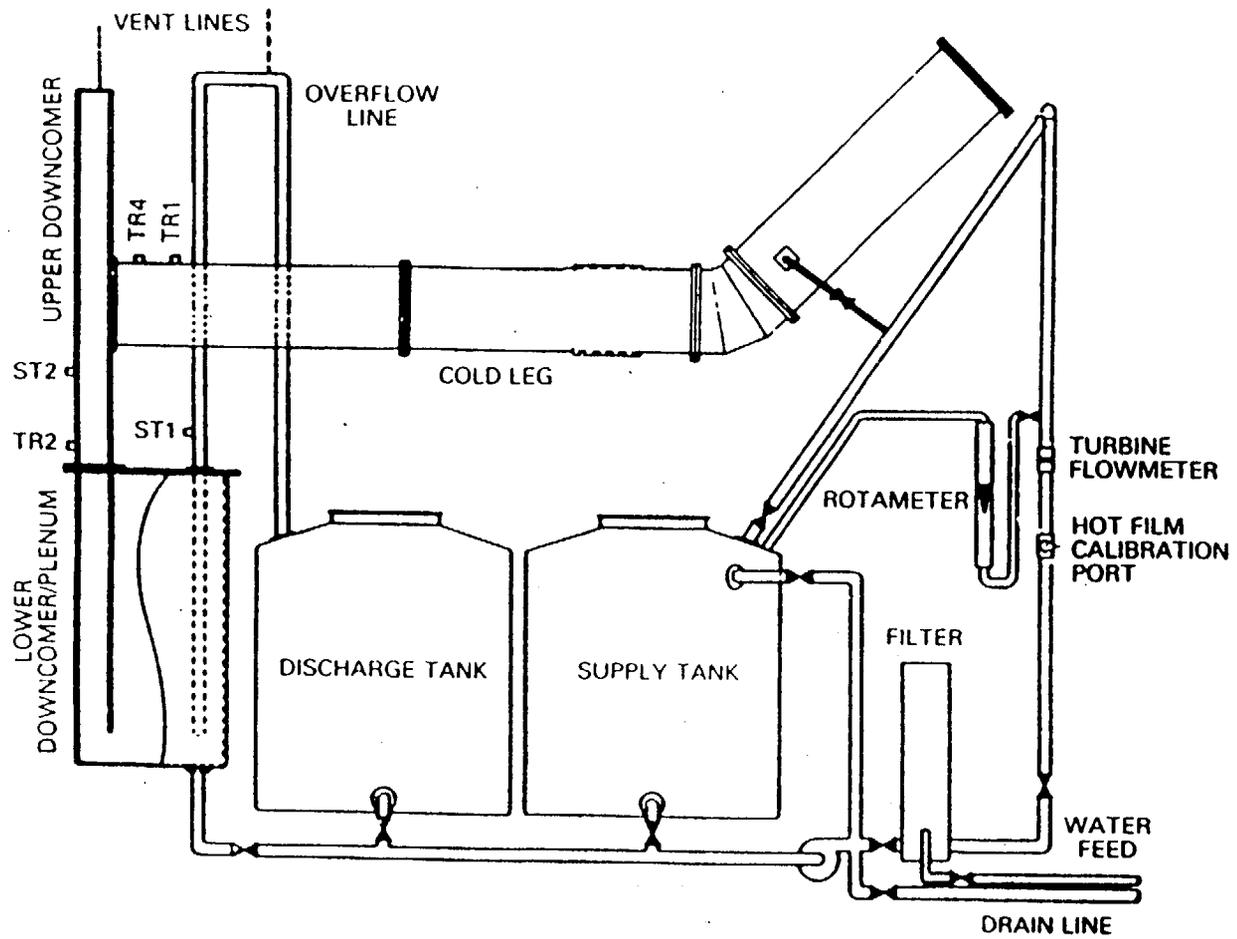
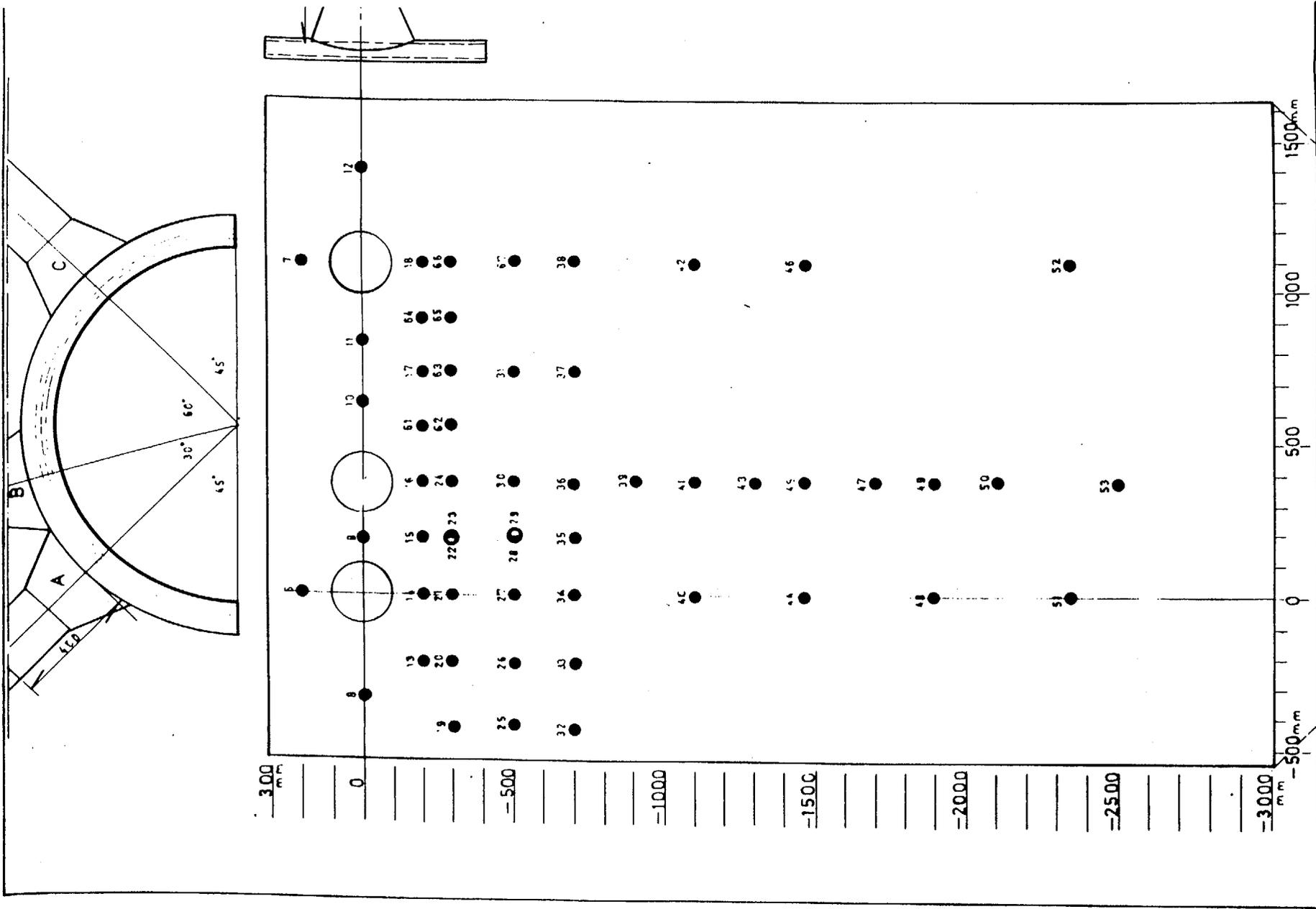
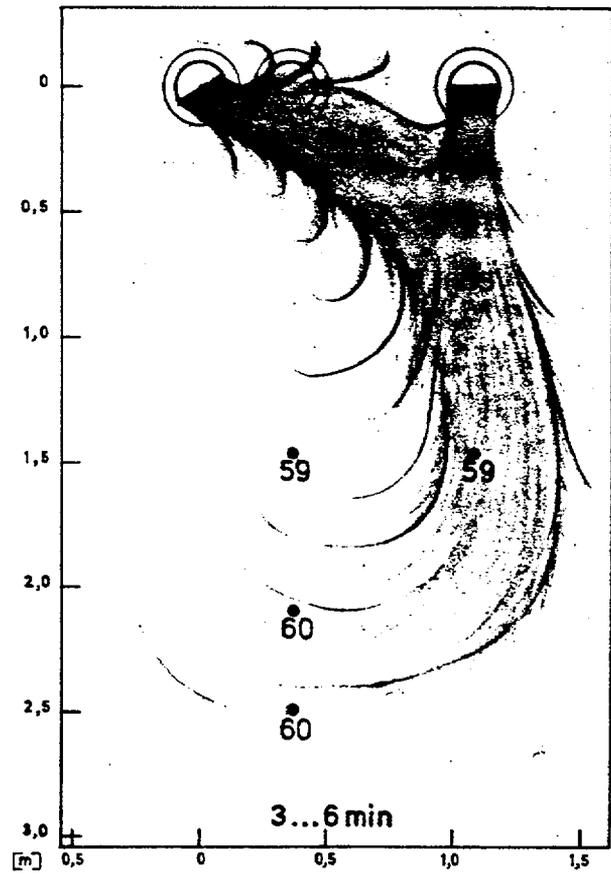
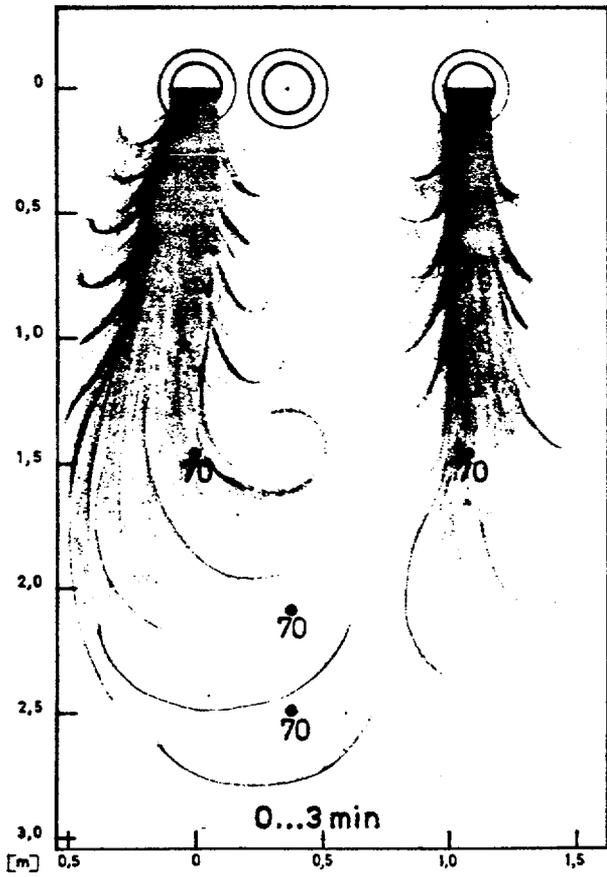
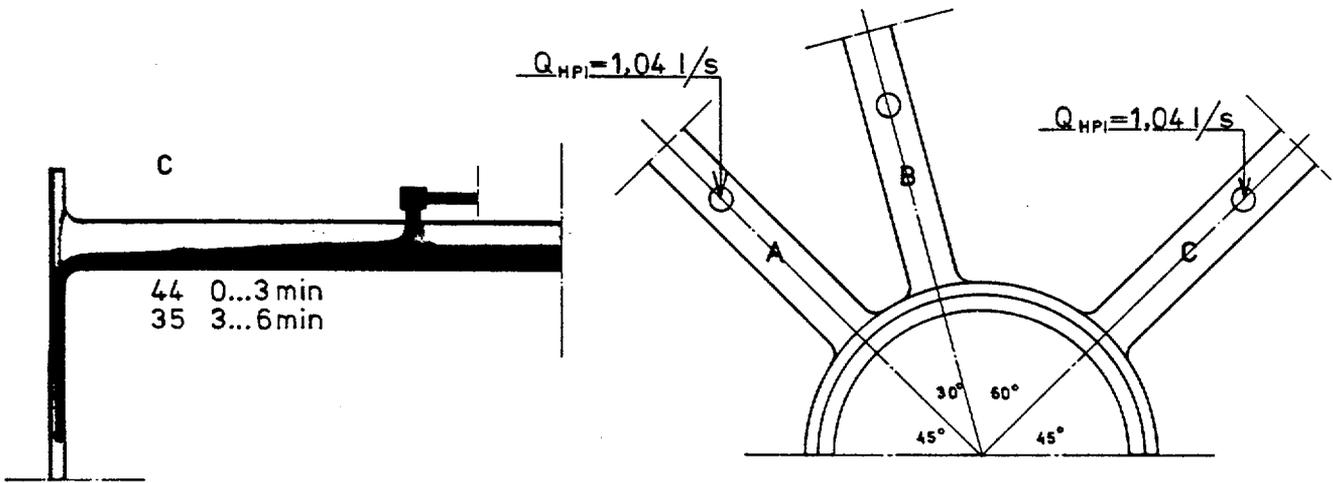


Figure 5.42 Schematic view of PURDUE's 1/2-scale facility (configuration B&W)





34 JVO Downcomer TC Locations



Drawing 8a  
 Interaction and mixing of two HPI plumes in the  
 downcomer during the test #112

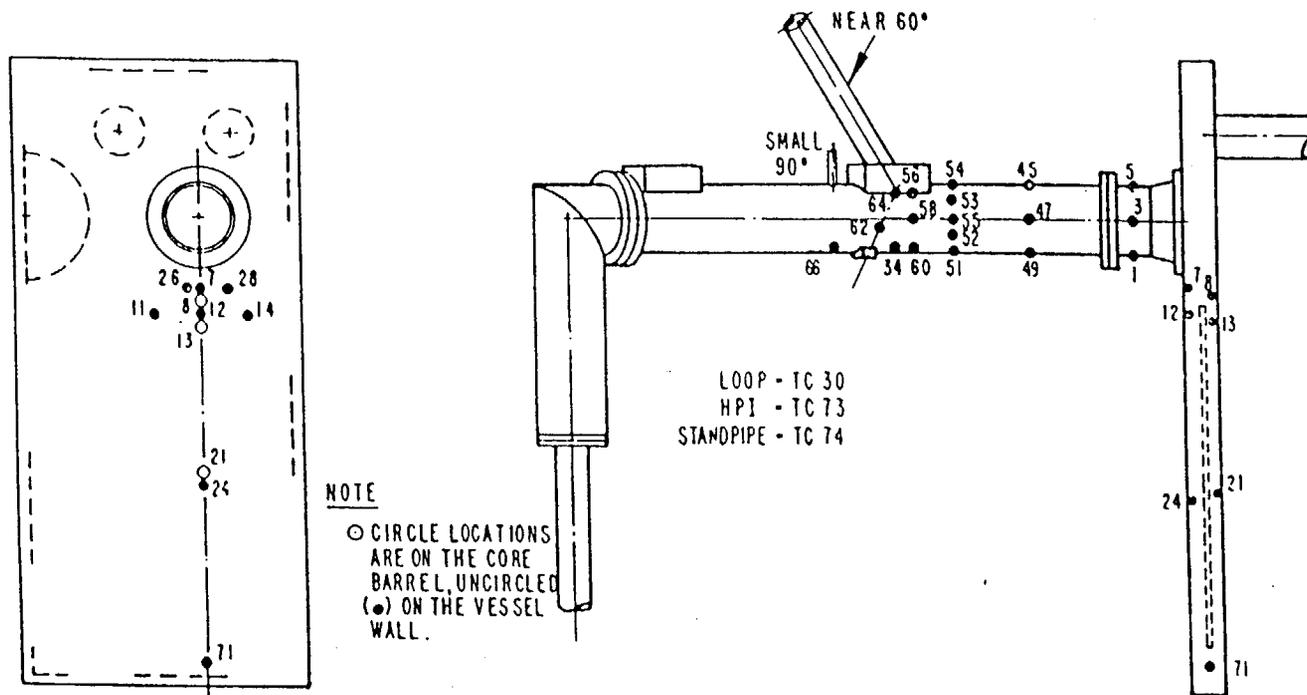


Figure 5.1 Schematic of CREARE 1/5-scale (MIX3) test facility

## Results of Past Calculations

### Categorization of PTS Events

- PTS represents a class of transients that can be grouped into two categories.
  1. Transients originating on the primary side resulting in injection of cold water into the cold leg, from whence it enters the downcomer and cools the vessel wall;
    - Examples are small hot leg break LOCA, small cold leg break LOCA, stuck open PORV or feed-and-bleed.
  2. Transients originating on the secondary side that cool down a steam generator, resulting in the return flow of cold water from the primary side of the generator to the downcomer where it cools the vessel wall.
    - Examples are steam generator overfeed, steam line breaks, stuck open steam dump valve(s), stuck open steam safety/relief valves.
- For a transient to be PTS-significant may require multiple failures in addition to the initiating event.
- In all cases, elevated pressure is required in conjunction with cooldown of the vessel

**Review of Past Calculations  
Oconee IPTS**

|   | Transient                                    | Description  | Code                   |
|---|--|--|------------------------|
| 1 | Turbine trip                                 | Actual plant transient of March 14, 1980   | TRAC,<br>RELAP         |
| 2 | Stuck open PORV                              | Failure to run back main feedwater; reactor coolant pump trip  | TRAC,<br>RELAP         |
| 3 | <b>Turbine bypass valves fail open (2/4)</b> | <b>from full power, w &amp; w/o failure of steam generator level control, restart reactor coolant pumps and throttle HPI</b> | <b>TRAC</b>            |
| 4 | Turbine bypass valves fail open (4/4)        | w & w/o failure of steam generator level control, restart reactor coolant pumps and throttle HPI                             | TRAC                   |
| 5 | <b>2-inch hot leg break</b>                  | <b>Located in pressurizer surge line, reactor coolant pumps trip, systems operate as intended</b>                            | <b>TRAC,<br/>RELAP</b> |
| 6 | 4-inch hot leg break                         | Located in pressurizer surge line, reactor coolant pumps trip, systems operate as intended                                   | TRAC                   |
| 7 | Rancho Seco transient                        | Loss of feedwater followed by feedwater initiation and failure to throttle.  | TRAC                   |

|    |  |  |             |
|----|--|--|-------------|
| 8  | Steam generator overfeed                     | Failure of feedwater trip on high steam generator level. all other systems operate as intended   | RELAP       |
| 9  | Stuck open PORV                              | Failure to run back main feedwater; reactor coolant pumps do not trip  | RELAP       |
| 10 | Main steam line break                        | 34-in steam line break; all systems operate as intended, steam generators isolated at 10 min., intact steam generatorrefilled by 15 min, restart one reactor coolant pump per loop upon regaining 50F subcooling margin  | RELAP       |
| 11 | Main steam line break                        | 34-in steam line break; all systems operate as intended, steam generators isolated at 10 min., intact steam generator refilled by 15 min, restart one reactor coolant pump per loop upon regaining 75F subcooling margin | TRAC, RELAP |
| 12 | Steam generator overfeed                     | Failure of feedwater trip on high steam generator level. all other systems operate as intended   | RELAP       |
| 13 | <b>Turbine bypass valves fail open (4/4)</b> | <b>from hot standby, w &amp; w/o failure of steam generator level control, restart reactor coolant pumps and throttle HPI, hot standby initial conditions</b>  | RELAP       |
| 14 | 2.5-inch cold leg break                      | Located in reactor coolant pump suction, all systems operate as intended   | RELAP       |
| 15 | Steam generator tube rupture                 | Broken steam generator isolated at 20 minutes  | RELAP       |

## Review of Past Calculations Calvert Cliffs IPTS

Twelve transients analyses using TRAC

1. **14-inch main steam line break from hot standby with failure to isolate feedwater to the broken generator**
2. 14-inch main steam line break from full power
3. 100% main steam line break from hot standby with two reactor coolant pumps operating (same as #1 except for RCPs)
4. **100% main steam line break from hot standby with failure to isolate auxiliary feedwater flow to the broken generator**
5. **100% main steam line break from hot standby with failure of all MSIVs to close so both steam generators blowdown (same as #4 but with additional failure of MSIVs)**
6. 14-inch main steam line break from full power with failure of a turbine bypass valve to close
7. 14-inch main steam line break from full power with failure of the MSIVs to close
8. Trip from full power with failure to stop main feedwater to both generators
9. Trip from full power with failure to stop main feedwater to one generator
10. Trip from full power with delayed actuation of auxiliary feedwater, followed by failure to control auxiliary feedwater
11. 2-inch hot leg break from full power
12. Stuck open PORV (1.4-inch) with stuck open secondary side atmospheric dump valve

## Review of Past Calculations

### H.B. Robinson Re-analysis (NUREG/CR-5452)

- Four transients analyzed using RELAP
  1. 100% main steam line break from hot standby
  2. Steam generator overfeed by auxiliary feedwater
  3. 2-inch cold leg break LOCA
  4. **2-inch hot leg break LOCA**

## Review of Past Calculations Yankee Rowe

| Transient             | Core Power | Injection T (F) | Injection Flow Multiplier | Break Size Diameter (in) | h Multiplier |
|-----------------------|------------|-----------------|---------------------------|--------------------------|--------------|
| small cold leg break* | 500 kW     | 175             | 1.0                       | 1-5/16                   | 1.0          |
| small* cold leg break | 100%       | 175             | 1.0                       | 1-5/16                   | 1.0          |
| MSLB                  | 100%       |                 |                           |                          |              |

# Importance of Loop Flow Stagnation

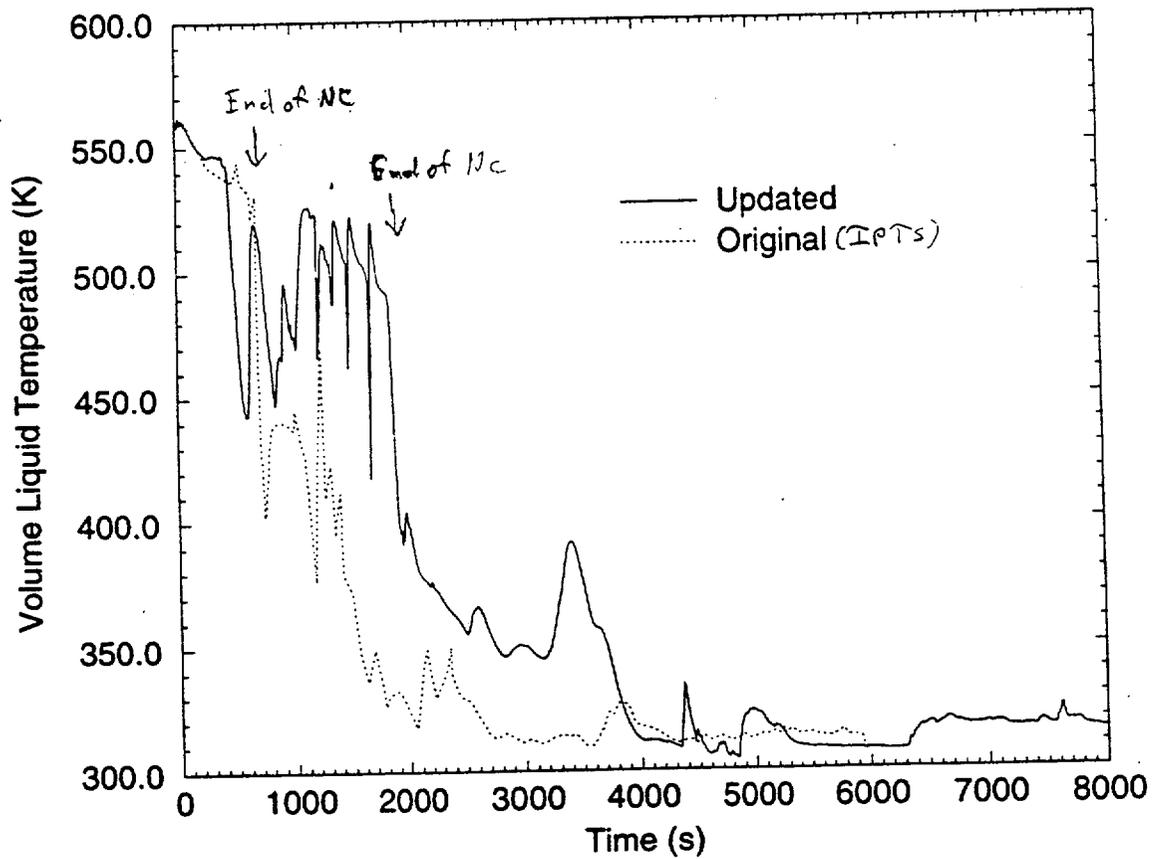


Figure 4-20. Loop A Cold Leg fluid temperature for the HL SBLOCA calculations.

AB Robinson

Importance of Reactor Coolant Pump Operation  
(also loop flow stagnation)

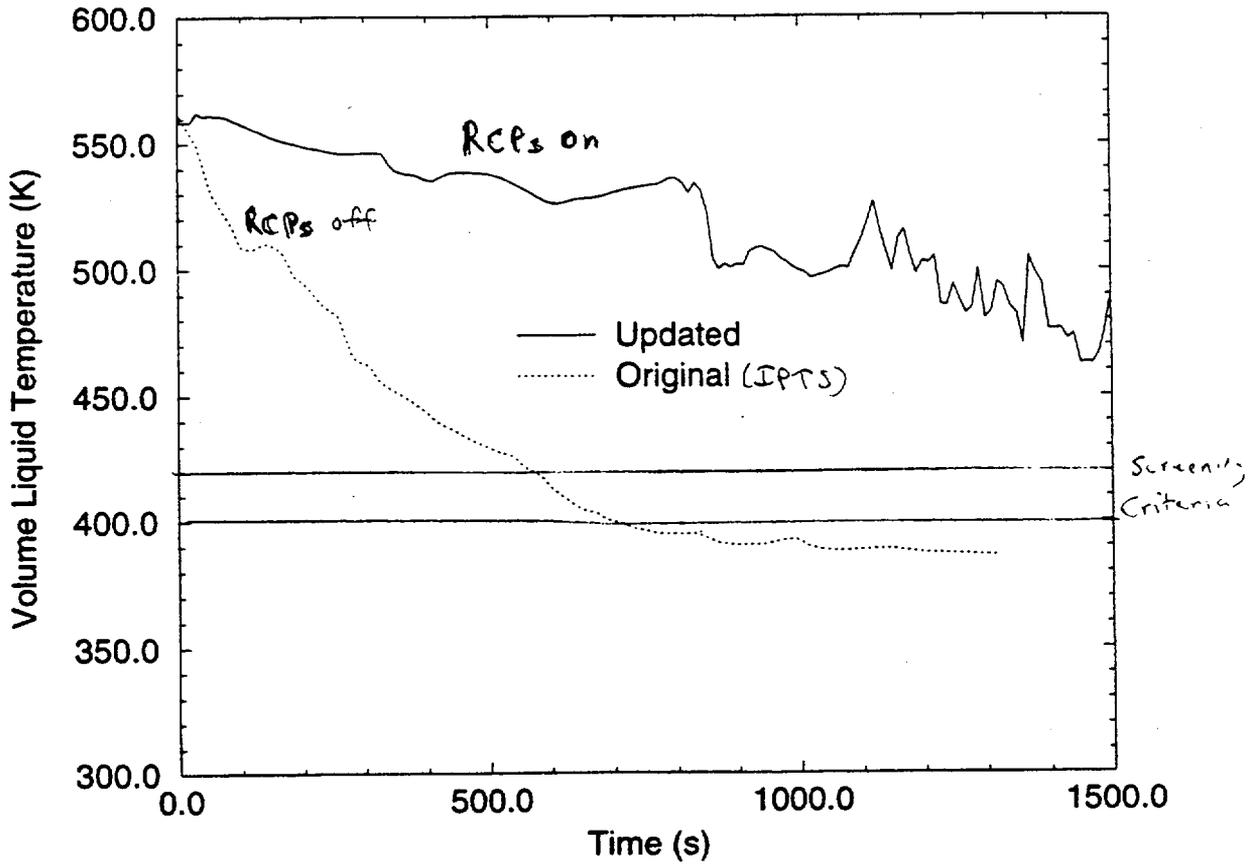


Figure 4-5. Downcomer fluid temperature for the MSLB calculations.

H B Robinson

# Importance of Injection Flow Rate

300 F = 422 K  
270 F = 405 K

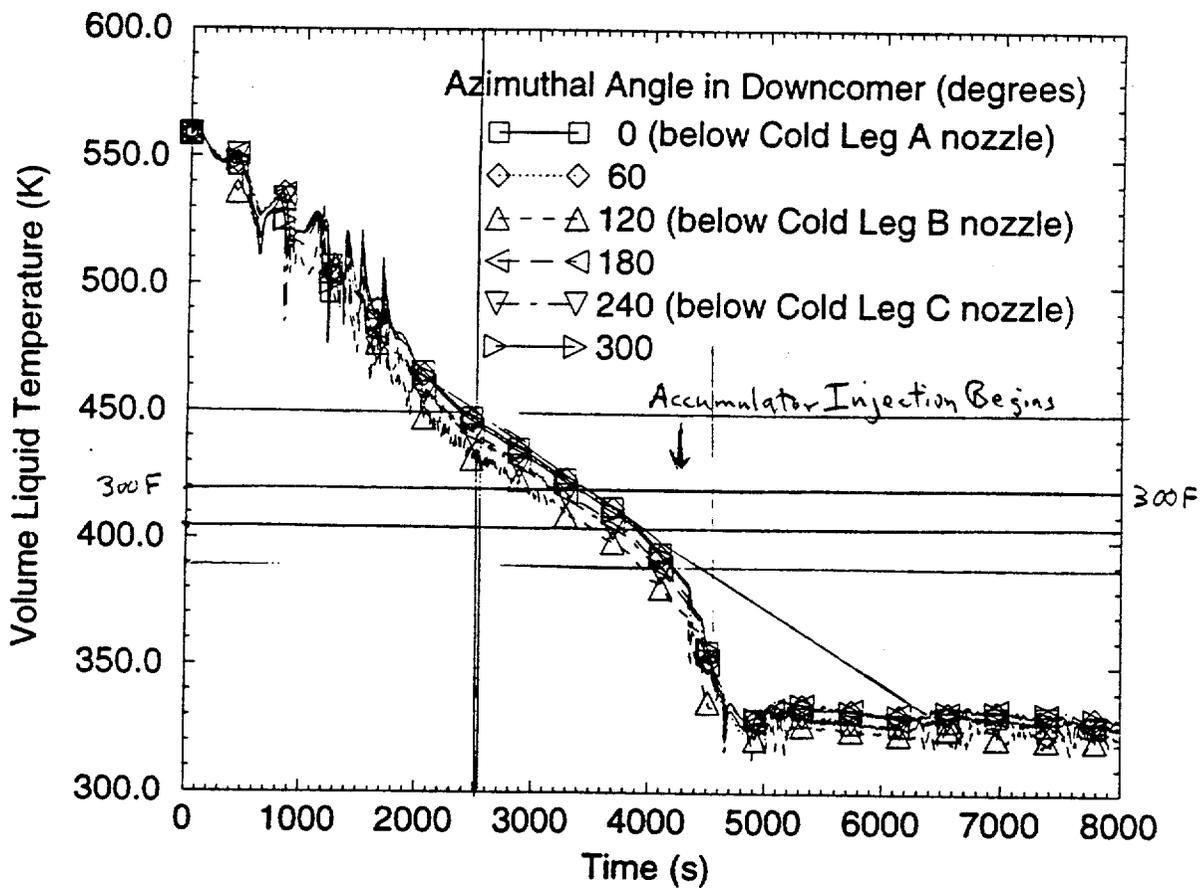


Figure 3-37. Hot leg SBLOCA fluid temperature in the azimuthal downcomer cells at the top of the core active length.

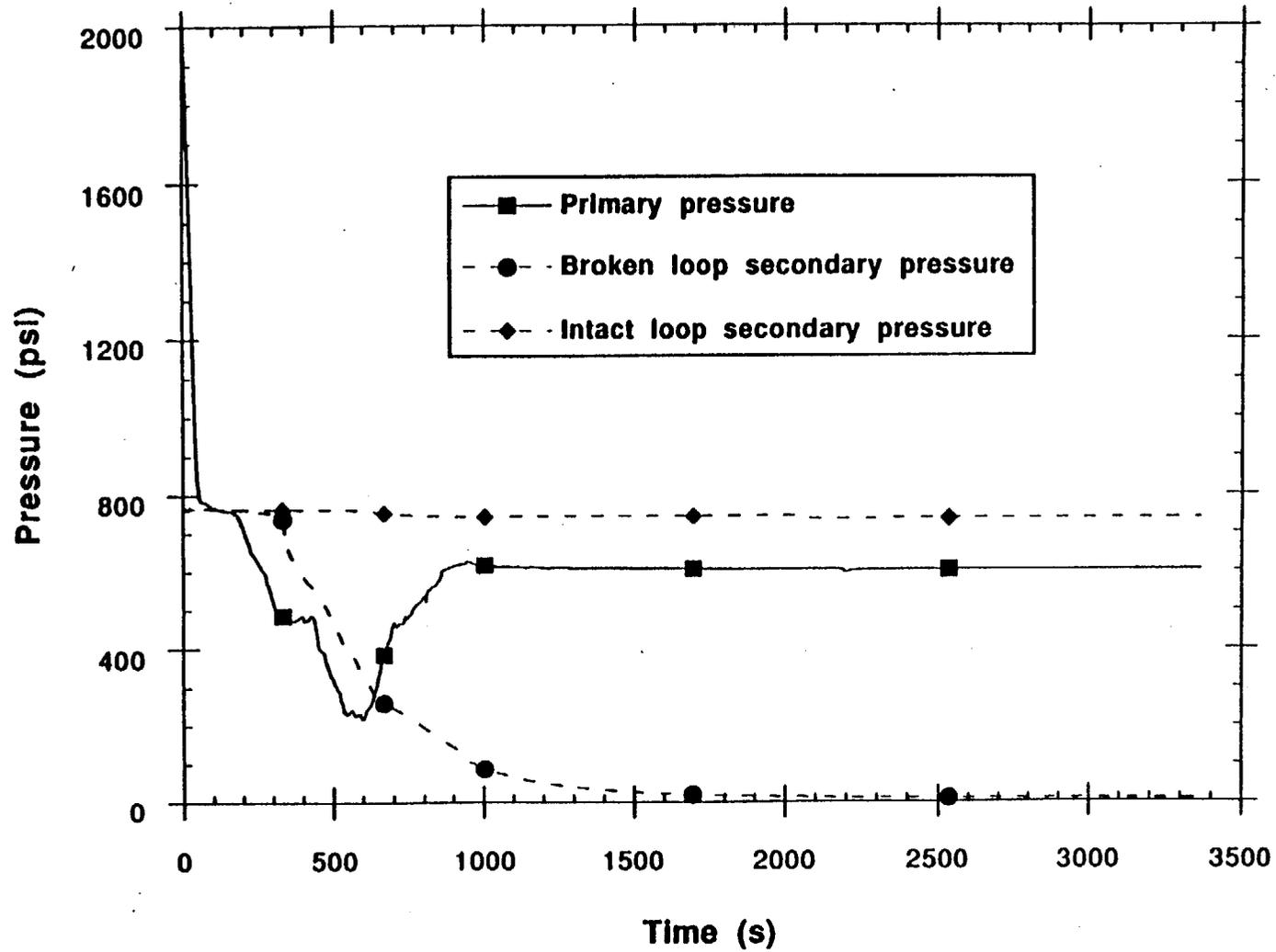


Figure 4 Primary and secondary pressures from the Yankee Rowe SBLOCA run #1.

# Importance of Injection Flow Rate

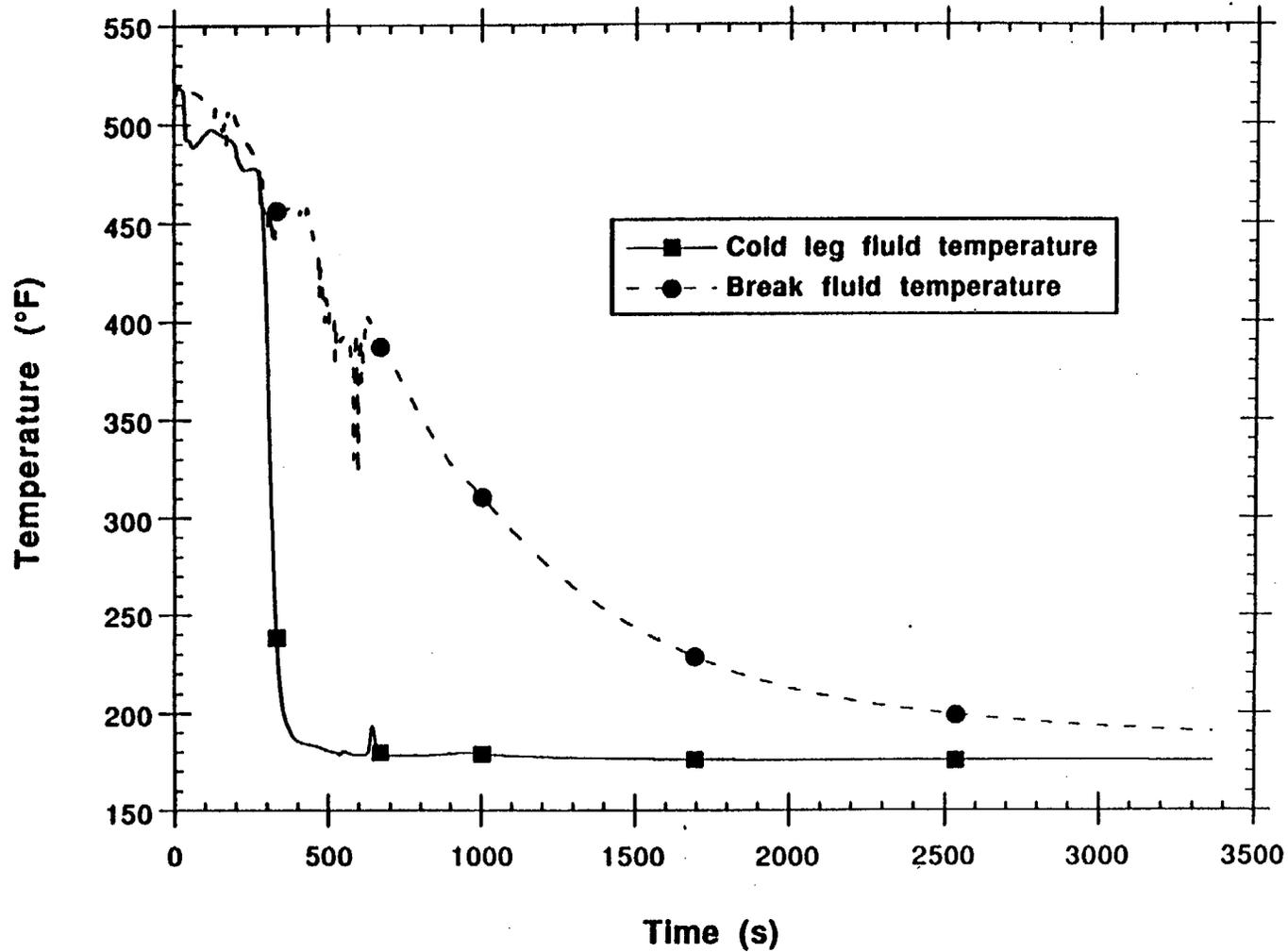


Figure 5 Broken loop fluid temperatures for Yankee Rowe SBLOCA run #1.

# Importance of Controlling Injection Flow

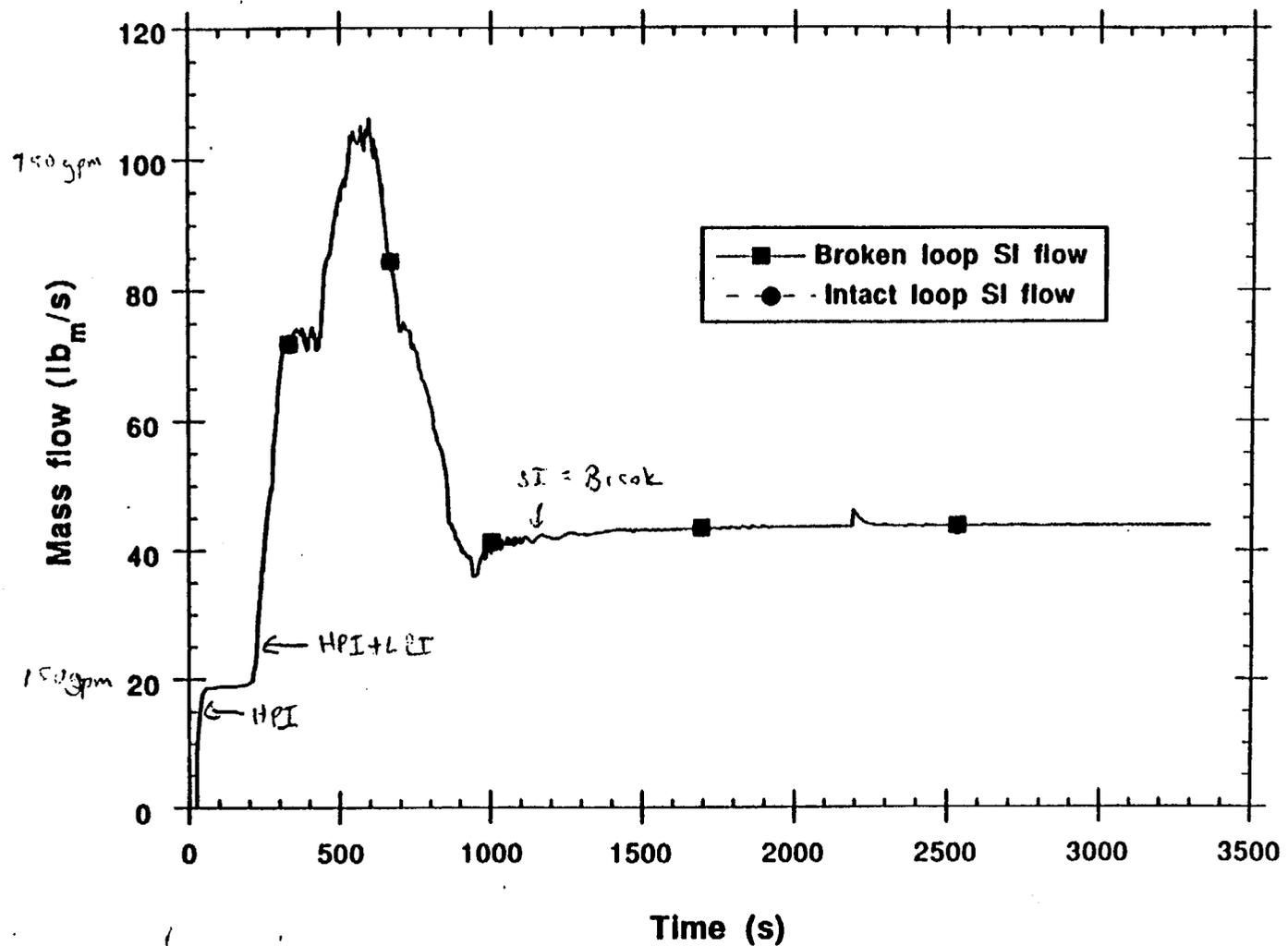


Figure 6 SI Injection mass flow rates for Yankee Rowe SBLOCA run #1.

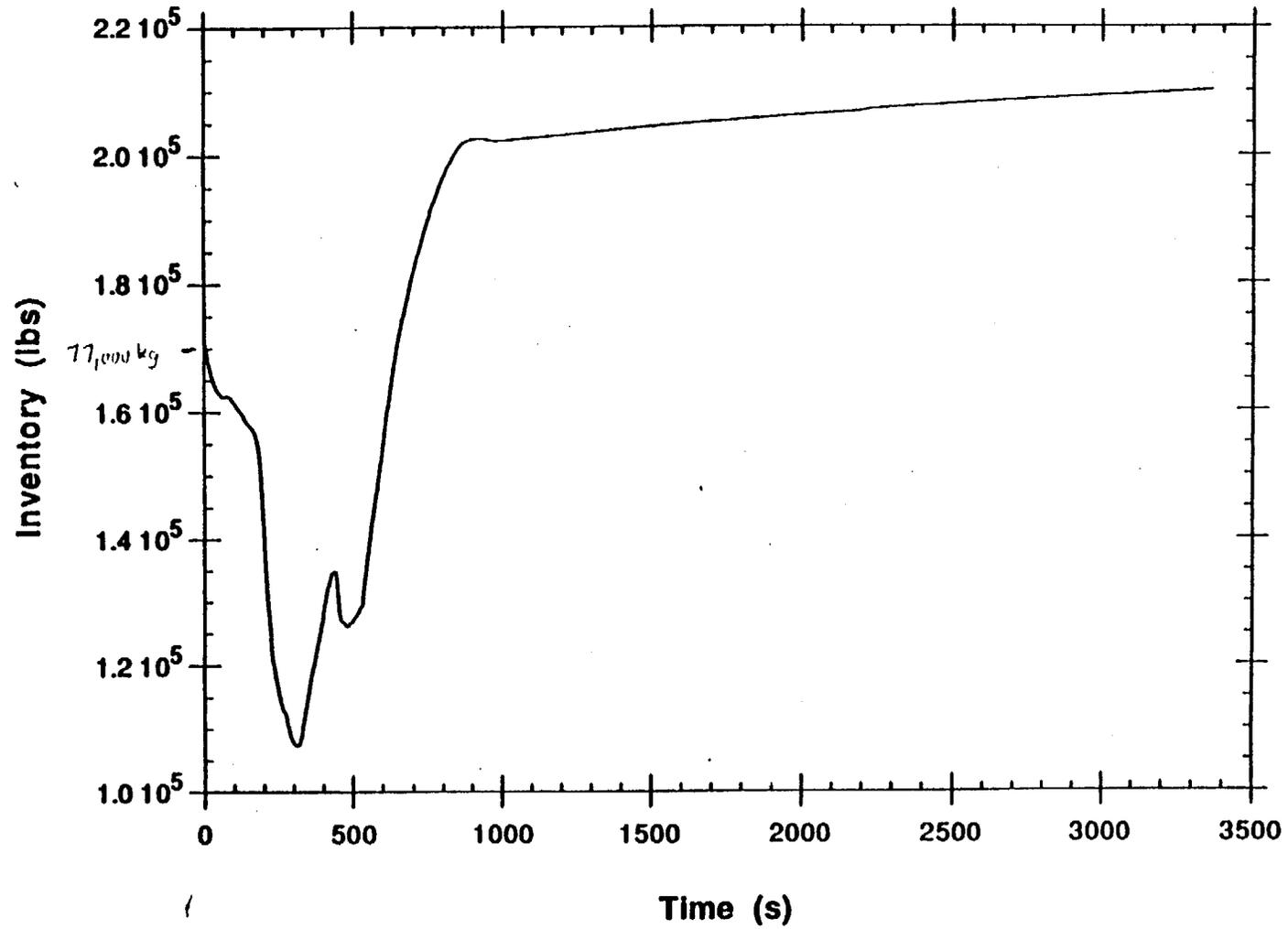


Figure 7 Primary mass Inventory for Yankee Rowe SBLOCA run #1.

## **Conclusions from Prior Calculations**

- Risk dominant sequences are
  1. Small break LOCAs in hot or cold legs; break size around 1.4 - 2.4 inches diameter.
  2. Open PORV and other very small break scenarios that include failure to throttle HPI such that the primary system is pumped water solid.
  3. Main steam line break.
  4. Smaller steam side leaks (stuck open valves) or breaks in combination with continued feed to the broken/open steam generator.
- Steam generator overfeed transients do not appear to pose a PTS risk.
- The time required for a PTS problem to develop is of the order of 15 minutes to 45 minutes (from the time a problem begins and not necessarily from the time of reactor trip).
- High head high capacity HPI pumps or events that lead to accumulator injection appear to be worse.

## **Some Important Design Considerations for PTS**

1. Accumulator injection is important to downcomer temperature because the injection flow rate is generally much higher (i.e. of the order of a factor of five) than HPI. Yankee Rowe had high head, high capacity injection pumps that caused the same effect.
2. Combustion Engineering plants have low pressure (200 psi) accumulators. Therefore, this is not a concern.
3. Combustion Engineering plants have low head (shutoff at 1200 psi) HPI pumps which reduce the probability of pumping the primary system water solid at high pressure.
4. Babcock and Wilcox plants have vent valves that begin to open at a differential pressure of 0.25 psi (0.85 kPa) and are fully open at twice this pressure. If the downcomer temperature is 300F (149C), the vent valves would begin to open at a core temperature of 318F and would be fully open at 336F.

# **Plans for Calculations and Analysis**

## **Some Analysis Principles**

- The results from PTS code calculation are strongly dependent upon
  1. The input assumptions.
    - As much time and pages of description should be devoted to determining the input assumptions to be used and describing the rationale for their selection, as to the discussion of results.
    - This requires that the operator procedures that apply to the plant to be analyzed be reviewed.
  2. Modeling of control and safety systems.
    - Generally a great deal of effort is required to ensure that the plant controls (i.e. operation of pumps and valves) are represented correctly and with sufficient fidelity in the input.

## **Some Analysis Principles**

- There has been a tradition in nuclear safety analysis to use conservative assumptions.
- These may include initial conditions, boundary conditions, equipment malfunction, and physical conditions.
- Often times conservative analyses are performed that obscure more realistic behavior.
- Such analyses may not consider the relationship to the probability of the event being analyzed.
- Ad hoc analysis of individual events or issues may place undue constraints on the way the plant is designed and operated and, furthermore, may be contrary to overall plant safety.

## Thermal Hydraulic Codes in Use

- Systems Codes

TRAC  
RELAP5

- Special Purpose Code

REMIX

- CFD Codes

FLUENT  
CFX

- Problems encountered: output files from the IPTS study have been destroyed; TRAC input deck notebooks and input decks from the IPTS study have been destroyed.
- The RELAP input decks and notebooks from the IPTS study are still here, but the input decks have been modified in ways that are difficult to trace.

## Currently Available Input Decks

|        |             |        |                |           |      |
|--------|-------------|--------|----------------|-----------|------|
| Code   |             |        |                |           |      |
| TRAC   | HB Robinson | Oconee | Calvert Cliffs |           |      |
| RELAP  | HB Robinson | Oconee | Calvert Cliffs | Palisades | APEX |
| REMIX  | HB Robinson |        | Calvert Cliffs | Palisades | APEX |
| FLUENT |             |        |                |           |      |
| CFX    |             |        |                |           | APEX |

Note: Palisades and Calvert Cliffs are very similar

## **Current Plans for RELAP/TRAC Calculations** (subject to revision<sup>1</sup>)

- **Transients to be analyzed**
  1. Small hot leg break.
  2. Small cold leg break. The results appear to be similar to the small hot leg break, but other things being equal, somewhat less severe.
  3. Depressurization/repressurization transient (e.g. a stuck open PORV which depressurizes the primary system, allows HPI to initiate, and natural circulation to stop. Then the block valve is closed and the system begins to repressurize). Feed-and-bleed is a similar transient, induced by total loss of feedwater or steaming.
  4. Main steam line break.
- **These events may include sensitivity studies or varying combinations of additional failures.**

---

<sup>1</sup> Everything is subject to revision until it is done, at which time it becomes subject to second guessing)

## Screening Criteria for PTS

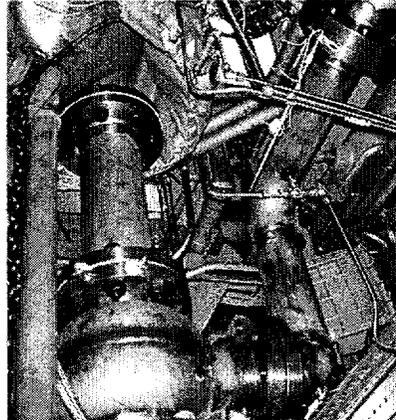
1. The vessel must be sufficiently embrittled
2. The temperature must drop in the downcomer region adjacent to the core below 300F for weld and 270F for plate (according to current 10 CFR 50.61).
3. The cool down rate must exceed 100F/hr:
4. The inside of the vessel must become cold for a certain period while the outside is hot and pressure is high (in order for the inside region to reach the ductile-to-brittle transition *and* to generate tensile thermal stress). The time constants for cooling the downcomer and the vessel are, therefore, important.
5. The primary system pressure must exceed some value (say 2 to 4 MPa). Screen out LOCAs whose pressure falls below this threshold, e.g. large and intermediate breaks.
6. Primary system loop natural circulation must be lost for small break LOCAs. To do so, primary system pressure must decline to below the steam generator secondary system pressures. Screen out break sizes too small to lose natural circulation or those so large that the primary system depressurizes to a low pressure.
7. Screen remaining transients on the basis of P-T-h input to FAVOR.

## Scaling Analysis for the PTS Experiments in the *OSU APEX-CE Test Loop*

Presentation to the T/H  
Subcommittee  
Advisory Committee on Reactor  
Safeguards

March 15, 2000

Jose N. Reyes, Jr.  
Department of Nuclear Engineering  
Oregon State University



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Outline

- Objectives
- General Scaling Methodology
- APEX Modifications
- Geometric Similarities
- Experiment Objectives
- PTS PIRT
- System Breakdown & Process Hierarchy
- Natural Circulation Scaling Analysis
- Primary Side Depressurization Scaling
- Secondary Side Depressurization Scaling
- Thermal Fluid Mixing Scaling
- Conclusions
- Remaining Scaling Efforts



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## OSU PTS Research Objectives

- The performance of integral systems overcooling transients in a 2 x 4 Loop CE model.
- The identification of the conditions that lead to primary loop stagnation.
- An evaluation of the adequacy of existing thermal hydraulic computer codes (RELAP5 or TRAC) to predict the conditions for primary loop stagnation, and
- An evaluation of existing CFD codes (CFX or FLUENT) to predict downcomer fluid mixing behavior.



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Scaling Analysis Objectives

- To establish the degree of geometric similarity between the Palisades Plant and the APEX-CE test facility.
  - This required obtaining the geometric scale ratios for the primary loop components.
- To develop the scaling basis for assuring that the following phenomena could be adequately simulated in APEX-CE:
  - The Onset of Loop Stagnation
  - The Onset of Thermal Stratification in the cold legs
  - Thermal fluid mixing in the downcomer
  - Preheating of injected ECC water in the cold leg



Nuclear Engineering & Radiation Health Physics  
Oregon State University

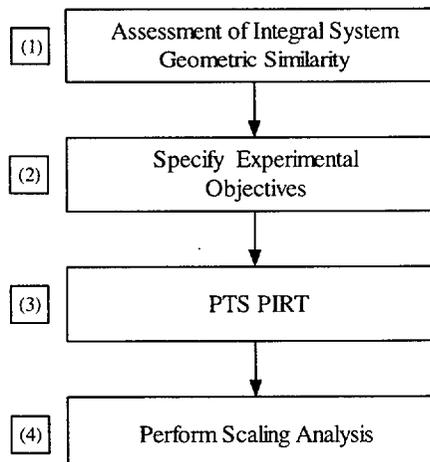
## Scaling Analysis Objectives

- To develop the scaling basis for performing MSLB and SBLOCA overcooling transients in APEX-CE.
- To identify which of the PTS PIRT phenomena would be adequately simulated in APEX-CE.



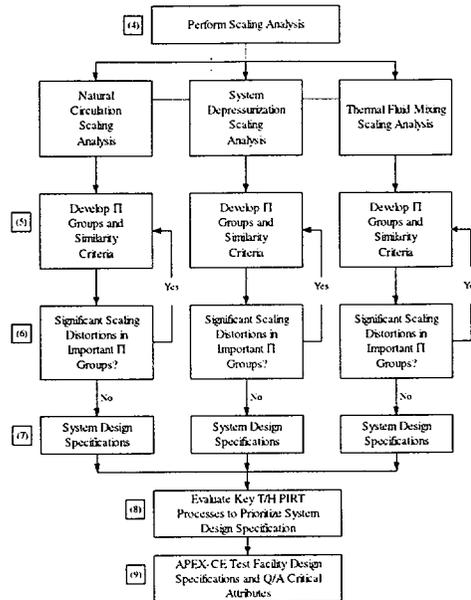
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## General Scaling Methodology



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## General Scaling Methodology (continued)



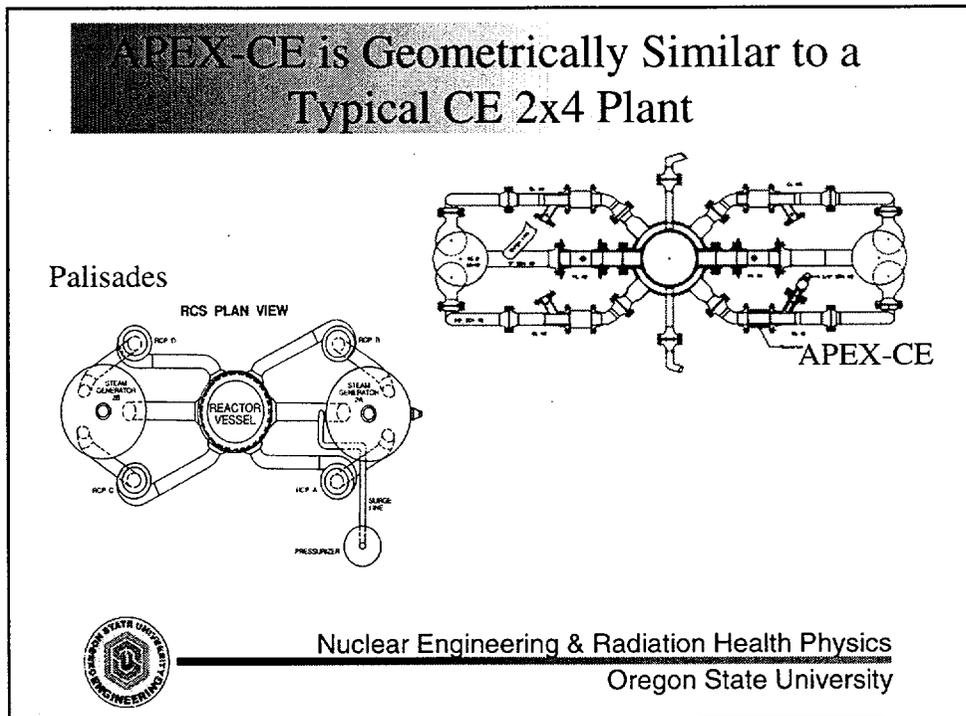
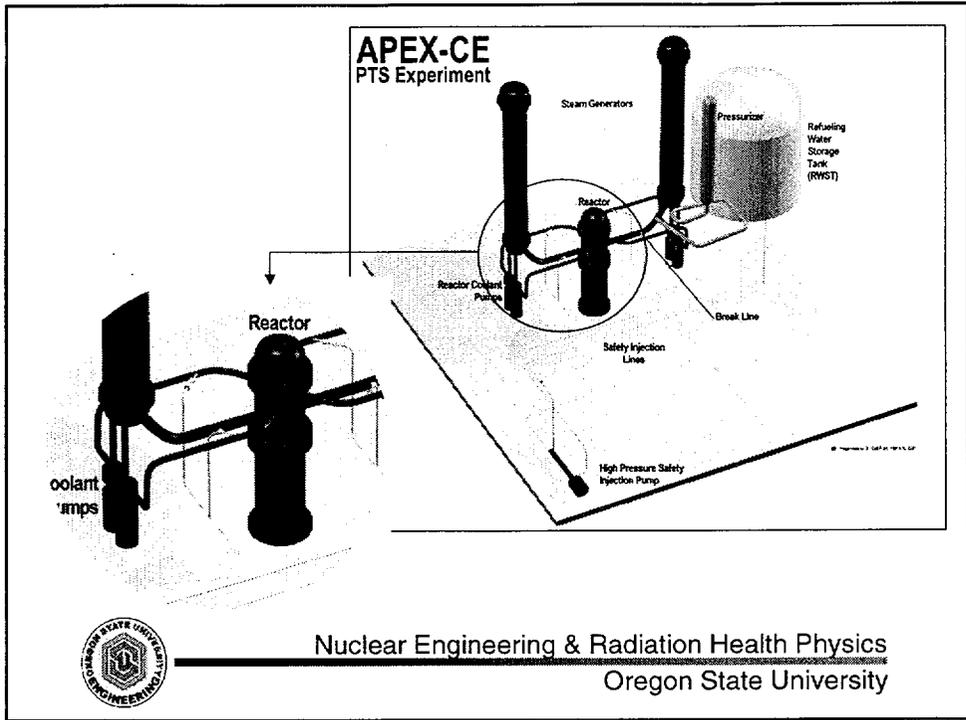
Nuclear Engineering & Radiation Health Physics  
Oregon State University

## APEX Facility Modifications

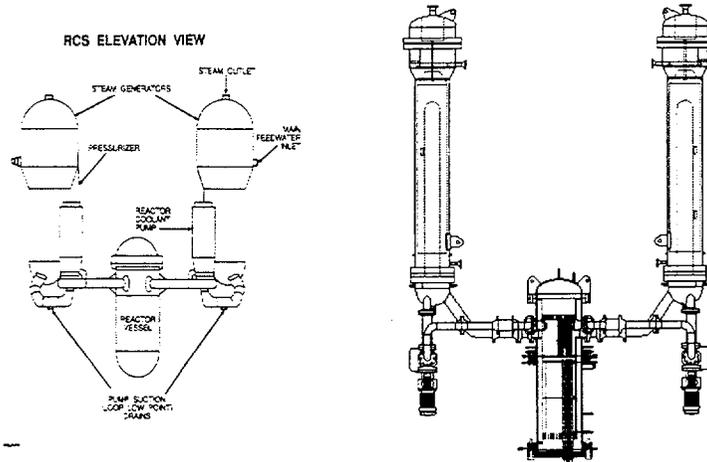
- OSU has modified APEX to simulate the Palisade's 2x4 PWR. The following has been added:
  - Four HPI lines
  - Four cold leg loop seals
  - Additional cold leg T/C rakes and flow meters
  - 50 additional downcomer thermocouples



Nuclear Engineering & Radiation Health Physics  
Oregon State University



## Geometric Similarity



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Comparison of Component Volumes

\*Ratio of APEX to Palisades

PROPRIETARY



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Comparison of Component Flow Areas

\*Ratio of APEX to Palisades

PROPRIETARY



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Comparison of Component Lengths

\*Ratio of APEX to Palisades

PROPRIETARY



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## APEX-CE/Palisades Scaling Ratios

| Geometric Parameter                 | APEX-CE to Palisades Scale Ratios |
|-------------------------------------|-----------------------------------|
| Flow Areas                          | -1/70                             |
| Piping Lengths                      | -1/3.7                            |
| Volumes                             | -1/276                            |
| Elevations                          | -1/3.45                           |
| <b>Operating Parameters</b>         |                                   |
| Power                               | 1/276                             |
| Natural Circulation Mass Flow Rates | -1/276                            |
| Fluid Velocities                    | -1/3.7                            |
| Total RCS Power/Volume              | 1/1                               |



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Geometric Similarity Conclusions

- The scaling ratios for the key components are relatively constant throughout the primary loop with the exception of the downcomer volume.
- Downcomer L/D scaling ratio is approximately 1:1.
- APEX-CE is geometrically similar to Palisades.



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Experiment Objectives

- Integral System Tests:
  - *Hot Leg Breaks.* Using cold leg injection, a spectrum of hot leg breaks (i.e., break energy equal to decay power) will be performed. The conditions leading to primary loop stagnation and the detailed temperature measurements and cooldown rates in the downcomer will be obtained.
  - *Main Steam Line Breaks.* A series of Main Steam Line Breaks (MSLBs) shall be performed to identify the conditions leading to primary loop stagnation. This will include asymmetric MSL breaks to determine if stagnation in two of four loops would occur. The conditions leading to primary loop stagnation and the detailed temperature measurements and cooldown rates in the downcomer will be obtained.



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Experiment Objectives (cont.)

- Separate Effects Tests:
  - *Thermal Fluid Mixing.* A series of steady-state Intermediate Head Injection tests will be performed to study thermal stratification in the cold leg and plume development and interaction in the downcomer.



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## PTS Phenomena & Ranking

| Rank | PTS Related Phenomena                                    |
|------|--|
| 1    | High Pressure Safety Injection (HPSI) Flow               |
| 2    | Reactor Vessel Wall Heat Conduction                      |
| 3    | Flow Distribution in Downcomer                           |
| 4    | HPSI Water Source Temperature                            |
| 5    | Break Flow Rate (or Break Size)                          |
| 6    | Safety Injection Jet Behavior in Cold Leg and Downcomer  |
| 7    | Decay Heat   |
| 8    | Surface Heat Transfer Coefficient on Reactor Vessel Wall |
| 9    | Loop Flow Upstream of Safety Injection Connection        |
| 10   | HPSI-RCS Mixing in the Cold Legs                         |

Adapted from NUREG/CR-5452



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## PTS Phenomena & Ranking

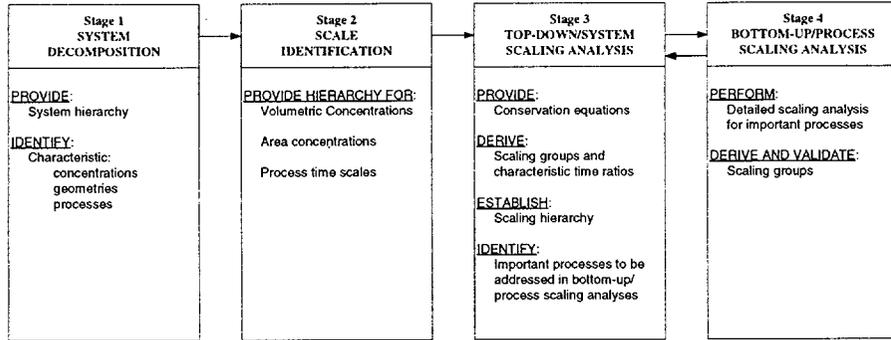
| Rank | PTS Related Phenomena  |
|------|--|
| 11   | Loop temperature Upstream of Safety Injection Connection     |
| 12   | Downcomer to Core Inlet Bypass                               |
| 13   | Downcomer to Upper Plenum Bypass                             |
| 14   | Upper Head Heat Transfer Coefficient under Voided Conditions |
| 15   | Liquid/Steam Interface in the Upper Part of the Downcomer    |
| 16   | Feedwater Temperature  |
| 17   | Feedwater Control  |
| 18   | Steam Generator Energy Exchange                              |
| 19   | Timing of Manual RCP trips                                   |
| 20   | Loop Flow Resistance   |

Adapted from NUREG/CR-5452



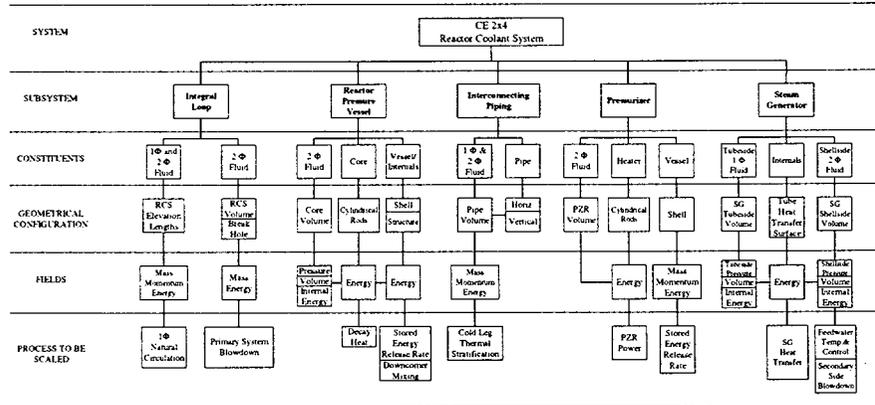
Nuclear Engineering & Radiation Health Physics  
Oregon State University

# H2TS Methodology



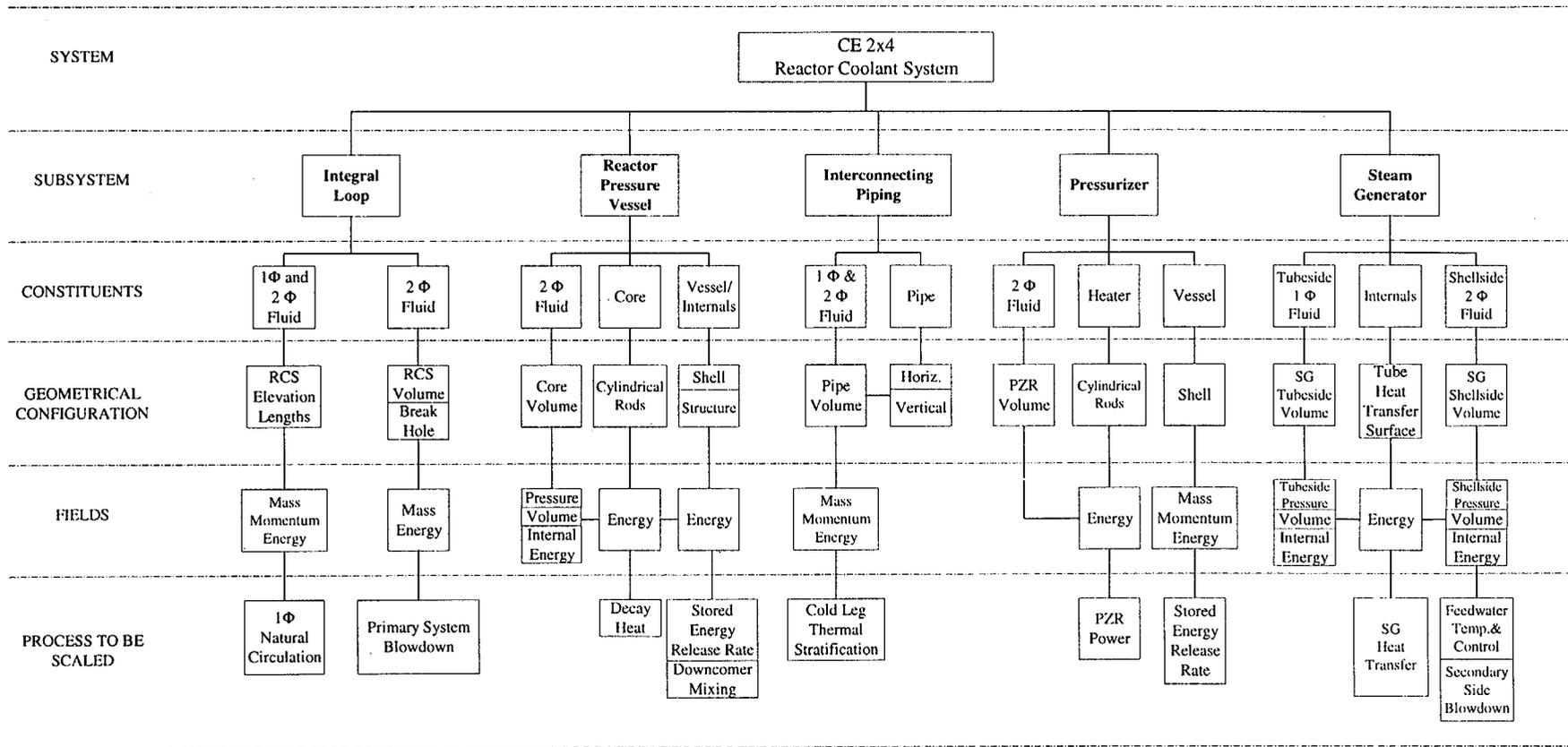
Nuclear Engineering & Radiation Health Physics  
Oregon State University

# System Breakdown & Process Hierarchy

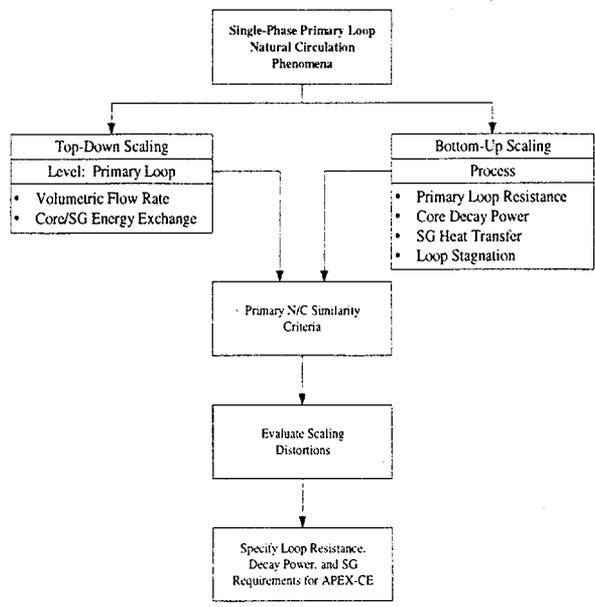


Nuclear Engineering & Radiation Health Physics  
Oregon State University

# System Breakdown & Process Hierarchy

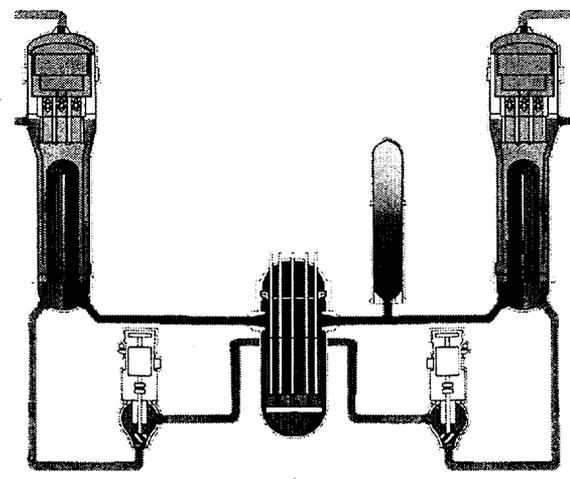


# Natural Circulation Scaling Analysis Flow Chart



Nuclear Engineering & Radiation Health Physics  
Oregon State University

# Natural Circulation Control Volume



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Balance Equations for Loop Analysis

- **Loop Mass Balance (at every cross-section):**

$$\dot{m} = n_i \rho_i u_i a_i = \rho_c u_c a_c = \text{constant} \quad (5.4)$$

- **Momentum Balance for Parallel Loops:**

$$\left[ \sum_{i=1}^N \left( \frac{a_c}{n_i a_i} \right) \right] \rho_c \frac{du_c}{dt} = \beta g \rho_c (T_H - T_C) L_{th} - \frac{\rho_c u_c^2}{2} \sum_{i=1}^N \left( f \frac{\ell}{d_h} + K \right)_i \left( \frac{a_c}{n_i a_i} \right)^2 \quad (5.5)$$

- **Energy Balance:**

$$C_{vt} M_{\text{sys}} \frac{d\langle T_c \rangle}{dt} = \dot{m} C_p (T_H - T_C) - (UA\Delta T)_{SG} - q_{\text{loss}} \quad (5.6)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Dimensionless Balance Equations

- **Momentum Balance:**

$$\tau \frac{du_c^*}{dt} = \varepsilon_{nc} \left[ \frac{(T_H - T_C)^*}{\Pi_{Fr}} - \frac{(u_c)^*}{2} \Pi_F \right] \quad (5.15)$$

- **Energy Balance:**

$$\tau \frac{d\langle T_c \rangle^*}{dt} = \Pi_q \dot{m}^* (T_H - T_C)^* - \Pi_{SG} U_{SG}^* \Delta T_{SG}^* - \Pi_{\text{loss}} q_{\text{loss}}^* \quad (5.20)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Characteristic Time Scale & $\Pi$ Groups

- **Loop Time Constant:**

$$\tau = \sum_{i=1}^N \frac{\ell_i}{u_i} = \sum_{i=1}^N \tau_i = \frac{M_{\text{sys}}}{\dot{m}} \quad (5.16)$$

- **Loop Resistance:**

$$\Pi_F = \sum_{i=1}^N \left( \frac{f \ell}{d_h} + K \right) \left( \frac{a_c}{n_i a_i} \right)^2 \quad (5.18)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Characteristic Time Scale & $\Pi$ Groups

- **Loop Richardson Number:**

$$\Pi_{\text{Ri}} = \frac{u_{\text{co}}^2}{\beta_T g (T_H - T_C)_o L_{\text{th}}} \quad (5.19)$$

- **Core Heat Transfer:**

$$\Pi_q = \frac{C_p (T_H - T_C)_o}{C_v \langle T_{\ell,o} \rangle} = \frac{q_{\text{Core,o}}}{\dot{m} C_v \langle T_{\ell,o} \rangle} \quad (5.21)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Characteristic Time Scale & $\Pi$ Groups

- **Steam Generator Heat Transfer:**

$$\Pi_{SG} = \frac{U_{SG,o} A_{SG} \Delta T_{SG,o}}{C_v \langle T_{t,o} \rangle} \quad (5.22)$$

- **Heat Loss:**

$$\Pi_{Loss} = \frac{q_{loss,o}}{C_v \langle T_{t,o} \rangle} \quad (5.23)$$



Nuclear Engineering & Radiation Health Physics  
Oregon State University

## Bottom-Up Scaling

- **Primary Loop Resistance:**

| Component                   | Palisades | APEX<br>(1/2 Time Scale) | APEX-CE<br>(1/1 Time Scale) |
|-----------------------------|-----------|--------------------------|-----------------------------|
|                             | $\Pi_F$   | $\Pi_F$                  | $\Pi_F$                     |
| Steam Generator             | 36.8      | 34.7                     | 73.6                        |
| Reactor Vessel and<br>Loops | 33.7      | 33.0                     | 67.4                        |
| All Loop Components         | 70.5      | 67.7                     | 141.0                       |



Nuclear Engineering & Radiation Health Physics  
Oregon State University