ORIGINAL ACRST-3110

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

Title: MEETING: THERMAL-HYDRAULIC PHENOMENA

TR04 (ACRS)
RETURN ORIGINAL
TO BJWHITE
M/S T-2E26
415-7130
THANKS!

Docket No.:

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

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.

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

***

MEETING: THERMAL-HYDRAULIC PHENOMENA

USNRC
Two White Flint North, Rm. T2-B3
11545 Rockville Pike
Rockville, Maryland
Wednesday, March 15, 2000

The subcommittee met pursuant to notice, at 8:30 a.m.

MEMBERS PRESENT:

GRAHAM B. WALLIS, Chairman, ACRS
THOMAS S. KRESS, Member, ACRS
DANA POWERS, Member, ACRS
WILLIAM SHACK, Member, ACRS
JOHN SIEBER, Member, ACRS

CONSULTANTS PRESENT:

VIRGIL SCHROCK
NOVAK ZUBER

COGNIZANT ACRS STAFF ENGINEER:

PAUL BOEHNERT

CONTENTS

P R O C E E D I N G S

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

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

MR. BOEHNERT: Yes, Julius Caesar.

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

MR. POWERS: Oh, yes.

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

The purpose of this meeting is to begin review of the thermal-hydraulic issues associated with the pressurized thermal shock screening criteria and reevaluation project being conducted by the NRC Office of Nuclear Regulatory Research; also, to discuss the status of the NRC staff acceptance review of the Siemens-S RELAP 5 and GE Nuclear Energy TRACG Codes; and furthermore to 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; ask many questions; and formulate proposed positions and actions as appropriate for deliberation by the full committee. Paul Boehnert is the cognizant ACRS staff engineer for this meeting. The rules for participation in today's meeting have been announced as part of the notice of this meeting, previously published in the Federal Register on 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 no written comments or requests for time to make oral statements from members of the public.

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

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

What I'm going to talk about is the status of the review of RETRAN-3D and the status of the review of RELAP5, S-RELAP5 and the status of the TRACG review. The package which you have been given has all of the slides for this morning. That they will not be gone through in one complete stream; we'll break after the RETRAN-3D discussion, because Greg Swindlehurst would like to say a few words on behalf of the RETRAN maintenance group. Then, we'll take up the topic of S-RELAP5, stop, and Siemens would like to say some words about the Siemens S-RELAP5 code. Then, we'll take up TRACG, and I believe Jens Andersen will be speaking on behalf of General Electric for TRACG.

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

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

The slides were put together to document really where all of the problems are that we see with the code as of last December and to have it on record what we've done, where we stand. At this point, we've stopped the review while we've been waiting for material to come from RETRAN maintenance group. In documentation of RETRAN-3D and the code itself were submitted for our review. I've prepared a timeline which gives an overview of all of the events which have gone forth on the review of RETRAN-3D. We're going to talk a little bit about some of the code problem areas. Currently, the review, as I said, is on hold because we have been waiting for material and further guidance from the RETRAN maintenance group.

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

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

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

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

We've looked at the 3D kinetics. The 3D part of the RETRAN title refers to kinetics, not to thermal-hydraulics. The staff assessed the 3D kinetics part of this code. We instructed EPRI on what to do in the way of providing us further assessment on their part. We've even gone so far as to provide the data for that assessment and to even provide the cross-sections for the use of EPRI in performing those assessments.

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

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

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

MR. ZUBER: The reviewers.

MR. LANDRY: That's the same version.

MR. ZUBER: And that is not for distribution.

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

MR. ZUBER: This is unbelievable.

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

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

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

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

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

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

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

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

MR. WALLIS: Because I remember when I was looking at the documentation, I couldn't quite figure out what this meant, as you might recall. For some reason, I couldn't figure out what they meant. The only way I could figure out what they meant would be to see how they are applied. To do that, you almost have to look at the actual computer code.

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

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

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

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

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

MR. ZUBER: Yes, okay.

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

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

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

MR. LANDRY: No, for their use.

MR. KRESS: For their use?

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

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

MR. LANDRY: That's our understanding.

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

MR. LANDRY: Correct.

MR. KRESS: Okay.

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

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

distributed?

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

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

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

[Pause.]

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

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

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

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

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

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

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

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

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

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

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

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

MR. KRESS: That's the definition?

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

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

MR. LANDRY: That gets on further into --

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

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

MR. KRESS: Okay.

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

MR. LANDRY: It has been assessed.

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

MR. LANDRY: Correct.

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

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

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

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

[Pause.]

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

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

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

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

MR. LANDRY: Right, right.

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

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

MR. LANDRY: Right.

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

MR. LANDRY: Yes.

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

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

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

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

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

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

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

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

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

MR. CARUSO: Right.

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

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

I'm a little bit concerned about saying that the information needs to be transparent to -- I'm not sure what level of expertise the information should be transparent to.

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

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

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

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

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

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

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

MR. ZUBER: I'm saying you can make good assumptions. They cannot violate principles. And what you're really doing is arguing that these are violating principles.

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

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

MR. ZUBER: It's dangerous.

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

MR. ZUBER: Let me say: if you have so many coefficients in these codes, and if they have a good assessment procedures, they can justify many of these shortcomings. But if they have shortcomings and inadequate assessment, then, you are left with nothing to defend.

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

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

MR. LANDRY: Okay.

MR. WALLIS: We should move on.

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

In August, when we had our training at Idaho Falls with the contractor's office, this reemphasized the need for user guidelines. While the training was very good -- we had no complaints about the calibre and the quality of the training -- it again pointed out to us that the code has so much flexibility that user guidelines are absolutely essential for this code. Based on that, we're prepared to say that each applicant will be required to provide and justify every assumption, every option, every model and every correlation chosen in the use of the code.

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

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

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

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

MR. WALLIS: With RETRAN, you're going to apply this fourth bullet?

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

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

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

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

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

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

The vendor codes that we're going to talk about -- S-RELAP5 for Siemens and TRACG -- will be used only by GE and by Siemens, so those people, that's a much smaller community. They're working closely with the code developers, and it's a different situation. In this case, if we have -- we're trying to review and approve a general purpose code for general purpose application by anyone, and that's what makes it especially difficult in the case of RETRAN.

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

MR. LANDRY: That's right.

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

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

MR. CARUSO: That's right.

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

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

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

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

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

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

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

MR. ZUBER: How can you do it if you don't have an assessment document to really say I'll run this with these correlations, and these are the results, and these are the observed -- this is where I can improve?

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

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

MR. ZUBER: The industry could have saved quite a bit of money had they used this approach: one document, one assessment; then, you pass it, and it's okay. Now, you leave it to every applicant to change something, and my own guess is they're going to present documents with inadequate assessments.

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

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

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

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

MR. LANDRY: Yes, yes.

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

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

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

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

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

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

MR. ZUBER: That's exactly.

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

MR. SCHROCK: That's the problem.

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

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

MR. KRESS: That's a tremendous --

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

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

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

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

MR. LANDRY: This is not an easy job.

[Laughter.]

MR. SCHROCK: We've seen enough of these presented to know that with the same options then applied to a variation in initial or boundary conditions, and you get a very poor result. So how, then, are you going to be able to say that you approve a version of this code for that kind of an application?

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

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

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

MR. ZUBER: And a large brick?

MR. LANDRY: This is --

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

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

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

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

I'd have to do that.

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

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

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

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

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

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

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

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

MR. CARUSO: Well, the agency has its own thermal-hydraulic codes which are --

MR. KRESS: You do?

MR. CARUSO: -- ELAP and TRAC.

MR. KRESS: And TRAC?

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

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

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

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

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

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

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

MR. LANDRY: Right.

MR. SCHROCK: And new cross-section evaluations and so forth. You've already done enough to write a statement in here that says you're satisfied with the 3D kinetics part of this package. It seems strange, then, that they've come in with some modifications to it. What's the reason for that?

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

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

MR. LANDRY: That is correct.

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

MR. LANDRY: Right.

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

MR. LANDRY: That's right.

MR. SCHROCK: I don't think.

MR. LANDRY: And that is where we --

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

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

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

MR. LANDRY: Yes.

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

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

MR. SCHROCK: Okay.

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

MR. SCHROCK: Sure.

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

[Laughter.]

MR. LANDRY: These are the conclusions.

[Laughter.]

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

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

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

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

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

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

MR. KRESS: Ah.

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

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

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

MR. KRESS: I still have the question, because apparently, they've already done something with RETRAN-02 --

MR. LANDRY: Correct.

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

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

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

MR. LANDRY: Right.

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

MR. LANDRY: 3D.

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

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

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

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

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

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

MR. KRESS: Yes.

MR. WALLIS: Any other questions on the conclusion?

[No response.]

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

MR. KRESS: I think that's right.

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

Mr. Swindlehurst, please?

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

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

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

MR. ZUBER: Okay; let me ask you.

MR. SWINDLEHURST: Sure.

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

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

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

MR. SWINDLEHURST: Right.

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

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

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

MR. SWINDLEHURST: Well, here is what changed, okay? And this, by the way, I'm reading from a document that we just submitted on March 6, and unfortunately, I just found out today it didn't arrive until yesterday. I can't explain why it took nine days for this document to get here. We were hoping, you know, it would get here a week before this meeting so that the staff could read it and react to it.

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

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

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

The non-kinetics with gas equations were revised. The staff found an error early on in the review of that. We fixed that, and that was revised. The five-equation interfacial mass transfer models were changed, and that's the big change we've been talking about, okay? Staff has characterized that as us sending in a code with a known error, and we disagree with that. We sent in a code, mod 2, which had a model for doing this modeling. Subsequent work done by one of the RETRAN users identified problems with that. So we fixed that model; we approved it. We resubmitted it in August of 1999. So that's a natural evolutionary thing of codes like this. If someone finds a better way of doing something, and we agree with this; we're spending money on it, we will reprogram the code and issue a new version.

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

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

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

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

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

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

MR. WALLIS: There's got to be a mechanism somehow for approving a code, but there has also got to be a mechanism for knowing what you're approving. I don't see how this committee can make a determination.

MR. SWINDLEHURST: Sure.

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

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

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

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

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

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

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

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

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

MR. SWINDLEHURST: I think the way we can answer that is we were asked a question; we answered it. It's up to the staff whether or not our answer was correct, and if they reject it, then, we'll be back discussing it some more

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

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

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

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

MR. SCHROCK: Yes.

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

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

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

As an example, when we did the SPIRT benchmark that we just talked about a minute ago, the staff provided us with cross-sections in a format from the NESTLE code, which is a staff or an industry code, I guess, a university code. We took those cross-sections as-is and put them into RETRAN exactly as they were in order to do good validation comparisons, okay? And that would just be another example of changing how you load the cross-sections into the code, but when the equations start pulling those cross-sections out of their tables, none of that was changed. So it's just an inputting of the cross-section library. That's all it was.

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

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

Okay; so we've had two rounds of REIs. I assume some of our answers are acceptable to the staff; some, they're still reviewing, and we're waiting to hear back from those. We had a meeting -- I met with the staff in mid-December. The purpose of that meeting was to find out where are we on this review. We've added two rounds of questions; we've had lots of meetings. We've had a lot of ACRS involvement, and we sat down and talked about what was the remaining problem areas. Mostly the same things which you just heard from the staff's previous presentation. We took back that information; put a plan together as to what do we need to do to answer all of these questions and move forward with this review. And then, we prepared an additional submittal, which I mentioned we mailed on March 6, and the staff now has it, and the intent of this submittal was to be responsive to all the known questions, all the known issues.

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

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

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

MR. SWINDLEHURST: We've defined it.

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

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

MR. ZUBER: Okay.

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

MR. ZUBER: Okay.

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

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

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

MR. SWINDLEHURST: There have been minor updates.

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

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

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

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

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

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

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

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

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

MR. SWINDLEHURST: Okay.

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

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

MR. WALLIS: So we'll just say unless you have fixed these things, and maybe you have, the way you're talking suggests that the message has not got through that there is something very fundamental here which needs to be fixed.

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

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

MR. SWINDLEHURST: Okay.

MR. WALLIS: That was a concern we had.

MR. SWINDLEHURST: Okay; so, we've got a line-by-line table for each new model as to how and where it's validated, and we can discuss those on a case-by-case basis with the staff to move forward. We've also developed a user guidance model -- excuse me, a user modeling guidance section, which goes through all of the new models in RETRAN-3D and provides the code vendors' state of knowledge regarding the use of that model, limitations, and this is trying to be responsive to the staff's interests in such a document, okay? And we'll be updating that into the set of the code documentation.

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

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

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

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

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

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

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

MR. WALLIS: Thank you very much.

Any other questions?

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

MR. WALLIS: Oh.

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

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

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

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

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

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

MR. SWINDLEHURST: The bar has been raised.

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

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

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

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

MR. WALLIS: That's good.

MR. SWINDLEHURST: There has been two code errors I mentioned. We've taken care of those. If you back up further, to another point in time, we had an independent design review of the code done by a group of senior industry people uninvolved with the development of this code. They also identified code errors. Those were all addressed, and this is a normal and good thing for us to find these errors and get them fixed.

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

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

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

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

MR. WALLIS: The problem is that they have in the documentation, I think, four or five examples where you can see that the answer given is completely wrong. What should we suppose about more complicated examples that are involved with a reactor? That's the level we're at now. And I think -- I hope you can come back with something that puts us -- our concerns to rest.

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

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

MR. SWINDLEHURST: And do we agree that --

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

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

MR. WALLIS: Okay.

MR. SWINDLEHURST: The last comment here is -- and I'm pretty sure the staff agrees with this -- it's a good thing for people in utility organizations to be looking after their own plants in terms of safety analysis and transient analysis as opposed to not having these kinds of capabilities, and EPRI codes like this are where this technology comes from for these types of organizations, and we think it's a good thing, and we'd like to be able to move forward with this in terms of improving the software, and we think RETRAN-3D is an improvement.

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

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

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

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

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

MR. WALLIS: But there will be a problem for everybody if you work with the staff and then you all come back, and you say well, we've beaten this thing to death, and we agree, and yet, the professional community looking in from outside says gee whiz, how did they ever do that?

MR. SWINDLEHURST: Okay.

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

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

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

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

MR. WALLIS: I understand.

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

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

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

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

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

MR. WALLIS: Thank you very much.

[Pause.]

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

MR. LANDRY: I'll try.

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

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

MR. LANDRY: For review.

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

MR. LANDRY: Correct.

MR. ZUBER: This is a frozen code.

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

MR. ZUBER: And has the complete assessment?

MR. LANDRY: I'll get into that.

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

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

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

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

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

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

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

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

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

MR. LANDRY: Right.

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

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

MR. KRESS: It has some set cases?

MR. LANDRY: Right.

MR. KRESS: As part of the input.

MR. LANDRY: Yes.

MR. KRESS: Okay.

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

MR. KRESS: That sounds like a good idea.

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

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

MR. LANDRY: Thank you for bringing that up.

[Laughter.]

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

[Pause.]

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

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

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

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

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

[Laughter.]

MR. LANDRY: The schedule which we have put together, and as I said, Siemens has not seen this internal part yet, we have done the acceptance review. We have completed the acceptance review. That is moving through the concurrence. Our plan at this point is to issue REIs formally to Siemens in early to mid-May. We plan to issue to them electronically, through email, questions as they come up and then follow up with a formal list of REIs in early to mid-May. We would ask that they respond to those by mid-July, or, if they can't respond by mid-July, then, we'll have to negotiate an end date again. We need responses by mid-July so that we can aim for an SER dealing with the small-break loca use of the code by the end of the fiscal year, the end of September, and we would also aim for an SER on the transient application, the chapter 15 application, of the code by the end of the calendar year.

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

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

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

Now, this code is also the basis for their best estimate of more realistic loca, which they have not submitted yet but which we will probably be receiving sometime in the future, so this is an interim stage in the path to getting the realistic loca.

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

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

MR. SCHROCK: Yes.

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

MR. LANDRY: Yes.

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

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

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

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

MR. WALLIS: That's why I'm a little nervous about that, so I'm not sure where we should fit in there. I've read as far as I got on the documentation, and the way I review it is that I write down comments almost every page. But it seems rather inappropriate to send all that stuff to Siemens.

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

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

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

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

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

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

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

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

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

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

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

MR. WALLIS: That's the first test.

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

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

MR. MALLAY: Yes; perhaps a little dark.

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

The reason I've brought these people is that this is the team you're going to be seeing. If we have to make presentations before you, I just wanted to let you know who these people are. Each is going to say a couple of words here this morning, but I thought it was important that we introduce ourselves so you know who we are.

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

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

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

SPEAKER: Could you identify yourself for the record?

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

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

MR. O'DELL: Well, in essentially the same version. We can get into the code control process if you want, but the way that we control the code is that we have specific versions. Those versions never change. So from that standpoint, it's frozen. The code that's been submitted with the submittals here for the non-loca and small-break loca, those are frozen versions of the code. If you come back 10 years from now, assuming that I have a computer that I can still compile an older code on, I will have the code to compile, okay? So in the code control process, that is a frozen version of the code.

MR. MALLAY: Thank you, Larry.

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

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

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

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

MR. MALLAY: Absolutely; yes, he does.

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

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

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

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

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

MR. MALLAY: Part of the documentation we're going to be submitting is individual test cases of separate effects tests, if you will, not just an integral test, but also, we've been asked by the staff to demonstrate that individual physical processes are modeled properly. I think that answers your question.

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

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

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

MR. MALLAY: Right.

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

MR. MALLAY: Okay.

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

[Laughter.]

MR. WALLIS: But not very often.

[Laughter.]

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

[Laughter.]

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

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

Larry, it's all yours.

[Pause.]

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

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

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

MR. ZUBER: Okay.

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

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

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

[Laughter.]

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

[Laughter.]

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

As I believe Ralph Landry already indicated, the code -- the original basis of the code is the RELAP5 mod 2, INEEL Cycle 36.02 version of the code. Siemens has made significant modifications to support the use of the code for chapter 15 loca and non-loca transients. Our primary concentration in S-RELAP5 was originally and continues to be the realistic loca work. One of our biggest changes with the addition of 2D thermal-hydraulic capabilities to the code; we've also included RELAP5 mod 3 features and models.

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

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

MR. KRESS: Thank you.

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

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

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

MR. O'DELL: Yes.

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

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

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

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

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

MR. O'DELL: In effect.

MR. ZUBER: Did you assess it against UPTF?

MR. O'DELL: Yes.

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

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

MR. ZUBER: Great.

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

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

MR. WALLIS: Are you following the CSAU approach?

MR. O'DELL: Yes.

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

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

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

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

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

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

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

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

The nuclear power plant model has been developed.

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

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

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

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

The current efforts, we're in what I would hope are the final assessments. We're going through those assessments now to determine the associated uncertainties and biases. Once we have done that, again, we will have another peer review of those assessment results to basically finalize it, we hope. And we're also in the process of developing the software for performance of the statistical plan analysis. We have, again, bringing in outside support. We've got statistical support being provided by Dr. John Jaech.

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

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

MR. O'DELL: Right.

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

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

MR. WALLIS: Kind of implied feedback loop there.

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

MR. WALLIS: That was going back to the question I sort of asked earlier. I see control volume drawn and an equation derived from the control, but it really doesn't have anything to do with the kind of control volumes I'm going to see in a reactor. And I have a question: why didn't someone say these are the kinds of control volumes we're going to have in a reactor? This is why we have this equation, which works on all of them, and when it doesn't work, how do you fix it? I'd like to see something like that rather than seeing control volume, which is sort of academic for straight pipe or something or the nozzles. This really isn't related to the engineering component.

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

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

MR. O'DELL: Okay.

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

MR. O'DELL: And I would agree with that. We're not doing it as part of our submittal. You will get a document that says this is how we build the plant model; this is the volumes that are in the plant model; these are the correlations that you use when you're running the realistic loca calculations. So, you will have a document in front of you that says we turn on these correlations, and this is the way we model the plant.

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

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

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

MR. O'DELL: Okay.

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

MR. O'DELL: Right.

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

MR. O'DELL: And really, we've gone through that process. It may not be documented in the current documentation that way, but you obviously go through that process, because when you're putting together the plant model, you're deciding which one of these correlations that you're going to turn on and which ones you're not going to use.

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

MR. ZUBER: See, let me say something. Eventually -- not this year but maybe in three or four years -- there will be a need to fit the safety markets, I mean, to come closer to increase the power. Then, you have to really know what is the effect of these assumptions? What is the effect of this approach? And I think if you do it to standard, you see, what you are really doing, you are really relying on something which was developed 30 years ago, RELAP and TRAC. At this stage, you could prepare a document or something which you provides a better basis for what you are doing, that says I am using this because of this, this, this, this and this, and the results is this. And then, you are in a much better position. You are addressing the problem from the beginning, not to try to justify at the very end. Because you are doing something which was developed 25 years ago. And you are going to use this something which you have the corporate environment for the next 25 years, and you have to think about that.

MR. O'DELL: I understand.

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

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

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

MR. O'DELL: Right.

MR. SCHROCK: And a lot of what you've talked about here is emphasizing large-break loca. Is this going to be a subsequent review in your review?

MR. O'DELL: Yes, yes.

MR. SCHROCK: In what time frame?

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

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

MR. O'DELL: Exactly.

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

MR. O'DELL: Yes.

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

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

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

MR. WALLIS: Thank you very much.

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

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

In closing, the S-RELAP5 upgrade of the safety analysis methodology is very critical to Siemens Power Corporation supporting our customers with the operation of their nuclear power plants and their requirements. For the realistic large-break loca methodology which Larry O'Dell stated we'll submit in September, we request a timely review of that with the targeted approval by early 2002.

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

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

[No response.]

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

[Recess.]

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

Back to you, Ralph.

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

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

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

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

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

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

MR. ANDERSEN: That is correct.

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

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

MR. WALLIS: Are these very large?

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

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

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

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

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

MR. KRESS: The gang of four?

MR. LANDRY: Minus one.

[Laughter.]

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

MR. KRESS: You guys are busy.

MR. LANDRY: We're scrambling.

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

[Laughter.]

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

MR. POWERS: Okay.

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

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

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

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

MR. KRESS: To look at the material.

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

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

MR. LANDRY: That is correct.

MR. KRESS: Basically?

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

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

MR. LANDRY: Yes.

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

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

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

MR. CARUSO: Well, one other thing we do is, and we've done this a couple of times in the last couple of months, is we send people to the licensee's site to actually look at the documentation, and that has turned out to be very useful, because there, they can get at the actual source documents and the people there to answer the questions: why did you write this down this way? And we're doing on-site reviews in some cases.

MR. POWERS: Okay.

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

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

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

MR. POWERS: Yes.

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

MR. POWERS: Yes.

[Laughter.]

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

MR. WALLIS: You don't have a standard review plan. If you had one, and if it had items in it such as every correlation must be checked for its application to full scale, the reactor on the conditions, and this might take you more than a month to just do that. If you had all of these items really seriously listed out on a standard review plan, and you did them conscientiously, you might find that it took a long time.

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

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

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

MR. LANDRY: We're going in that direction with the SRP and with the reg guide as soon as those get out.

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

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

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

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

MR. WALLIS: I'm following you.

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

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

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

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

MR. LANDRY: Right.

MR. WALLIS: I see.

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

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

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

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

MR. ZUBER: But this surprise to me today is when I hear the staff, which is supposed to do a review, arguing where the shortcoming is, okay. This is not necessary to address, because the outside public is not involved, and there is no interest in objective knowledge. I think at that level, this is a standard which NRC should maintain. And then, we should really justify -- if you have an error, address and justify why you can -- not just this is okay; approximations are okay. That's the wrong approach for a safety agency like NRC. I think my surprise or shock is just looking at it today addressed at that level. It's a sad, sad testimony for this agency if you proceed along these lines.

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

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

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

MR. ZUBER: Nobody argues that.

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

MR. ZUBER: How you can defend it.

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

MR. WALLIS: To go back to Dr. Zuber's earlier point, there's a difference between an approximation and an error, and I think one of your standards has got to be that you don't let something go through which some independent person then -- and he tells a graduate student to look at later on and say that's all of this that you want.

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

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

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

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

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

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

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

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

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

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

MR. LANDRY: Yes.

MR. WALLIS: No.

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

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

MR. LANDRY: That is correct.

[Laughter.]

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

[Laughter.]

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

[Laughter.]

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

MR. POWERS: No.

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

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

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

[Laughter.]

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

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

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

MR. WALLIS: Are we ready to move on?

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

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

TRACG, we view that as a realistic code for BWR transient, and we realistic -- I mean, a code that has as little bias as possible and as small uncertainty as possible.

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

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

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

This material is probably familiar to you. TRACG is based on the TRAC code that came out of the national lab. These particulars were solved in the corporation; it was beautiful GE and Idaho National Engineering Lab in the late seventies and early eighties on the development of the BWR version of TRAC, and that's the basis for this code. It has a multidimensional model for the vessel that allows two- and three-dimensional simulation of the flow in the reactor vessel component. For the remaining internal BWR components like channel, guide tubes, jet pumps, separators, the one-dimensional model is used.

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

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

The code has been extensively qualified, and we have done that in four steps, starting with the separate effects test; done qualification and begins component data that involved full-scale BWR component and a core system effects test that is a scaled simulation of the BWR; and finally, particularly in support of this submittal, we have done an extensive amount of assessment against full-scale plant data. We have a large quantity of full-scale plant data available from plant startup testing and various events that have occurred at operating reactors, and we have used that in our assessment of the code.

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

MR. ANDERSEN: Reactor internal pressure differences.

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

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

TRAC has been used in the past for numerous applications, and I just want to point out that the code has been around for a long time. It was used in the eighties as the benchmark for SAFER. It has been used to address issues that have come up over the time, such as the time you're in axial power shape. That's used for transient. It was used extensively for evaluation stability following the LaSalle event in 1988. It has been used for the ABWR and numerous other applications, particularly, I want to point out the SBWR. It was used extensively on the SBWR project and was reviewed extensively by the NRC staff as part of this project.

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

MR. WALLIS: What does Nordic mean here?

MR. ANDERSEN: Excuse me?

MR. WALLIS: What does Nordic mean here?

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

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

These are the same events that we are currently licensing with the ODYN/TASC code that are design codes in use today.

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

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

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

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

MR. ANDERSEN: Yes.

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

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

MR. ZUBER: I see.

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

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

MR. ANDERSEN: Yes.

MR. ZUBER: You will ask for approval.

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

MR. ZUBER: Where have you included it?

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

MR. ZUBER: Where is it included?

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

MR. WALLIS: For these legal things.

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

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

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

MR. ANDERSEN: I can answer your question in two parts. There is an SER that has been issued by the NRC on applications to the option three plant, and TRAC is approved in that SER for some stability applications. So part of the applications of stability has already been approved. Whether we want to submit applications for NRC approval beyond the AOO is something that we may do in the future, but we have not made a decision on that.

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

MR. ANDERSEN: Right now --

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

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

Okay; the reasons we are doing it are we are combining the analysis of the AOO transient into a single code. Right now, to do the analysis, we are applying a series of four or five computer codes, so we eliminate the potential in errors in the data transfer between the codes. I also think we are getting a better analysis of and understanding of the process, and this would include all organizations: utilities, vendors and the regulatory organizations.

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

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

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

MR. KRESS: Sure.

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

MR. ANDERSEN: This is the version that was developed as a result of the cooperation between Idaho National Engineering Lab and General Electric. We worked together to develop the BWR version of TRAC, and that was the joint project between GE and Idaho National Engineering that lasted up until probably the mideighties. After 1985, we made a number of additions to the code; probably most important for this application is that we incorporated the 3D kinetics model that's consistent with the GE design methods. At that point, the only kinetics option that was available in TRAC was the point kinetics model.

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

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

Okay; I'd like --

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

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

I'd like to just point out that the major differences between the currently approved process and what we are proposing to do with TRAC, that we have the same objective of scope as if we want to use it to calculate the operating safety limit. Currently, we are using a set of code. The two dominant codes, main code is ODYN and TASC, where ODYN calculates a core average power response, and then, we use the TASC code to calculate the limiting hot fuel bundled response in the core and, in particular, calculate the transient CPR response for that channel.

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

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

There are three of those tests, and that is what is used to determine the uncertainty. What we are doing here is that in TRAC is that we have said, well, a more rigorous approach is the CSAU type approach, and we are following that type of approach where we go through the CSAU step by starting at the individual model uncertainties and finally coming up with a combined overall uncertainty. And then, we go back and do the comparisons of the plant data like the tests in order to confirm that when you apply that statistical methodology, you actually bound the plant data that we have.

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

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

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

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

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

MR. SCHROCK: For all of them?

MR. ANDERSEN: Yes.

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

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

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

MR. ANDERSEN: We have very few options in this particular version of the code. There are a few options for some of the models. For example, at the separator, we can choose between the two-state and the three-state separator, because there are variations between the plants. We can choose between different critical power correlations because they are fuel-type dependent, but we don't have several different correlations for a given heat transfer regime. We have put in the one we believe is the best, and that's the only one that's available.

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

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

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

We have done extensive assessment to quantify and determine the code uncertainty, and again, we have several effects components, integral and full-scale plant data, and again, we did a cross-reference to the PIRT table, and all of that is included in the application methodology report in order to make sure that everything that was medium and high importance were included in the qualification basis and also that we had the data that allowed us to quantify the accuracy of the code for the statistical assessment.

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

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

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

MR. ANDERSEN: Yes; that is in the application methodology report. And essentially, for the critical safety parameters, we have determined a one-sided statistical limit as the bounding value for that parameter, and that is demonstrated in the application methodology that we have submitted. We have, in the application methodology report, we have included the PIRT tables. We have quantified the uncertainties. We have done the sensitivity studies for the plant to show which parameters really are important and affecting the critical safety parameters and which are not, and we have demonstrated the applications of the statistical methodology on actual plant calculations.

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

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

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

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

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

[Laughter.]

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

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

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

[Laughter.]

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

Similarly, for the assessment, which are the assessments that demonstrate the applicability of the code to these events? A cross-reference between the PIRT tables and the assessment will show what is important in the qualification report. The model description and the qualification reports are revision two of those reports. Earlier revisions have been submitted to the NRC and were reviewed as part of the SBWR program. What we have done is that we have expanded on the descriptions; we have tried to address all of the questions that were asked during the SBWR review and incorporated the response to those questions into the document, and that's what's in revision two.

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

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

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

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

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

MR. WALLIS: Right.

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

MR. WALLIS: Right.

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

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

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

MR. BOEHNERT: Yes.

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

MR. BOEHNERT: Yes.

MR. ANDERSEN: So --

MR. WALLIS: Somebody failed to remove it?

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

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

So, in summary, the scope is application to BWR226 transients. We have met and intended to meet all of the regulatory requirements that are specified in the general design criteria appendix A and B. We have demonstrated the applicability of the model for these events. There has been extensive prior reviews and acceptance of TRAC, and we have addressed the comments that we have received as part of those prior reviews.

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

Thank you.

[Pause.]

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

[No response.]

MR. WALLIS: The committee is remarkably silent.

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

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

MR. ZUBER: The thing of my concern was the attitude, the attitude that errors can be just glossed over.

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

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

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

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

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.]

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

[Laughter.]

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

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

[Pause.]

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

You are the first to see this view graph. We just put it together this morning. This is kind of the general structure of the thermal hydraulics work. As I say, we want to review the prior PTS studies just as a baseline, and the idea is to try to decide what revision on these to those prior studies, and we do this together with the revisions to the PRA work, the prior PRA treatment of PTS that was done at the same time in conjunction with these studies to see what transients we need to reanalyze, and the idea is we review these calculations, and then, this is an iterative process between us and the PRA people as to how this feeds into our view of the risk-dominant sequences.

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

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

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

MR. BESSETTE: The PRA people will discuss that.

MR. ZUBER: Today?

MR. BESSETTE: Tomorrow.

[Pause.]

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

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

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

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

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

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

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

MR. BESSETTE: Not yet.

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

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

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

MR. ELTAWILA: I think the experiment, this protocol, the experiment at the APEX facility is very important, because we want to look at the variation in the temperature in the down comer, because, as you know, the FAVOR code is a two-dimensional code, and if there is a large variation in the down comer, it might have impacts on additional development in the FAVOR code that we might have to go 3D. So, I agree with you that we really need to get this data as soon as we can and hopefully today, after you hear the presentation from Jose about the scaling analysis for that experiment and we get your endorsement, we'll try to run these tests as soon as we can.

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

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

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

MR. BESSETTE: Well, the immediate --

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

MR. BESSETTE: We may use it. We have to discuss it still. But the reason that we've focused so far on APEX is it looks very much like a CE plant, and the -- let's say the first plant in line in terms of PTS is Palisades, which is a CE plant, and it's configured quite closely to APEX, and that's why this has been the focus of initial attention, but we haven't -- I think we were thinking about using Maryland for PTS testing. We haven't formulated anything yet.

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

MR. BESSETTE: No, it's not.

MR. ZUBER: You are right.

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

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

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

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

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

[Pause.]

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

MR. BESSETTE: Yes.

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

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

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

MR. BESSETTE: Well, this is by way of background. So, this goes back to one of the key principles in terms of why we worry about PTS is that they can't allow the vessel to fail, and this led, in 1966, to the establishment of the heavy section steel technology program at Oak Ridge and continued attention to assure vessel -- the probability of vessel failure remains low. Until about 1978, it was postulated that the most severe thermal transient vessel experience would be following a large-break loca, and this just gives some description of what would happen in that event. But the mitigating thing with a large-break loca, of course, is there is no pressure on the vessel.

[Pause.]

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

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

[Pause.]

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

So, following the Rancho Seco event, the pressurized thermal shock was designated as an unresolved safety issue A-49. So, the basic idea is should an overcooling event occur in conjunction with high pressure in an embrittled vessel in an existing flaw, the potential exists for that flaw to propagate into the vessel wall.

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

[Pause.]

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

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

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

MR. WALLIS: Is there steam there?

MR. BESSETTE: There can be steam at times during the cold break or during the small-break locas. So, you can either have steam up here, steam, water and then steam, hot water and then cold water or just hot water and cold water.

But although this is stratified, there is some pre-heating that occurs.

MR. WALLIS: This is a strange picture, because the cold water comes in usually, as I remember, with such velocity that it actually swells up around the sides of the tube. It doesn't just go and lie on the floor.

MR. BESSETTE: Not all the time. In the CE and the Westinghouse plants, this velocity is not that high. It's on the order of a couple of feet a second or something like that.

MR. WALLIS: It's a bigger pipe.

MR. BESSETTE: It's a big pipe. It's about -- yes, an 8 or 10 inch diameter pipe. So this pipe, the thing is -- the high pressure injection line comes into this pipe, which is sized for low pressure injection. So this pipe has been sized for a flow rate 10 times the high pressure injection flow, so that's why the velocities are not that high.

And then, you have this mixture region three or mixing region three, where the flow comes in and makes this turn as it enters the down comer, and then, you have this -- that's this region here. Then, you have a plume dissipation region, and then, you end up with some uniform temperature distribution all the way around the down comer at some --

MR. SCHROCK: What does TJ represent?

MR. BESSETTE: TJ is -- let's see.

MR. SCHROCK: You have the --

MR. BESSETTE: Oh, here?

MR. SCHROCK: Yes.

MR. BESSETTE: Yes; the temperature of the jet as it enters the down comer from the cold leg.

[Pause.]

MR. WALLIS: Is this based on someone's imagination or on something else?

MR. BESSETTE: Well, it's reality, actually.

MR. WALLIS: This is based on experiments?

MR. BESSETTE: Experiments show the same thing. The fluid mixing experiments show this kind of behavior. The one thing to point out, though, this region here is not present in BMW and CE plants, because BMW plants, the cold leg comes this way, and then, it inclines like this before it gets to the pump. So there can't be any back flow. And the CE plants have some kind of a dam here which prevents back flow. So, this mixing region is not there for those two vendors.

MR. SCHROCK: It looks almost like TJ is defined as the temperature, sort of the incoming flow and reaches the position 2BCL on the left hand side.

MR. BESSETTE: Yes; and theo, of course, differentiates this entrance region from the plume dissipation region, and this is also how REMIX works. This is exactly how REMIX works.

MR. WALLIS: I think while there are boundary conditions, such as pressures and flows in the ends of these things that have to be specified in some way, that changing with time.

MR. BESSETTE: Well, the pressure basically -- well, for the purposes of REMIX or for any of this, once you have flow stagnation, pressure is essentially uniform, as everything is being driven by gravity.

MR. WALLIS: Well, this is where small pressure differences, though, could make a difference, so essentially uniform needs to be described properly, because it may be that if your gravity head at one foot is driving a flow, then, the pressure drops half a PSI, it becomes very significant.

MR. BESSETTE: Yes, but, of course, the only way to generate the pressure drops at that point is by the flow itself.

MR. WALLIS: I'm not sure you can predict that that accurately anyway. I mean, you have a lot of uncertainty associated with it when it's near stagnation. There's a little change where it could go this way or that way.

MR. BESSETTE: Well, if you're talking in terms of TRAC or RELAP, you can get numerical noise that is significant with respect to these.

MR. WALLIS: Well, RELAP may well be predicting that this is banging around the bottom, because there are just lots of numerical oscillations in the code itself.

MR. BESSETTE: Yes, that's what I mean.

MR. ZUBER: I have two questions. That TJ, if you have in these two regions and this mixing and dissipation region, that could be that as it is now, this is only depending on the geometry. I think that mixing the regions should also really depend on the flow.

MR. BESSETTE: The flow velocity.

MR. ZUBER: Yes, right.

MR. BESSETTE: Yes.

MR. ZUBER: So, I think this is a shortcoming, or it may not be, but it should be looked into.

And the second thing is how sensitive; how sensitive are the results to that temperature?

MR. BESSETTE: Yes; of course, you know, what REMIX does, this makes a simplifying approximation as to what's going on.

MR. ZUBER: I know, you see, but the point is -- my question is, I mean, you're right; we're discussing REMIX, but apart from it, you would expect, you know, not only to depend on the geometry on the two diameters. It would depend on the flow.

MR. BESSETTE: Yes.

MR. ZUBER: And, okay, so, the point is if that thing doesn't make much difference, that's fine. I mean, the approximation may be quite good. On the other hand, if the results are sensitive to TJ, then, this approach, the initial thing it does, this might not be too good.

MR. BESSETTE: Well, I think, as you said, I think probably, you can show that -- not today, perhaps, but we can show eventually, I hope, that once we get down to this region, down to this elevation, this -- that mixing region three, whatever it's called, is up here, and once we get down here, according to some of the fluid-fluid mixing data, it looks like this temperature is going to uniform around the circumference of the vessel, that already, the plume will have dissipated by here. There's enough mixing.

MR. ZUBER: What were you saying that the TJ ratio has not much influence?

MR. BESSETTE: Well, in terms of REMIX.

MR. ZUBER: The question is not about information experimental you have, I mean, to justify it.

MR. WALLIS: That sort of surprised me, because usually, fluids look like your fluid here. They don't spread very rapidly. And so, it's hard to imagine something being fully mixed when it's only gone a couple of diameters.

MR. BESSETTE: Yes; well, you notice a further constraint here in that the gap width is about 8 or 10 inches, and probably the incoming plume is of the same order, the same dimension in terms of its diameter. And so, when it comes in, of course, it hits against the core barrel, and there kind of is a tendency for it already to start spreading circumferentially from that. So, it's not an unconstrained plume. It's constrained in one of the dimensions.

MR. ZUBER: But that spreading will also depend on inflow.

MR. BESSETTE: Yes; the higher the flow rate, the more spreading --

MR. ZUBER: Yes; but the point is, then, the question is really what is the effect on the flow rate on TJ?

MR. BESSETTE: Well, we have experimental data from different flow rates in the database.

MR. WALLIS: It looks like an easy experiment to do.

MR. BESSETTE: Yes, and that's why it's been done.

[Laughter.]

MR. BESSETTE: So, just to keep on with the history of this, the integrated pressurized thermal shock study, this was done in the early 1980s following this Rancho Seco event and the establishment of it as an unresolved safety issue. The research program was initiated to develop a technical basis for a pressurized thermal shock rule to aid in the development of guidance for plant-specific analysis as well as acceptance criteria for proposed corrective actions.

The objective of that study was to provide an estimate of the probability of a crack propagating through the wall; determine the most dominant -- risk-dominant over cooling transients and also to investigate the effects of plant features and operator actions on the event and also to determine the effectiveness of potential corrective measures in terms of changes in the way the equipment set points or the operator procedures.

There was one plant selected from each of the three vendors, so, for BMW, there's Oconee 1. For combustion engineering, it was Calvert Cliffs. And for

Westinghouse, it was H.B. Robinson, which is a three-loop plant. I said this is called the integrated pressurized thermal shock study. These studies for these three plants were all published in 1985.

[Pause.]

MR. BESSETTE: So, the result of that was this current regulatory basis that we have today that is described in 10 CFR 50.61, which is fracture toughness requirements for protection against pressurized thermal shock events and reg guide 1.154, which is this accompanying guidance format and content of plant-specific PTS analysis reports. It's interesting that this rule doesn't really have -- say anything about thermal hydraulics that has focused on the fracture toughness considerations and embrittlement considerations, but the reg guide does have a section that deals with how you analyze these events from a thermal hydraulic perspective.

MR. SCHROCK: What is the basis for the setting of a requirement in 10 CFR? Do you have any idea?

MR. BESSETTE: Well, it's the -- it's -- the basis was tied up into this outcome of the integrated study that was done at the time, that involved considerations of risk; the thermal hydraulics calculations; and the -- what was known about vessel embrittlement and flaw distribution and orientation and density. So, in back of it, there's some consideration of limiting the probability of vessel failure from a PTS event, and embedded in that, so that was the governing objective.

So embedded in that is some probability of getting to a low -- probability versus -- probability of getting to different temperature, different minimum temperature. So, there's a rationale in back of it that includes considerations of PRA safety goal and the thermal hydraulic analysis. I don't know if that's clear or not.

[Pause.]

MR. BESSETTE: So, the objective of the current re-evaluation effort for thermal hydraulics is to ensure that for the risk-significant classes of events, you know, and this again involves some interaction between PRA and thermal hydraulics and fracture mechanics, the thermal hydraulics inputs developed at the time in the IPTS study are still operative or otherwise corrected and updated as needed and that additional, the objective is to provide an estimate and a certainty in these thermal hydraulic calculations.

MR. WALLIS: You say risk-significant. Do you mean the measurement in terms of likelihood or measurement in terms of consequences?

MR. BESSETTE: Well, it's probability and consequence.

MR. WALLIS: The conservative view is to say we'll just make sure that the things that have big consequences, the likelihood is so remote.

MR. KRESS: I think you said in some of the writings that it was the risk-dominant sequences, so it's based on risk-dominance.

MR. BESSETTE: It's based on risk; it was based on a probability of a given scenario times the consequence of that particular scenario.

MR. KRESS: And there were just three or four sequences that made up 95 percent of the risk.

MR. BESSETTE: That's right; you know, they started -- when the PRA people did the fault tree analysis, of course, they started with the thousands of scenarios, and then, about a dozen were analyzed with the TRAC or RELAP. now, of those dozen, typically about two or three for each plant that show up as dominating the risk.

MR. ZUBER: I've got a question. While you say the steel operative, the first bullet --

MR. BESSETTE: That means that with the calculations we did back in 1985, do we still believe in them?

MR. ZUBER: Is there any evidence that you should not believe that?

MR. ELTAWILA: No, they are in addition to the changes in the code, there have been changes to the plant itself, you know, as a result of the PTS regional rule. They have made a lot of changes to the plant. So, you want to reflect these changes into our current analysis right now.

MR. BESSETTE: Yes, that's right.

MR. ZUBER: What about aging? Plant aging?

MR. BESSETTE: Well, the aging, I mean, that's really the vessel embrittlement. The aging doesn't effect the thermal hydraulics analysis.

MR. ZUBER: No, but I mean, the thermal hydraulic analysis together with the aging.

MR. BESSETTE: Yes, but the aging -- yes, the aging is strictly the embrittlement, you know, continued embrittlement of the vessel, in this case.

MR. ZUBER: I could say that much of the changes that you are getting are getting older.

MR. BESSETTE: Yes.

MR. ZUBER: And therefore, I mean, you have to have better accuracy in determining the thermal hydraulics. This will be one way of rationalizing it.

MR. BESSETTE: Yes; well, even in the earlier study, there was a model of the predicting vessel embrittlement with continued fluence and tracking, you know, the fluence, the cumulative fluence to the vessel -- I guess fluence is cumulative, but the cumulative flux to the vessel is tracked and calculated, and so, and it's predicted to the end of life of the plant.

And there is the correlations between fluence and embrittlement that are projected out to the end of the plant. So this is tracked on a continuing basis. So, that's taken into account into the models, and, of course, the models are continually reverified or updated as --

MR. ZUBER: But you're not setting them up in the thermal hydraulic models, are you?

MR. BESSETTE: Not seeking which?

MR. ZUBER: Somehow, I don't know really the justification. Is the problem the reason why you are revisiting this problem is because originally, the thermal hydraulics model was insufficient, or you developed doubt in the models; then, you'll need a better approximation?

MR. BESSETTE: Well, I don't see any particular problems in the thermal hydraulic calculations for the most part that were done at the time.

MR. ZUBER: Then, my question, then, is why do you need this program?

MR. BESSETTE: It's more of a matter of there have been changes in the probability of different sequences due to changes in operating procedures and the way the plant -- the operations, then, controls of the plant.

MR. ELTAWILA: Can I -- I don't know if I'm going to answer your question or not, but in the original study, the fracture mechanical uncertainty was the most dominant part of the transient. So the emphasis on thermal hydraulics was not that great, and the -- you know, we did not really sharpen our pencil and try to get a better answer, because it was limited on -- because of the fracture mechanics.

Now, with the reduced uncertainty in the fracture mechanics, they are looking for a better estimate of the thermal hydraulic condition to be able to take advantage of all of the realistic assumptions to see if we can come up with a better answer than what we came --

MR. SHACK: But I think the answer is that vessels are getting closer to the limit, and so, you know, they're looking for more margins.

MR. ELTAWILA: That is correct.

MR. SHACK: You know, it's a very practical sort of problem for at least, you know, 10 or so plants.

MR. BESSETTE: Yes, and the other thing is that I think most plants are looking for life extension, and that's one of the issues there, too.

MR. ZUBER: So, to sum it up, you need better calculating tools for thermal hydraulics.

MR. BESSETTE: Well, of course, like Farouk said, all along, the large majority of the uncertainty has been embedded in the fracture analysis. But, you know, still, people want to know, well, what is the uncertainty in the thermal hydraulics, and what portion of the total is this?

MR. ZUBER: Okay; and then, the expression will be a numeric -- think about it. The improvements you plan to do, by how much you would improve your uncertainty calculations, by how much you have really to push it to bring these two things together.

MR. BESSETTE: So, I don't think the codes today will give much -- for the same input, for the same transient, I don't think the codes today will give a very different answer than they did in 1985.

MR. SHACK: But when I looked at that round robin study, you know, and I saw heat transfer coefficients that ranged from zero to 10,000, you know, as the people did the calculations the different way, yes, the same code run today will probably give you the same answer it did, and if it was wrong then, it's probably still wrong today, I mean, but you seem to get a variety of answers depending on how you analyze the problem.

MR. BESSETTE: Well, yes; if you vary it from zero to 10,000, but if you vary it over a realistic range of, say, 1,000 --

MR. SHACK: Well, that's what the code predictions were giving you when they did that analysis with the 21 people or whoever did it. Now, yes, I mean, maybe some of those guys were producing rubbish; I don't know.

MR. SCHROCK: Probably.

MR. BESSETTE: You know, if you give them --

MR. SHACK: Well, the thing was they were all predicting the kind of gross features; those were all narrow as could be. Then, when you got inside the plume, and you looked at the heat transfer coefficients, they went everywhere.

MR. BESSETTE: Yes.

MR. ZUBER: But, no, the reason for my question here is you have a set of data as a calculating tool for the last 15 years. Now, we want to do something more. The question is why, and then, once we determine why, then, you have to see how far, what kind of improvements, what kind of refinements, I would need, and can I achieve them? I think this sets your program into a perspective.

MR. WALLIS: I think what Novak is asking for is the focus of the research. It's easy to say we'll do research to measure all this stuff, but what's the output, and how good does it have to be? Where are the improvements really going to have a payoff and so on is I think what we're asking.

MR. ZUBER: That's the point.

MR. BESSETTE: Well, in my view of it, like I said, I don't think the codes have changed. If you give the code the same transient, I think it will give much the same answer today.

MR. WALLIS: Be careful to specify your output, because if you give it to a university, their objective is to get a Ph.D. out of it.

[Laughter.]

MR. WALLIS: The criteria for that are quite different sometimes than your criteria, utility.

MR. ZUBER: See, this raises the question of what kind of data, first, what kind of data do we have in REMIX? What is the database? What is the database 10 years ago to verify REMIX? What kind of data do I need to improve REMIX? Or do I need such data? And what kind of improvement do I have to do?

MR. BESSETTE: Well, I don't think I can cover all that today. I think there is a pretty good database for REMIX.

MR. WALLIS: I guess next time we see you, we'll expect you to have a really good answer to that.

MR. BESSETTE: Yes; I mean, I can answer that question.

MR. ZUBER: See, when I was reading the thing I got from Paul, I had all my questions here.

MR. BESSETTE: Yes.

MR. ZUBER: This is one question.

MR. BESSETTE: Because I've looked at the REMIX assessment, and, you know, I've looked at REMIX and the REMIX peer review, and, you know, it's okay.

MR. ZUBER: Well, to some extent, it's a volume average thing, and the question is really how do you do it? What kind of changes do you have to put in the REMIX to obtain a better answer?

MR. BESSETTE: The other thing about this, too, is I think we can show, like I said before, I think we can show -- I mean, the whole idea behind REMIX is to model the nonuniformity of the temperature, the stratification which was not really considered in the first PTS study back in 1985, and it tended to arise while this study was going on, and then, a lot of experiments were done afterwards.

MR. ZUBER: You see, what would be really helpful to me is if you said okay, this is where we were 10 years ago; this is the set of data, and this is the codes. These were the short comments I would like to improve for the next 10 years or something, something really -- I know, what are the deficiencies in the REMIX, in that data which were used to verify REMIX and then what changes I have to do? This would have specified what kind of experiments you have to perform.

MR. BESSETTE: Yes; well, I hope to be able to explain that to you someday.

MR. WALLIS: I'm not sure we're going to get it today.

MR. BESSETTE: Yes, but not today.

MR. WALLIS: We should probably go on, but we're going to ask this question again.

MR. BESSETTE: You know, but that's the purpose of, like, this box here and these boxes here.

MR. ZUBER: This is actually, before you start, you have to see where I am now; how good it was; what kind of improvements I have, and this would then set your -- what kind of tools do you have?

MR. WALLIS: And where do I want to be in the future.

MR. BESSETTE: Yes.

MR. ZUBER: And where do I want to be in the future.

MR. BESSETTE: Well, I think from what I know of REMIX, I think it's satisfactory.

MR. ZUBER: But I'm not sure, because 15 minutes ago --

MR. BESSETTE: Yes.

MR. ZUBER: -- I saw it. It may have been good for the purpose it was developed. Is it good for where you want to get now?

MR. BESSETTE: Well, like I was saying, too, you know, REMIX, the intent of REMIX was to model this temperature nonuniformity, and like I said, I hope to be able to show convincingly that by the time you get to the region of interest down here, you have a uniform temperature axially.

MR. ELTAWILA: It wasn't one of the problems that was identified, and that's why we want to do this additional analysis, is that in the original IPTS study that they predicted flow stagnation by the code in certain cases, and for other cases, they did not predict flow stagnation, and they dismissed the scenario based on this analysis without any supporting experimental data. The code predicted, so it was okay that it was predicted, and that's why we would try to verify some of this -- the basis for -- that some of these analyses really were based on actual physical evidence. Is that something that you were looking at in this program or not? Isn't that part of the work that we will be doing at OSU?

MR. BESSETTE: Yes, I think so.

MR. ZUBER: I think Theo did some experiments with salt.

MR. BESSETTE: Yes; I'll talk about all of the experiments that have been done with fluid-fluid mixing. I won't talk about them all in detail, but I'll list them all, at any rate. So I'll come to that.

So, what's our input to, say, the Oak Ridge people to the FAVOR analysis? We had to supply them three boundary conditions: the system pressure, the downcomer temperature and the region -- axial region corresponding to the core and a wall -- and a fluid-to-wall convective heat transfer coefficient. So we've got to tell them whether it's a zero or a 10,000 or something in between and some uncertainty estimate in these three parameters.

MR. WALLIS: These are a function of time and also location. The temperature isn't uniform.

MR. BESSETTE: That's right; we gave them like a next --

MR. WALLIS: How precise do we need to be in our sort of --

MR. BESSETTE: Nodalization?

MR. WALLIS: -- nodalization for temperature and -- presumably, there's one place where everything is the worst.

MR. BESSETTE: Yes.

Now, so we have these three parameters. They're not necessarily independent from each other, but their dependencies are not, let's say, not constant. They're varying as a function of time and conditions during a transient.

But given these parameters, what can the codes do? Well, system pressure is something that's generally calculated reasonably well with TRAC or RELAP.

MR. WALLIS: You're not going to revisit that one, are you?

MR. BESSETTE: Not too much, no. Not through any experiments or anything. That's -- because this is a global -- some kind of a global measurement of energy.

MR. WALLIS: That's not a part of your research program, to investigate that boat.

MR. BESSETTE: No; this is what I say we do fairly well right now.

I think we can calculate down comer temperature reasonably well, too, either using TRAC or RELAP or some combination with REMIX.

MR. ZUBER: I have a question. I just heard that the temperature can go all over the place.

MR. BESSETTE: No; he said they use heat transfer coefficients from zero to 10,000.

MR. SHACK: No, they predicted those from the model.

MR. BESSETTE: Yes.

MR. SHACK: That's what they were predicting for the fluid to wall convective heat transfer.

MR. WALLIS: They actually predicted zero?

MR. SHACK: Yes; very low.

MR. BESSETTE: Pretty hard to get zero.

MR. SHACK: I'm only reading the report.

MR. ZUBER: What was measured? What kind of variation temperatures were measured?

MR. BESSETTE: Are you talking about in terms of assessing the code now?

MR. ZUBER: No, in terms of experiments.

MR. BESSETTE: Oh, in terms of experiments.

MR. ZUBER: In terms of experiments, I have some thermal couplers; I have measurements; then, you have the scatter and oscillations.

MR. BESSETTE: Yes; well, that's part of the reason for the experiment at APEX is they've got additional data on this, and I have to go back and look at the record more with respect to, say, the ROSA test that we've analyzed so far.

MR. ZUBER: But in ROSA, you would not have that kind of details.

MR. BESSETTE: But they have a fair amount -- they have about thermal couplers distributed throughout the down comer.

MR. ZUBER: How many thermal couplers did Theo have?

MR. BESSETTE: He didn't use thermal couplers, I guess.

MR. ZUBER: For the salt.

MR. BESSETTE: I don't know how many measurement locations he had off hand.

MR. WALLIS: Well, you're saying you need to get H&T, but then, you also say the plumes have dissipated so that they aren't -- it looks to me as if they've dissipated, none of this matters, does it?

MR. BESSETTE: Well, you still need an H&T, but what you have is more of a global as opposed to a location-specific. So this is important to the Oak Ridge people, because they have a one-dimensional -- their code right now takes a one-dimensional temperature input and not a two-dimensional.

MR. WALLIS: Well, when the plume mixes, there's no more cold water, is there? It's all sort of the temperature of everything else.

MR. BESSETTE: It's a mixed-beam temperature, ambient, you know, it's a mixture temperature you end up with.

MR. SHACK: But you're still going to have a difference to the wall, so that there's a thermal stress, and the wall is undergoing a transient. The temperature has changed.

MR. BESSETTE: Yes; and that doesn't mean that the whole -- just because it's well-mixed, that doesn't mean the whole down comer can't get cold either.

MR. WALLIS: Well, my impression is that this program is fairly vague about the need for the work. We've asked you that already.

MR. BESSETTE: You're focusing now on thermal hydraulics.

MR. WALLIS: Why is it really necessary to do some more work? If we can reasonably predict these things --

MR. BESSETTE: Well, it's like I say: just because we're being asked to predict different scenarios than we did the first time around.

MR. HARDIES: This is Bob Hardies from Baltimore Gas and Electric Company, and I'm the chairman of an EPRI group that is working on this same problem. The program to reevaluate the basis for the PTS screening criteria is being undertaken largely because there is a lot of information that the flood distributions were extraordinarily conservative that were used in the prior analysis; thousands of flaws all put on the surface. There has been destructive analysis and a lot more work done that shows that that's not the case, and that has a very, very large impact on the risk, so the NRC has undertaken a program to revisit these bases. The thermal hydraulics analyses that were done before formed part of those bases, and it was deemed prudent to re-evaluate the correctness of that thermal hydraulics analysis work that was done in 1985, not to redo it but to sort of evaluate it to see if it's good enough or if it needs to be done over.

So this is not an extensive effort. It's merely to make sure that, as we go forward in re-analysis of the PTS screening criteria bases, we use something that is technically justifiable, well-documented, adequate.

MR. WALLIS: Flow distribution was very conservative. That's where the real payoff is.

MR. HARDIES: That's right. Now, this work is just to show that the thermal hydraulics work that was done before is adequate, that there's a good basis for it.

MR. BESSETTE: Maybe I should have said that before. There's probably at least two orders of magnitude conservatism in the flow assumptions.

MR. WALLIS: Errors in thermal hydraulics are only 10 percent.

MR. SHACK: Yes; they're minuscule in comparison.

MR. BESSETTE: And so, if you look at the relative level of effort in this three-pronged approach, most of it is going into the fracture, you know, the flaws and all of that. The second tier is the PRA, and it's -- the thermal hydraulics reanalysis is a relatively minor part in this.

MR. WALLIS: Usually, with the uncertainties in the PRA, you can make the thermal hydraulics uncertainties go away and move on.

MR. ELTAWILA: One more reason for the re-evaluation of the program; the temperature which was eventually produced at the 1983-1984 had 152 points of relationship between -- since that time, a much larger number of points has become available. At the same time, the pedigree, so to speak, of those original points was in dispute and could not be retraced or re-evaluated, so that basis has been reviewed entirely.

MR. BESSETTE: This one last bullet on this, we did a study that said that within a reasonable range of uncertainty in the heat transfer coefficient that the uncertainty in H is small with respect to this influence on the probability of vessel failure. And that's because this process is conduction control as opposed to convection control.

So in terms of the thermal hydraulics or the coupled thermal hydraulics and the convection and conduction, there are two characteristic times that are important. That is how fast you cool down the vessels that the liquid that's stuck in the vessel, in the down comer, and also how fast you cool down on the vessel walls.

So, just to give you an order of magnitude, this is a simple calculation where you just take -- this is the volume of liquid that you typically deal with that's contained in the vessel in the cold legs. It's about 60,000 kilograms, and initially, it's around 570 F or so. And this is the typical high-pressure injection flow rate. It's about 60 kilograms, and it comes in at about 70 degrees Fahrenheit. So, the time it takes under these conditions, the time it takes to cool down this water down to 300 degrees Fahrenheit, which is the first screening criteria you come to, is on the order of 15 minutes.

So once you initiate a high-pressure injection, once you interrupt natural circulation, the vessel is going to get cold in about 15 minutes, the water is going to get cold in 15 minutes. Now, then, the other thing is the vessel wall time constant. I'm going to show you some examples. It's three cases, just sort of arbitrary cases, just to give an idea of what kind of time constant this is for an 8 or 10 inch thick vessel. This shows a cool-down rate, the same cool-down rate in each case, from 550 to 150 degrees; same depressurization, from 1,000 psi to 600 psi and over three different time periods. In one case, this is a constant rate over 20 minutes, 40 minutes and 60 minutes. I'll just show these six figures in each case. Let's just show you these temperature and pressure histories.

That's the vessel hoop stress. That includes a residual stress; through wall temperature distribution at various times and hoop stress distribution at various times and also the ratio of the -- this is like a stress over the fracture stress.

So, that's a repeat case. One was the cool-down from initial, 550 down to 150 over 20 minutes. Then, this is a depressurization from 1,000 psi down to 600 psi over the same 20 minutes. This shows the -- what this does to the vessel tensile stress. There, you see the -- this is a stress that's due to pressure, and you can see how small this is. At 1,000 psi, you only have, let's say, less than 10,000 psi of stress on the vessel. So that's, you know, that's about 20 percent of the yield stress or something like that. So under normal conditions, the vessel pressure doesn't contribute. It's a very -- it's not -- nowhere near any kind of failure limits.

So, this is a thermal stress that you generate at the inner surface of the vessel over time, and this is the total stress.

MR. WALLIS: Before, you said that the vessel had to be pressurized, but it seemed to me that the thermal stress is the big actuator.

MR. BESSETTE: That's right.

MR. SCHROCK: It did sound like you said the opposite before.

MR. BESSETTE: No, no, it's because --

MR. WALLIS: So what is the matter if the vessel is pressurized or not? You can still get big thermal stresses.

MR. BESSETTE: Because you can't get the crack to propagate all the way through the wall. See, once you're cracked --

MR. WALLIS: Pressurize it again later on.

MR. BESSETTE: Well, yes, presumably, you look at it before you restart it.

If you just put a thermal stress on the vessel, it will crack until the stress is relieved, and then, it will stop. So you need the pressure stress in order to get that crack to go all the way through the wall. But you can see that the peak tensile stress at the inside of the vessel is still increasing when the -- at 20 minutes.

MR. WALLIS: There's nothing here about plumes or anything like that.

MR. BESSETTE: No.

MR. WALLIS: This is just to the model; everything's all mixed.

MR. BESSETTE: That's right.

MR. WALLIS: The plume would make things worse, I believe?

MR. BESSETTE: Well, you know, in all the input, like I say, was that temperature trace I showed you. It doesn't say anything about local or mixing or anything. This is just to illustrate the time constant of the vessel.

MR. WALLIS: The local cold plume presumably makes things --

MR. BESSETTE: Locally worse.

MR. WALLIS: -- the stress bigger?

MR. BESSETTE: It makes it locally worse.

MR. SHACK: Yes, I mean, you've got 15 minutes mixing the entire volume.

MR. BESSETTE: Yes.

MR. SHACK: Whereas, if you were only looking at a small down comer region, presumably, you could chill it a whole lot faster, couldn't you?

MR. BESSETTE: If you put an ice cube in one spot and held it or something.

MR. ZUBER: See, if you calculate that your 15 minutes is based on the mixed main temperature.

MR. BESSETTE: No, I'm not doing anything like that. I'm only showing you this to give you a feel for the time constant of the vessel.

MR. ZUBER: Okay; the vessel time constant. The mixing of the plume can be smaller than 15 minutes.

MR. BESSETTE: So let's forget about the plume for a minute.

MR. SCHROCK: This argument you make about leaving the pressure stress to propagate it on through raises a question in my mind as to whether you can really show this on a graph like this. Once you begin cracking, you do indeed relieve the thermal stress. You modify the geometry, and therefore, you change your thermal stress problem. You change the location of concern, and it's moving outward into positions of different thermal stress.

MR. BESSETTE: You're talking about a crack that makes --

MR. SCHROCK: Thermal stress itself is changing due to -- it's more complex than just playing one or the other. I think it's the hoop stress at the inner surface over time.

MR. BESSETTE: Well, I mean, are you thinking in terms of maybe a crack that propagates in steps or something? Or I'm not sure --

MR. SCHROCK: What I'm saying -- I'll try to say it one more time.

MR. BESSETTE: Yes.

MR. SCHROCK: You argued that you need this pressure stress in order to propagate a crack on through the wall --

MR. BESSETTE: Yes.

MR. SCHROCK: -- because the thermal stress relieves itself as soon as cracking occurs. The cracking also modifies the geometry for the thermal stress calculation, and it also moves the location of concern from the inner surface to someplace out in the thickness of the vessel.

MR. BESSETTE: Yes; let me show you something.

MR. SCHROCK: I'm questioning can you simply look at the thing in terms of stresses at the inner surface, a, from pressure bloating and, b, from thermal stress of an intact wall?

MR. BESSETTE: I'll jump ahead; I'll skip over one slide. This is the -- this is the stress on the vessel at, say, this direction as a function of distance through the vessel wall. This is the inside surface, and this is the outside surface. When you cool down a vessel or whatever, you put the inside in the tension that you see here, and the tensile stress increases with time as it's getting colder. You put the outside into compression, and it's similar to kind of, let's say, bending a beam where one side is going to be intentions and the other side compression.

So, when I say you can't propagate the cracks through the wall, as the crack starts to run, it runs into compressive stress.

MR. SCHROCK: Those stresses are calculated for the intact wall.

MR. SHACK: You better leave that for --

MR. ELTAWILA: Yes, Professor Schrock, I really think David would like to -- this is the subject of tomorrow's discussion. If you want to present something for illustration, lets go through them quickly.

MR. WALLIS: Yes; I'm wondering about this, because I looked at your slides, and they all seem to be talking about uniform mixed water, and I thought the whole issue was the plume, and I don't see where the plume is affecting anything. If you could tell us that you're uncertain about the plume, it jumps around a lot; that's where you're doing research. Help us. Where does the plume come into this?

MR. BESSETTE: This is totally different than my objective of showing this. What I wanted to show was that the -- you have to put a cold water on the inside of the vessel and keep it there for something like 15 to 30 minutes in order to develop, let's say, a PTS-significant stress distribution in the vessel.

MR. ZUBER: Okay; I can say if I have a plume, presumably, I can keep it there for longer than 15 minutes. The thing is the way I see the purpose, what would be the purpose of this research, everything depends on the plume, and if the plume moves down and keeps it for 15 minutes, I have a problem. If I can focus on the plume, what kinds of temperature and measurements you have, how you can model it, et cetera.

MR. BESSETTE: I'm going to skip the rest of these.

MR. WALLIS: I question what you're saying. You're saying that there's a time constant of 15 minutes or something, because we have to cool down all the water?

MR. BESSETTE: No, no, it's how long it takes to cool down the vessel in order to create a tensile stress on the inside, and also, you have to cool down the vessel. So, it's one thing to cool down the water in the down comer, but that hasn't done anything to you yet. You've got to cool down the vessel. The vessel really doesn't care what the water is. You have to cool down the vessel material itself to below 300 F.

MR. WALLIS: You have to cool down the surface of the vessel.

MR. BESSETTE: But not just the surface; you've got to cool it to a certain depth.

MR. ZUBER: You see, the thing is this. You're shifting two things. If you have a plume, and your argument is I would have that to make the heat, I mean, the conductions in the vessel, at a two-dimensional or three-dimensional rate. Is this what the fracture mechanics are doing or not?

MR. BESSETTE: I shouldn't have started any discussion of vessels with thermal people, with hydraulics people.

MR. ZUBER: No, look; my question is if what you are saying is you have to cool the vessel, and you have a plume, you would have heat transfer around the perimeter and vertically down. It's a three-dimensional problem.

MR. BESSETTE: Let's just forget we ever got into this.

MR. ZUBER: You ask do the fracture people need that detail or not? If they need it, then, you have to do a different kind of experiment. If they don't need it, you can forget it.

MR. BESSETTE: That's why I was talking before about -- that's why I wanted -- we were going to talk about, we're going to work on the plumes, and we're going to show that either the plumes are a significant thermal, you know, thermal -- either the plumes cause a significant circumferential variation in temperature, or they don't. If they do, then, you may have to do some kind of a 2D input to your -- instead of as a temperature boundary condition to your fracture code, instead of being a 1D temperature distribution, you might have to use a 2D if the plumes are significant. That's right, yes.

MR. SCHROCK: I don't think it's ever less than

3D. I don't know what you're looking at here. Do you mean to say that you believe that 1D stress analysis will give you a meaningful answer to this question?

MR. ELTAWILA: Can we talk about stresses tomorrow? Really, I don't like -- let me try to simplify the purpose of the presentation.

MR. ZUBER: I cannot follow it.

MR. ELTAWILA: Well, I apologize for that. I think the purpose of the presentation is to try to look at the thermal hydraulic condition, and we will try to get enough data to see if there will be a variation in the temperature in the axial and the circumferential direction and assess the code and see the magnitude of the variation, and we will see the effect of that magnitude on the heat transfer.

MR. ZUBER: Okay; my question, then, is do you have data from the experiments of Theo to support that you have this proof of this region -- they would be the first questions to ask. If you have the proof, then, you have to address the proof.

MR. BESSETTE: Well, I think we are not going to look just at the data from Theo but also from UPTF and the Finnish experiments and all the other experiments to do this and also the APEX experiments. But we're going to show one way or the other, the plume is significant or is not significant.

MR. ZUBER: Based on information that you have from Theo's test, is it significant or not?

MR. ELTAWILA: Not significant.

MR. ZUBER: Not significant?

MR. BESSETTE: Not significant; so far, all of the data we have looked at is not significant, but by the time -- it's not to deny that it's the plume coming into the down comer, but by the time it gets to the core, it's mixed.

[Pause.]

MR. WALLIS: Well, hopefully, when you get to tomorrow, someone can explain why it's not important if you get a cold area. To my understanding, the thermal stress, if you have this cold area there, you have to worry about it.

MR. BESSETTE: Well, I think that's right, yes.

MR. WALLIS: It's an average around the whole thing.

MR. BESSETTE: No, no, I agree.

MR. ELTAWILA: And it's duration of that cold area is going to be adjacent to the wall of the -- you know, you're going to get cold water, but is it going to remain cold for the duration that would sort of produce the significant load on the vessel or not? And that's the information that we will try to work together with the fracture mechanic people to decide about the importance of our findings here.

MR. BESSETTE: Yes; the same spot has to stay cold for the same time. These plumes have a way of kind of meandering, too.

[Pause.]

MR. BESSETTE: So, skip all of those other temperature slides and go on to the phenomena, the PIRT. We have three PIRTs identified so far. One was done in conjunction for an H.B. Robinson reanalysis we did about 5 years ago. One was done for -- when we did a Yankee Row analysis about 10 years ago. And there was one done in conjunction with the REMIX code.

MR. WALLIS: Are you talking about old PIRTs or new PIRTs?

MR. BESSETTE: This is existing PIRTs.

MR. WALLIS: These are old PIRTs?

MR. BESSETTE: What's an old -- you know.

MR. WALLIS: Ancient PIRTs.

MR. BESSETTE: Not ancient.

[Laughter.]

MR. ZUBER: When did you perform them?

MR. BESSETTE: Well, H.B. Robinson was about 5 years ago; Yankee Row was about 10 years ago.

MR. WALLIS: You're not talking about the eighties. These are recent PIRTs.

MR. BESSETTE: Well, the REMIX PIRT, I think, goes back to the eighties, late eighties.

MR. WALLIS: A PIRT is a very primitive stage in the process. I'm trying to figure out what important phenomena they want to fix their arms around. I thought that was all done.

MR. BESSETTE: For PTS? You know, the PIRT process changes with each event you're trying to analyze, whether it's a small break or whatever.

So, a PIRT that was focused -- these are the only PIRTs that I know of so far that have been focused on PTS.

MR. WALLIS: They've ended up showing what you know already, that you don't get down comer temperature in the heat passage walls.

MR. BESSETTE: The PIRT shows what you know already, yes, or what you think you know already.

[Pause.]

MR. BESSETTE: This is the PIRT that was done for H.B. Robinson. These were the panel members. It was Cliff Davis from INEO; Professor diMarzo; Professor Griffith; Professor Hassan; and Professor Barkley-Jones. The four transients were considered: main steam line break from hot standby; steam generator overfeed following a turbine trip; and then a small cold leg break loca and a small hot leg break loca, and of course, the key parameters are what I already mentioned: down comer temperature; system pressure; and convective heat transfer coefficient.

I list the -- from this PIRT, these were the top 10 phenomena identified in rank order. And, of course, some of these -- it's a typical thing. Some of these, you can consider to be phenomena, and some are, let's say, some kind of a boundary condition for the problem.

So, it's accumulator injection flow rate; in this case, they considered three-dimensional vessel wall heat conduction to be significant. It's an HPI injection flow rate; it's the flow distribution in down comer; this is the plume mixing in the global down comer flows; the accumulator liquid temperature; break flow; HPI injection temperature. You see temperatures and flow rates showing up several times.

This is the mixing the HPI jet as it enters the cold leg and the mixing at that location where it enters the down comer, so this is, you know, that's these two mixing regions there.

MR. WALLIS: You could write this down without a PIRT, though, couldn't you?

MR. BESSETTE: Well, yes, I think so; well, that's -- a PIRT is just writing it down. I mean, one person can write it down, or a group can write it down.

MR. SCHROCK: Well, the ranking is a group process.

MR. BESSETTE: Rankings, any individual can write it down, and then rankings --

MR. SCHROCK: And then, you can rerank.

MR. WALLIS: Maybe 8, 5 and 4 and 8.

MR. ELTAWILA: I think in terms of -- you want to do some variation on the top ones and try to see their effects on the overall uncertainty.

MR. WALLIS: You can't do the whole problem.

MR. KRESS: It's surprising that decay heat enters that mix.

MR. BESSETTE: I wasn't part of this PIRT, but I think anytime somebody looks at it who wasn't -- the way these PIRTs evolve to some extent depends on the discussions amongst the people who were there, and there's a lot behind these things. Sometimes, people will rank things lower because they say, well, we know that very well. So, for any given transient, we know what the decay heat is, so, therefore, the uncertainty is low. So that kind of thing enters into people's thinking sometimes.

MR. WALLIS: It doesn't help me to understand what you're doing and why. Perhaps we should go on to that.

MR. BESSETTE: Yes; okay. I mean, I don't want to dwell on this, but I figured somebody was going to ask me about PIRTs, so --

MR. WALLIS: Well, you've done a good job on your PIRTs.

[Laughter.]

MR. BESSETTE: And so, this is the Yankee Row, and, of course, those are the people, and they come up with another list of phenomena which we can puzzle over in a known set of rankings. And then, the PIRT that was done for REMIX, of course, as you might expect, it looks just like REMIX does. So all these things that are ranked high, at least, are those things, are those aspects that REMIX focuses on.

[Pause.]

MR. ZUBER: Well, did anybody confirm the experimental data, the fluctuations in the different PIRTs, how they read this process?

MR. BESSETTE: Comparing the data directly against the PIRT?

MR. ZUBER: Yes; right. The question is really did you make any use of the experimental data since that time? Because here, you have a graph experimental facility.

MR. BESSETTE: Yes.

MR. ZUBER: Some which has quite a -- presumably quite a bit of data. What information did you draw from these experiments?

MR. BESSETTE: Bill will tell you that better next time.

MR. ZUBER: I don't mean to be sarcastic. This you should do before -- when you start a program.

MR. BESSETTE: Yes; well, it's difficult to do everything at once, I know.

MR. ZUBER: I looked at --

MR. BESSETTE: Well, you know, if you compare this data, let's say, if you compare these experimental programs with, let's say, the REMIX PIRT, there's quite a bit of correspondence. They were all, you know, they were all inspired, let's say, by the questions that -- after we had the first PTS studies, the questions that arose with respect to what's the effect of the plume. So, as a result of that, we had a number of these experimental programs, and these were the issues that they were focusing on: how much mixing is there at the injection location? How much mixing and stratification is there in the cold leg? How much is there when you get the junction between the cold leg and the down comer? And then, the -- trying to find out how much mixing occurs in the plume and how quickly it disperses.

MR. WALLIS: I guess what we're trying to find out is what is the state of the art of all of this? And we sort of accept all of this. This is all important. Then, you've got to go through -- I don't know if you need to go through all of these facilities. What we need to do is get a picture of what you know now and what you need to know.

MR. ZUBER: You see, you have six facilities here. What kind of information did you get from these facilities? And where is the whole that you have tested here?

MR. BESSETTE: I think the purpose -- I mean, you know, if you -- well, no, the objective of -- this all leads --

MR. ZUBER: No, no, this summary of the experiments.

MR. BESSETTE: You know, when you go through at least these first four.

MR. WALLIS: We believe that. Let's go on.

MR. BESSETTE: Yes.

MR. WALLIS: What do you know about all of this stuff?

MR. BESSETTE: What are you trying to do?

MR. WALLIS: What's the state-of-the-art?

MR. ELTAWILA: Why don't you go over the view graph that summarized the result of these test facilities two view graphs later?

MR. BESSETTE: Well, I told you: the state-of-the-art is that the plume seems to be gone before it reaches the core region.

MR. WALLIS: Then what's the problem?

MR. BESSETTE: That's what we're trying to say, is that as far as we can tell, there is not a problem.

MR. ZUBER: Then, the normal question: why do it?

MR. ELTAWILA: I'm going to repeat myself again, okay? They have done all what they can do in the area of fracture mechanics. Some plants are going to be hitting the PTS limit very soon. And now, we try to do a more realistic thermal hydraulic calculation to see that the assumption that we used previously is still valid with the known plant design modification.

MR. ZUBER: Fine.

MR. ELTAWILA: Okay.

MR. ZUBER: Let me say this: you have six facilities with quite a bit of data. Then, you analyze these data to see what you have and determine what you need.

MR. ELTAWILA: I think the only remaining issue is the flow stagnation and interruption and resumption in flow. What we've seen in some of the tests at OSU and at the University of Maryland that you have, for a plant that has two cold legs per hot leg, that if you want, that you will get flow -- one loop stopped but the other loop circulate, and that will enhance mixing, and we want to see the importance of that phenomenon and to get additional data to assess the flow to be able to do a better, realistic analysis.

MR. REYES: Jose Reyes with Oregon State.

Many years back, I was involved with some of the testing in this. The thing is that where the state-of-the-art was then as compared to now, back then, as far as detail of the down comer calculations for fluids, looking at the plumes, we had two options. We had a code called SOLA/PTS, which was like a CFD version, and we had REMIX was the other option. Now, REMIX came about because SOLA/PTS was taking 10 hours to run 10 seconds of transient, and, of course we had --

MR. WALLIS: When was this?

MR. REYES: This was back in 1985.

MR. WALLIS: But now, we can do things about 1,000 times faster.

MR. REYES: Even better; so, as far as state-of-the-art, the ability to perform some of these new CFD calculations is now in reach. So, that's one thing that is a bit different. The other thing that is really different was that all of these tests were basically separate effects tests. So, if you look at that list of facilities, they were all separate effects tests. Nothing really looked at the fact that you had multiple loops with a potential for stagnation in one loop and not stagnating in the other. The only one that was close to that was the IVO test facility, Imatran Voima Oi (phonetic) back in Helsinki, and they did do multiple loops, but it wasn't integral.

So, for example, things that we've observed that are really different compared to the tests that were performed back then is this idea of loop stagnation due to the steam generator tube draining. What we've seen is that the top, the long tubes, will drain first, but you'll get lots of natural circulation flow through the loop until you finally drain those bottom tubes. So, how well can the computer codes predict this loop stagnation? The codes that were used back then were using one tube to model the whole steam generator. So when that tube voided, you stagnated. So, in fact, you have, you know, thousands of tubes.

So that's one area that I think we will be able to shed some light on in these experiments. The other thing which I will show later on has to do with the onset of thermal stratification and some revisions to that stratification criteria, which I believe may be necessary for some of the high injection HPI flows, which we didn't know before.

MR. KRESS: And the point is that these things have a significant effect on the temperature and pressure transient on the wall --

MR. REYES: Absolutely, absolutely.

MR. KRESS: -- and that is an input into the fracture mechanics.

MR. REYES: That is correct; more recently, and hopefully someone will speak to this tomorrow, Oak Ridge did approach me with regards to a 3D finite element model of our vessel, because we're trying to, in essence, sharpen the pencil; learn more about the fracture mechanics as well as the thermal hydraulics in order to be able to address, as Dr. Zuber had mentioned, in order to be able to say, well, we're getting closer to the limits of these vessels; we need to know better where we stand. What side of the line are we on? And so, that's how I see a lot of this work being directed towards.

MR. ZUBER: Which code are you going to use for the rest of it?

MR. ELTAWILA: For which one? For the detail mixing calculations?

MR. ZUBER: Well, you are talking about stagnations, different tubes; I don't know how many steam generator tubes are going to participate. Which code are you going to use to do that?

MR. ELTAWILA: We would like to observe the data, the information in the experiment first, and then, we will decide. Of course, we have the system code log, the RELAP5 and the TRAC and base on the additional needs. We might go into a CFD code or something like that. And that's still in the plan, but we have not developed that work in details until we see some of the data coming out of the experiments.

MR. WALLIS: You have two questions, really. One is can the codes predict the transient, which you know if you've got stagnation on all of those. And if you do get stagnation, can some code predict what's happening in the down comer well enough? Two separate questions. You're answering both of these questions in effect?

MR. REYES: We are developing data for both of those questions. We will be using two codes, and I will describe that a little bit later. Of course, this is at our university level as far as code operations. More detailed codes, I'll leave that to Farouk to see which ones would be used for that.

The other item that, as far as the difference between then and now is the operator actions that were assumed for these transients were very extreme. I think maybe in our facility, we can model all of the control systems. We can simulate actual plant controls as well as feed water control, steam generator level control, steam flow controls, so we can model some of these things and look at the effect that the operator actions or the control logic has on these scenarios, and they do have significant effects. Whether you repressurize or not depends on -- in certain transients depends on the operator action, or how quickly you cool down will depend -- or whether you cool down at all will depend very strongly on operator actions. So we have that capability to look at some of those issues also.

MR. KRESS: That will change the frequency of the initiators for these particular events.

MR. REYES: Right; the assumptions that you make as far as operator actions affect which way the transient will go.

MR. KRESS: So you might lower the frequency of initiating events.

MR. REYES: Correct.

MR. WALLIS: Now, Jose, you have a presentation coming up after the break.

MR. REYES: Yes.

MR. WALLIS: According to that, you have.

MR. REYES: My focus will be on the scaling analysis.

MR. ZUBER: You should also address the code, because this is your primary tool.

MR. WALLIS: I just wonder where we're getting with the present presentation. Are you getting across what you wanted to get across in terms of a message to this committee?

MR. BESSETTE: Well, I'm not sure. It doesn't seem like it.

MR. WALLIS: What is it that you wanted to tell us?

MR. BESSETTE: Well, I wanted to --

MR. WALLIS: You can throw away your slides and tell us what you want to tell us.

[Laughter.]

MR. BESSETTE: It's time to go home. That's what I wanted to tell you.

[Laughter.]

MR. BESSETTE: Well, let me think. I wanted to -- well, there have been a few things, a few perspectives, that I haven't touched on like some other people have. One was that, like was said before, that the thermal hydraulics is part of a three-prong effort. And why are we doing it? Because some of the scenarios have changed from what we analyzed in the first go-round. Like Jose said, there are conservative assumptions made in terms of operator actions, like typically, these old calculations, the -- in combination with initiating event, you had a steam drainer overfeed, and high pressure injection was never throttled. So a lot of these old transients, the primary system filled up water-solid, so that you had an upward pressure of around 2,400 psi.

So in terms of why are we doing some of the calculations, it's because -- it's in conjunction with the, let's say, PRA is what -- what are really the highest probability, highest consequence scenarios.

MR. WALLIS: So, there are some new kinds of scenarios which either weren't analyzed before or couldn't be analyzed using the old methods.

MR. BESSETTE: Or weren't analyzed.

And, you know, like I was saying, one of the, let's say, outstanding issues that developed during the first PTS study was this issue of what was the plume effect, because that really wasn't considered in the bulk of the calculations. And so, there was this lingering questions of, well, what happens if you have a very strong cold plume? That's going to make things much worse for the region where the plume exists. And so, in the meantime, there were these six or so different experimental programs that were run to develop fluid-fluid mixing data in the cold leg and down comer. And the idea is to show, well, how does this plume threat?

MR. WALLIS: Now, the output from these six programs in the past was presumably some standing of phenomenon and some modeling effort and some computer models which could be used to assess transients.

MR. BESSETTE: Yes; well, these were experimental programs. The only modeling effort, I guess, that I know of that was associated with it was the REMIX code.

MR. WALLIS: Is the problem that in the past, the experiments were run, but nobody really pulled it all together, and that's what you need to do?

MR. BESSETTE: To some degree. You know, Theophonus did that to some extent when he analyzed REMIX against most of this data, but his purpose there was to, let's say, assess or validate REMIX and not necessarily to carry it to the point of what is really the temperature distribution adjacent to the core.

MR. ZUBER: See, this is the comment that I have on most experimental programs carried out by NRC, and I was part of it 10 years ago. NRC never made a synthesis of their results. Without it, you have a synthesis of the broad experiments, but you don't have any synthesis of the last experiment. There is nothing you can take that says okay, this is what I have; something you can transmit to the next generation.

MR. BESSETTE: Yes.

MR. ZUBER: You and I, we are also here, and most of the people here, we cannot come now to an agreement of what we have learned 10 years and 15 years ago, and what it means is once this cohort of people has gone, a new cohort will probably come which doesn't know anything about it. Then, you have to spend more money and more time. But in my comments to the committee here and the NRC, you need a synthesis of the knowledge you have accomplished 10 years ago. On the PTS, you would have a document; this is what I learned from an experiment; this is what was important; this is where I have holes in my methodologies, and I have to fill them.

MR. BESSETTE: Well, I agree. I mean, I feel like there doesn't exist a complete synthesis of these experimental programs, and this is something I would like to be able to accomplish.

MR. WALLIS: Well, it would seem that would be a starting point for new programs, a work order for the new program would be to figure out the state-of-the-art for where we were before.

MR. BESSETTE: The other thing, I think we have adequate database in terms of fluid-fluid mixing from these programs as far as they go. What I see is missing is what Jose was just describing as we're doing this program. It's for the class of events -- many of the events, many of the PTS-significant events are small-break locas in the cold leg or the hot leg. There hasn't -- and so, the key to when you start the vessel cooldown is when you lose loop natural circulation, so that's a precursor to cooling down the vessel.

There hasn't been a careful look at what are the criteria: can you predict exactly when you lose loop natural circulation?

MR. WALLIS: Do you have this figure up there?

MR. BESSETTE: Yes, yes.

MR. WALLIS: Can you put it up?

MR. BESSETTE: Yes.

MR. WALLIS: This is presumably someone's observations from experiments?

MR. BESSETTE: Yes, this is the Finnish experiments.

MR. WALLIS: Simulating conditions which you're interested in for this problem.

MR. BESSETTE: Yes.

MR. WALLIS: And what I see here is plumes which are certainly not very well mixed two diameters below the pipe. That doesn't go with your statement that everything is well-mixed when it goes --

MR. BESSETTE: Well, let's see. You can't see here the temperature -- well, like at this elevation here, you're already well-mixed.

MR. WALLIS: That's -- the reactor -- it's not a --

MR. ZUBER: It is more than two diameters below.

MR. BESSETTE: There's a lot of other data, too.

MR. ZUBER: See, the thing is this is where you need a synthesis.

MR. BESSETTE: I just wanted to show you this to illustrate the type of -- this is from the Finnish experiments. This was just to illustrate the type of data they generated.

MR. WALLIS: 70, 70, 70, 70, 60, 60, I mean, those are the temperature measurements?

MR. BESSETTE: Yes; these numbers here you see are temperature measurements.

MR. SCHROCK: What is the technique that produced those?

MR. BESSETTE: They -- I'm not quite sure. How they get this?

MR. SCHROCK: Yes; how is that image created?

MR. BESSETTE: From what I can tell from looking at the report, they took a picture, and this is an artist's rendition of what he saw. This is like a drawing.

MR. SCHROCK: These little hairs are intriguing.

MR. BESSETTE: But, yes, you can see the swirl patterns here, you know.

MR. SCHROCK: Somebody say that and drew it is what you're saying.

MR. BESSETTE: Yes.

MR. SCHROCK: Okay.

MR. BESSETTE: And what you're seeing is -- for example, this is the same test; this is some period between

0 to 3 minutes, and this is between 3 and 6 minutes. Then, you see how this plume has drifted over here and combined with the other one.

MR. ZUBER: How many temperature measurements did they take?

MR. BESSETTE: They had -- in the down comer, they had something like 60 this way and that way.

[Pause.]

MR. BESSETTE: Typically, once you get down to about --

MR. ZUBER: Since you have a thing, I guess you need more than that, more -- because after that, on the right picture, you would have that not that far down, two diameters.

MR. BESSETTE: In fact, they ran some tests, and then, they stopped, and they added more thermal couplers.

MR. WALLIS: Well, I think what I would really benefit from would be a sort of summary paper of the type that you wouldn't be embarrassed to stand up in front of an audience at the ASME or at somewhere and say this is the state-of-the-art. Here are the experiments; this is what we learned; this is what we know now; this is why we know it, and this is where the holes are. I don't -- you seem to be ready for that. It would help a great deal, because there is so much that seems to be going every direction here.

MR. ZUBER: I have a question: when did you start this program?

MR. BESSETTE: Last -- let's say about the middle of last year.

MR. ZUBER: Of 1999?

MR. BESSETTE: Yes.

MR. ZUBER: When did you determine the need and then start the program?

MR. BESSETTE: Well, on a global basis, when did we determine the need to revisit the PTS rule? That was sometime early last year, I think. And then, but, you know, it took some time to decide well, what do we need to do to do that?

MR. WALLIS: Well, my impression is if I took this problem here and gave it to an undergraduate honors student who was familiar with the latest CFD programs, where all you have to do is put in the geometry and the boundary conditions and then run it, that this would be over in a couple of weeks. And the question then might be did the CFD modeling adequately model things like porosity and mixing. It can be done.

MR. KRESS: Before you ever get to this point in the transient, though, you have to have reached stagnation conditions.

MR. BESSETTE: That's it exactly.

MR. KRESS: And that's the hard thing to predict, and CFD code won't predict it.

MR. WALLIS: Is the stagnation problem the real problem?

MR. ELTAWILA: Stagnation is the key.

MR. ZUBER: Which code are you going to use for stagnation?

MR. KRESS: Well, they used RELAP before. And that was one of the problems. They couldn't really pick out just when stagnation was occurring in RELAP because it doesn't have a stagnation flow. It leads you up to it, and then, you try to decide, well, based on what I know about stagnation flow, we'll probably get it here or here or here. And that's the big uncertainty. That fixes all of the initial conditions for you.

MR. ZUBER: Then, the question is any program which does not address the stagnation is almost doomed to failure.

MR. KRESS: That's probably the truth.

MR. BESSETTE: Well, that's why we have the APEX. That's one of the main reasons we're running APEX tests.

MR. KRESS: So you run experiments to help decide on what criteria to use in something like RELAP to decide when you're going to have stagnation.

MR. BESSETTE: Maybe I haven't said it. We're just as interested or more interested in the stagnation issue as we are in the plume issue.

MR. ELTAWILA: The plume is not an issue.

MR. WALLIS: It seems to me that you're in a transient that will pass through stagnation perhaps, but not more. I mean, things are happening all the time. It would be very unusual for stagnation to peter on for several minutes.

MR. BESSETTE: But that is what we are saying. It takes some minutes. It can take some minutes to go through stagnation.

MR. WALLIS: And the flow stops for several minutes?

MR. BESSETTE: No; the thing is you've got a small break loca. It's not the interruption of a single loop that's the thing. You've got a small break loca and a plant that can have four loops. So all four loops don't stop at the same time that loop one stops, and then, the other three loops keep going until loop one, the generator drains. It takes some time for the generator to drain; the other three will keep going. And with two stops, and then, that generator has to drain; and then, loop three stops, and then, finally, loop four stops. And each individual loop doesn't stop all at once. It stops over a period of time, because you've got long tubes; you've got 60 banks or 100 banks of tubes. So the longest one stops first; then, the second-longest and the third longest, so that it's not just a switch. The stagnation develops over some -- it can be 20 minutes even, 10 or 20 minutes, depending on the break size

MR. ZUBER: Question: given that the stagnation is one of the initiators, the most important one, two, that we cannot really calculate it very closely or realistically, on what basis, then, are you going to make a decision that you can --

MR. BESSETTE: Well, what we're trying to do --

MR. ZUBER: If you don't have the two, you don't have a coefficient that you can trust, and this can go all over the place. How are you going to address this question?

MR. BESSETTE: Well, you know, we said well, what are our key parameters here? System pressure; down comer temperature and heat transfer.

MR. ZUBER: You cannot calculate stagnation if you go to one loop to another.

MR. BESSETTE: Yes.

MR. ZUBER: You can start and stop.

MR. BESSETTE: So, what do we do? We try to take the two extremes and see what effect did this have on the parameters we're interested in. We try to -- we take the uncertainty range.

MR. ZUBER: You must have a code that you can do it with.

MR. BESSETTE: Well, you know, the codes will calculate stagnation.

MR. ZUBER: And you want to be conservative.

MR. ELTAWILA: The issue is not to reduce conservativism here. It's to try to validate the analysis that we have done in the past, and we see that the more plant improvements and the operator action and things like that just try to calculate the thermal hydraulic conditions during this phase of PTS.

MR. ZUBER: You cannot calculate that.

MR. ELTAWILA: We can calculate it. We can look at the result of the experiment, and, with several tools -- we have to look at results of the experiment before we can make a judgment about what modifications are going to be made to the code or what other codes are going to be used in this analysis.

MR. KRESS: I seem to recall that someone looked at the RELAP calculations and had a set of what I would call criteria that he said, oh, if these things hold true in the RELAP calculation at some time, I will call that the time in which stagnation is thought. So one of the things you might be doing is checking to see if these criteria are any good, because they weren't really based on real stagnation experiments, now. They were based on what he expected would lead to stagnation. Is my recollection correct?

MR. ELTAWILA: I think your recollection is correct, and I think that's the information we're trying to get from the OSU facility, and we are trying -- we went through the painful process of trying to scale the facility to represent one of the plants in the PTS study at least to be able to see what can happen in the plant.

MR. REYES: Jose Reyes again, and I'll be talking about that criteria in the next presentation.

MR. ZUBER: Okay; thank you.

MR. WALLIS: Do you expect some feedback from us on what you're telling us today, or is this sort of for information purposes?

MR. ELTAWILA: I think we need feedback particularly on the test program and the scaling analysis and the criteria that we are going to use for stagnation and so far.

MR. WALLIS: Because my feeling is I would need to see a more focused presentation before I would know what to tell anyone. And that's the way the questions from the committee seemed to go.

MR. ELTAWILA: That's fine; let's wait until we see Jose's -- I think the presentation should have come just to say that we are running an experimental program to try to find some thermal hydraulic conditions from which we try to develop criteria that we can use in our codes. We have made modifications to our thermal hydraulic codes, and the plants have made some modifications, and we have tried to just see if we could use or come up with the information that's needed for the fracture mechanic people to do the work, and the focus of the presentation is on the scaling analysis and the tested program.

MR. WALLIS: Well, when is there going to be closure on PTS?

MR. ELTAWILA: PTS closure is supposed to be by December 2001. We're supposed to issue the rulemaking. You're going to hear more about this information tomorrow.

MR. WALLIS: I'm not here tomorrow. Tomorrow is about --

MR. ELTAWILA: Okay; we are supposed to be issuing the rulemaking. I can get you a copy of the schedule in the break and review it with you. But the whole activity has to be finished by January 2001.

MR. WALLIS: The road map of activities to get you from here to there.

MR. ELTAWILA: But this is the subject of tomorrow, and that's what, in the last meeting, I heard a member, the chairman of the committee, said that we do not want to have a separate subcommittee meeting, because that will confuse the issue. This is an integral issue, and we thought that we were going to have a full committee meeting to discuss the whole issue as a whole and not to direct stress analysis calculation to people that don't know anything about it.

MR. WALLIS: I thought we were going to hear today about the thermal hydraulics side and what inputs it needed to give so that the overall picture -- when I said road map, I really meant a road map of how you're going to resolve the thermal hydraulic part, and I don't see that.

MR. ELTAWILA: Have you finished your presentation there?

MR. BESSETTE: Yes.

MR. SCHROCK: I was looking at your conclusions from prior calculations, David, and I noticed that the PTS problem develops on the order of 15 to 45 minutes for some comments there about the date, the starting time for that, but those times seemed very long compared to what you're showing us in this picture. It seems a long time for a thermal stress problem to develop, 45 minutes.

MR. BESSETTE: That's what I was trying to show you something about these time constants that say that the time involved to cool down the vessel sufficiently, to get down to 300 degrees, is on the order of 15 minutes. It can be longer. And then, the time required to cool down the vessel sufficiently to develop a stress, the thermal stresses needed, is on the order of 15 minutes. So the median there is about, you know, 15 plus 15, it gives you the 30. That's why --

MR. WALLIS: You injected ECC into the vessel and poured it down the wall so that it stayed in the jet, you could have a problem there.

MR. BESSETTE: Possibly, yes, yes.

MR. SHACK: I mean, just think of it in simple-minded terms. If you just cooled the first mill of the wall, it's not much of a problem. You know, you can accommodate that easily. So you have to cool a significant amount of the wall. No, it's really a 1D kind of thing. You're going through the thickness. I mean, you really have to chill the surface of the material enough in order to get a differential strain between that surface and that, and it just takes awhile to cool, you know, a certain depth of material. It's really a heat conduction problem, you know, once you're getting the temperature in there. What his calculations are showing is that, you know, he's sort of, by chilling that surface, he's building up that stress there, you know, and it sort of takes him about 15 or 20 minutes to really chill it enough to get it dry.

MR. KRESS: That time constant conduction leg going through the wall is not 15 minutes. That's a pretty short time for it. So it's not that.

MR. ZUBER: Another one plume, I mean, something like you have here, and this can stay there for 10 or 15 minutes. You don't have mixing, and this goes two diameters, and then, that's where you can obtain the problem.

MR. SHACK: Well, I mean, he's got his temperatures there.

MR. BESSETTE: I mean, other than making the conduction calculations.

[Laughter.]

MR. SHACK: It's 8 inches of steel, and it's stainless steel, and it's not the world's greatest conductor. I mean, it's not high-tech. You know, I think one of his earlier points was that there is a time delay in here, so some of these fluctuations don't become as important as they might seem, you know, because you are smearing these things out in dimensions.

MR. ZUBER: The picture doesn't show this. I can obtain the cold plume, let's say, four or five diameters below for a long time.

MR. BESSETTE: You have to realize, this --

MR. KRESS: You have to realize this is not a time constant, the way it goes through the wall. It's a time constant for cooling the whole wall around this to these depths.

MR. SHACK: Okay; you're cooling --

MR. KRESS: So it's not the normal constraints.

MR. WALLIS: Well, maybe we should move on to the later presentation.

MR. KRESS: Yes, I think that might help.

MR. WALLIS: I think we need to come back to this, to come back again. Let's have a break and then see where we are.

We'll have a break now. Would you like to break until 3:00? Ten of 3:00; okay.

[Recess.]

MR. WALLIS: Let's come back into session. We'll hear from Jose Reyes about great things happening at OSU.

MR. KRESS: I keep forgetting whether that's the Ducks or the Beavers.

MR. REYES: We're the Beavers.

MR. KRESS: You're the Beavers.

MR. REYES: That's fine; and the Beavers have been -- we've been beaten by the best.

[Laughter.]

MR. REYES: Today is March 15, which is the Ides of March.

MR. WALLIS: Right.

MR. REYES: So beware the Ides of March, I guess, was my concern.

MR. KRESS: What exactly is the meaning of Ides?

MR. REYES: That was when Julius Caesar --

MR. KRESS: I know what happened.

MR. REYES: -- was killed.

MR. KRESS: What's the original Latin meaning of that?

MR. ZUBER: No, he was killed by --

MR. KRESS: I think it's the middle.

MR. WALLIS: They had -- it was known as the 9th.

MR. KRESS: Yes, the numbers was the ninth.

MR. WALLIS: I think we can go into a long discussion of the Ides of March.

[Laughter.]

MR. WALLIS: And we'll probably be just as uncertain about that as we are about some of these concepts.

[Laughter.]

MR. REYES: Before you, I have given you quite a lengthy presentation. The committee has a proprietary copy. There are basically two pages there which have some information which is still considered proprietary.

MR. ZUBER: By whom?

MR. REYES: By the previous facility. So, it's tied basically to some of the owners.

MR. ZUBER: Okay.

MR. REYES: I've given you -- it's a long presentation. There are 70 slides there, and I'm not going to go through that, so I wanted to encourage you with that information. For the outline which I present, I will not be presenting all of that unless you have very specific questions of some of those things, but I'll start with just an overview of the program. These are the things that we're looking at.

The number one item there is to review the TASC peak thermal hydraulics experiments. So that's one of the things that I've already done quite a bit of that. The documentation for that sounds like something that you would like to have right now, so that's something that we will --

MR. ZUBER: Before this presentation.

MR. REYES: Yes.

MR. ZUBER: Before you started the program.

MR. REYES: Oh, yes.

MR. ZUBER: These tell you what you mean.

MR. REYES: Yes; so, that was the first thing I did. I reviewed the existing data. What you don't have before you is a document that shows you the results of that review, and so, I'm remiss in that.

MR. ZUBER: Okay; when does the document come about?

MR. REYES: It sounds like I'm going to have to help with one of my former students who may be able to work with me on this. This could even be put together within about -- at this point, about 45 days. So we're looking at a month and a half.

So we have all of the references. I've looked at all of the existing data as far as the mixing data. I'm now familiar -- this data is in a logical format. And I'll share with you some of the things --

MR. ZUBER: What specific has been plugged in the holes.

MR. REYES: Right, right.

MR. ZUBER: Which you have to review.

MR. REYES: Right, and some of the holes, I'll talk about today, and this is why -- this is where these things come from is basically from that review.

Okay; the focus today is on the scaling analysis of the test facility. We're calling it the APEX CE just to distinguish, because we have modified some aspects of the facility. We'll talk about some of the facility modifications which we knew we would have to make just for geometric similarity, and so, some of those have been done already. The scaling analysis, we're looking at three parts of the loop natural circulation: primary and secondary site blowdowns, and then, the new area is thermal mixing, thermal fluid mixing, so I've done some scaling on that which is different from what you've seen. You may not have ever seen any of this before.

Also, we're looking at some of these criteria. That was mentioned earlier.

MR. ZUBER: I'm sorry.

MR. REYES: Sure.

MR. ZUBER: Are you going to, in that document, also discuss what there is done by REMIX or just these experiments?

MR. REYES: Actually, I won't just do the modeling of REMIX in that document. As we go through, I'll show you what we will do. I've got a team assembled that's going to do, instead of REMIX, the CSD calculations of all of the data, okay? So I'll show you that down here below.

So, scaling off over here; some facility modifications. These are the areas that we knew that we needed to change in order to be geometrically similar to the plant which we're using as our benchmark. We've broken it up into three areas here: integral systems tasks; main steam line breaks; hot leg breaks; getting the pressure out of the core. The CFD models, where the model is the cold leg and down comer geometry; it will be half the down comer; two cold legs; the lower plenum on the steam generator, and this will be specifically looking at injection into those cold legs. We'll look at whether or not you're stratified and what the plume conditions would be in the down comer.

That's basically it.

MR. ZUBER: If you want to -- this could be also desirable to prepare a --

MR. REYES: Sure; that's --

MR. ZUBER: Because then, we have run or at least fixed the capability to have shortcomings on that one.

MR. REYES: Right, right.

MR. ZUBER: And not necessarily have another box on the same level REMIX evaluations.

MR. REYES: I'll show you some REMIX calculations we did for our facility and for Palisades, so we've already run some REMIX for our own facility.

MR. WALLIS: Most CFD models have some sort of turbulence model in them.

MR. REYES: Right.

MR. WALLIS: This doesn't do a very good job of modeling the pressure turbulence by stratification.

MR. ZUBER: It seems to me that the model will --

MR. REYES: We've been looking at three different codes: fluid, CFX and one called STAR-CD, and they seem to have similar models in all three, so that's going to be a challenge.

MR. WALLIS: They traditionally don't do too well when you get stratification that changes the turbulence.

MR. REYES: We also have our RELAP5 model of the

APEX facility which we are modifying to simulate the loop seal, and the changes we are making, we've already made to the APEX CE facility. So we will be -- again, this is -- you can kind of think of this as predominantly a student effort. There is a lot of student work involved in these types of calculations so --

MR. ZUBER: Two questions: when did you start the property -- where do you start?

MR. REYES: On the overall program?

MR. ZUBER: On this thing here, the first box.

MR. REYES: Oh, the first box. We're looking about -- it's been over 9 months.

MR. ZUBER: Okay; how many budgets?

MR. REYES: Overall budget for the year is -- with the modifications, about $310,000.

MR. ZUBER: How many people?

MR. REYES: Of course, we have a lot of student support.

MR. ZUBER: No, people.

MR. REYES: They're people. I count them, you know.

[Laughter.]

MR. REYES: Right now, we have a team. What I've done in the CFD area is next -- this spring term, they're teaching a special class on CFD, and I've given them the challenge to the class. I said, well, you know, I've got all this data, and we've got all of these students. We'd like the class to take it on as a chance to evaluate all of this data by using CFD codes.

Now, if you had to pay cash for that, that's a lot of people, so I'll have basically two post docs working with about five students, so it's a big group.

MR. WALLIS: We should bring that solution to the NRC's review of other codes. Just get classified students and go to work.

MR. REYES: The bright students; that's what you want to be sure you've got. So, I trust our post docs. I'm not sure about the rest of them.

[Laughter.]

MR. BOEHNERT: That's on the record now.

[Laughter.]

MR. REYES: Uh-oh; I'm sorry. We have excellent students. They can go anywhere in --

[Laughter.]

MR. REYES: -- the world.

MR. WALLIS: We have the opposite problem: the ability of the student seems to go down the more they know.

MR. REYES: The more they know.

[Laughter.]

MR. REYES: So, we're looking at the -- so all of this modification information goes to the three different areas, and what we would like to do is develop an integral system data from the test loop. We would like to determine the conditions for loop stagnation, and we're looking at two conditions primarily. We're looking at loop stagnation when you have a primary site break, okay, which is going to be due to -- most likely due to voiding on the tubes, and then loop stagnation when you have a secondary site blown out, when you lose your heat sink, okay? So, you can potentially stagnate under those circumstances, but a single-phase and a two-phase loop stagnation condition.

So we'd like to study that very carefully. We'd like to study the effect of multiple cold legs and loop seals on the stagnation condition, and again, one of our goals here is to also look at thermal mixing, so we've added lots of plates to our down comer to try to measure the temperature profiles along the down comer and also in the cold legs.

MR. ZUBER: How many do you have?

MR. REYES: In the down comer, we've just added an additional 50 thermal couplers.

MR. ZUBER: How many do you have overall?

MR. REYES: So, I think we have a total of 130, I believe, and I can get you a number. That would be to get the temperatures in the cold legs and in the --

MR. SCHROCK: Would they be on the vessel surface or --

MR. REYES: Those, actually, those are actually the type that penetrate, so it will be fluid and some wall frame couplings. I don't know the ratio of the -- I may have it in a later presentation. So, we're looking at wall temperatures and fluid temperatures.

We had a series of heat flux meters that were commercially available, and those, we are actually replacing those because they didn't function quite well. So, integral systems data will be developed with some of this. We'd like to feed it to our team over here to provide this for some RELAP5 calculation assessments. Can RELAP5 predict the onset of loop stagnation for the tests that we've run. So we're just going to focus on our own tests and see if we can run the existing code to kind of see if we're predicting the onset correctly.

On the other side, we've got this separate effects test data which we're gathering in digital type form to try to compare to CFD codes, and it would be straightforward to do REMIX, although in Theophanus' report, he did already prepare all of these things for REMIX, so that already exists actually. But you learn quite a bit when you try to learn a new code.

There, we're looking at the assessment of the ability to predict the temperature gradients in the cold legs in the down comer, and I have one other faculty person working with me also on the --

MR. WALLIS: You're trying to predict temperature.

MR. REYES: I'm sorry; temperatures and the gradients, yes.

What does all this go to, well, the results we would like to provide this data for code validation. We would also like to provide all of our calculations in terms of the NRC and in terms of how well do these things compare to the test data, and more recently, we would like to provide some of our thermal couplers, actual thermal coupler measurements from our tests to Oak Ridge so that they can do some direct analyses for -- they're looking at different options, but one of them is a 3D finite element type of analysis, usually with opportune data.

MR. ZUBER: How many are around the perimeter? How many temperature measurements are you taking?

MR. REYES: Well, that's the total number for the whole circumference, about 100 and --

MR. ZUBER: No, no, I mean you've got directions and --

MR. REYES: Oh, yes, yes; I don't know if I have that map or not. I have a map book I'll show you which shows the -- it's an unwrapped vessel now, I think. Thanks.

I thought I had it.

Okay; so, that's an outline of the program. The basis for it, again, was because of our initial review, and, of course, my experience was with what was lacking in the previous study, and so I haven't mentioned things like the control systems and what we're going to do there. But we've been working very closely with the Palisades plant. They provide us with lots of data. They provide us with a real list of control systems and the control logic, so we're able to model those things, and that's a matter of deciding which is the best way to execute these transients and what would be the most realistic, or do we really want to do a completely realistic study or have some -- how many failures do we assume kind of thing.

Okay; so, in this presentation, I won't be presenting all of the things that are listed in the outline. I'll just go and basically talk about two of the main areas which would be different, and we've talked in the past about single-phase and actual circulation scaling, and we've talked about some of the blow-down scaling. So today, what I'd like to talk about is a little bit about some of the modifications -- the general scaling methodology; the modifications of geometric similarities, and then, we're going to jump down over to the thermal facility mixing scaling, because there are some interesting criteria, and this is a new area which you haven't seen before. So, in other presentations, you've seen some of this other type of scaling behavior. But you're welcome to ask questions on any aspect of it that you want.

MR. ZUBER: What is the schedule that you are supposed to reach?

MR. REYES: The last box, we're shooting to perform our testing. We would like to go to the shakedown by the beginning of the summer, because the summertime, of course, is the best time to do these tests, and so, hopefully, we will be running several tests over the summertime, and we will provide data as we get it.

MR. ZUBER: When do you complete the program?

MR. REYES: The total program, we're trying to match the schedule with Farouk's needs there, so I'll say -- I'll let -- right now, we have a one-year contract. We'll try to get as much done in one year if not all of it.

MR. ZUBER: You're talking about the whole facility or for PTS?

MR. ELTAWILA: Oh, for PTS, we have to meet the schedule of -- by next summer, a year from this -- by the summer of 2001, we will have all of the data and analysis of method to be put into the fracture mechanics and into -- so they can proceed with the rulemaking. So that program is going to continue until that time, but we have long-term plans for the APEX facility.

[Pause.]

MR. REYES: Okay; so, let's begin talking about the general scaling methodology. I'm on page 4, the top slide on page 4. Whoops; I'm sorry. The bottom slide on page 3.

So this is the methodology that I've been using to do the scaling analysis. The first thing was deciding whether or not we should even use the APEX facility; it was a determination of if it was sufficiently similar geometrically. So if it was going to require quite a bit of changes and was very expensive to do, then, it might not have been the best choice to do that. But as I'll show, the results were actually very good.

So the first thing was assessment of the geometric similarity. The second thing was we had -- having decided to use the facility, identifying -- stating what our specific experimental objectives would be, and we actually performed main steam line breaks or primary side loca, so we did that. We did have a PTS PIRT available to us, which was from that one NUREG, and that was related to Robinson. But we did look at the phenomena on that list. We didn't really rank it, per se, although in the presentation, I list all 20 items there. When I looked at them, I said, well, these are the items that I should be looking at in terms of the facility in terms of scaling, so I didn't necessarily rank one above the other. We just tried to see if we can address as many of those as we could.

In terms of the scaling analysis, I broke it down into three major areas of scaling. One is natural circulation scaling; the second is system depressurization, and that's primary and secondary side blowdowns and then the thermal fluid mixing scaling. I think this is one of the areas that you will find interesting. Basically, the way we performed it, I used the H2TS methodology, and we develop sets of dimensionless groups or pi groups, and we develop similarity criteria against each path here. We do an evaluation of the distortion to determine if it's significant or not.

If it's a new system, of course, you can come up with some new system designs, but since we have two existing plants, the Palisades plant and our test facility, there are a lot of things that are very locked in, so you can't change those. So the evaluation of the distortion then becomes important.

MR. ZUBER: There was significant distortion?

MR. REYES: Right now, I'm looking at our down comer volume, and for that one, that is large-scale basis. But I'll show you some of the things that are helpful within design.

So these are the three areas, and what we tried to do was prioritize them, how we should operate the facility and come up with very specific specifications that had to be met with regard to modifications. There were certain things that we had to modify in order to get the similar results in our facility that you see in Palisades.

MR. SCHROCK: How did you come out on the geometric similarities?

MR. REYES: I was surprised. It actually came out pretty good. Now, in your handout, I've given you actual tables with numbers. So I won't be presenting those on the screen, but we can talk about that.

These are the modifications that we did, and that's coming up in about three or four slides. These are the modifications to the facility. We had to add four high-pressure injection lines, four cold leg loop seals, additional cold leg thermal coupler rates in the cold leg. We had to add additional flow meters for each of the H guidelines, and then, we added 50 additional down comer thermal couplers. So these are the basic modifications. The remainder of the plant, really, as far as the similarity, the design that we had compared to the CE plant is remarkably similar.

Sizewise, I said if we were to try to come up with a closer match, the only other plant out there that probably would match closely is Fort Calhoun. That plant is -- it's a 500 megawatt electric plant somewhere in that vicinity, and so, that's already in the zone of where we have already modeled.

This facility, this shows the modifications we've made. We've added these loop seals. There's a little bit of a blowup here, so you come off of the steam generator; a loop seal; and out to the cold leg. So we've added four of those loop seals.

As far as similarities, the next picture shows the Palisades plant and a CE facility, so you can kind of see that they're both two hot leg, four cold leg designs. This is APEX, and this is the Palisades, so your reactor vessel; you have two hot legs, and you have four cold legs. These are the reactor cold pumps here. In our facility, the angles coming out are in the right location as far as the hot leg; the orientation. These are 2D guidelines which we valved out, so these would not be operating during a test. This is a steam generator, steam generator, and then, our pumps.

We've lowered our pumps to the right elevation to get the loops there, so our pump location, I think on the next picture, shows it better. Our pump location is not prototypic, but for the cases of interest, that shouldn't be -- as far as resistance, that doesn't seem to be a problem in terms of our calculations for loop resistance. So here is the Palisades plant; the loop seal; reactor cold pump over here, and here's our facility, a little bit hard to see. Here's our pumps. So that's one of the big differences.

MR. SCHROCK: Your vessel thickness is very small compared to --

MR. REYES: Oh, absolutely, yes.

MR. SCHROCK: So the extent to which it interacts in the thermal hydraulic strain in cooldown associated with blowdown, that's going to be rather different.

MR. REYES: Right; I have a calculation to show that. We were expecting to see a much more drastic effect than we actually did see, but that's why we would like to do some additional calculations.

The next couple of slides, I guess the audience will have, and these are comparisons of component volumes for Palisades and for APEX. So we have component volumes and then component flow areas and component lengths. And the thing that I was looking for there, the thing that I was looking for in an assessment of the geometry of the plant was do the constants, the flow area ratios, the volume ratios, the length ratios, do they vary much as you go around the loop? If there are significant variations, then, that's going to be a potential spot for some distortion. So

I was pleased to find that in general, if you look at the -- for example, the first one, the volumes, the overall volume scaling ratio for most of the components fell around 1 to 276 is kind of the mid-number; so for almost all of them except for one component, which was the down comer volume, which I'd mentioned before, which was about 1 to 95.

Early on in the scaling of the facility, one of the concerns that I had was if your gap is too narrow, you have an -- you overestimate the amount of -- well, it's kind of the same -- I call it the semi-scale effect, okay? You think back to the semi-scale, the gap was too narrow, and as a result, if you had any type of ECC bypass that was exaggerated; so, in the literature, what I found was that if you kept your gap at least two inches wide, you can avoid some very unrealistic phenomena.

MR. WALLIS: Changing the scaling of the booms; you've got to be changing the down pump.

MR. REYES: Right; so, my first assessment looked at the geometry and said okay, now, we've got the successively large volume. How is that going to affect the plumes? And we did some calculations, and this is what -- it turned out better than I was expecting.

MR. ZUBER: In the experimental data which we already have from other facilities --

MR. REYES: Yes.

MR. ZUBER: -- what does your down comer come? Is it on the side?

MR. REYES: Well, we found with our down comer, the way they characterized it, as far as the dimension, the length to the aspect ratio, and ours is one to one with Palisades, so the advantage, so one of the things as far as gap size, there was the Finnish facility was two-fifths scale, and the way they scale it is linearly, so they look at about a four-inch diameter foot in their terms of scaling. So, two-fifths of a 10-inch gap is about four, so they did linear scaling. And the same thing with the half-scale.

MR. ZUBER: Well, you have data from different facilities.

MR. REYES: Right.

MR. ZUBER: And you have a discussion in the down comer. Do you think that spectrum of available data, what is your -- is it outside the range or --

MR. REYES: No, it's within the range. So, the one-fifth was about a two-inch gap, and our gap is about two and a half inches. And then, the two-fifths scale is a four-inch gap. So we're within that scale.

Now, as far as L/D, the gap to the length of the down comer, we're just about one to one with Palisades, so that was a good thing.

So, if I try to summarize, again, the component, the volume, the flow airs and the lengths, they were different than the previous testing facility or the previous design, so that's why you see a difference in one to 276 in the volume approximately; one to about 70 in the flow areas; and about one to 3.7 in the lengths, okay? But overall, they were within a tight band, relatively tight band.

MR. WALLIS: I think it's funny, though, because if you were completely geometrically scaled then --

MR. REYES: Right.

MR. WALLIS: -- the volume would be the length ratio, but it isn't at all.

MR. REYES: No, it would be the length times the area.

MR. WALLIS: The area, which is the area of the length squared, so if it were really geometrically scaled --

MR. REYES: Yes.

MR. WALLIS: -- it would be --

MR. REYES: So, if I were to compare our facility to, let's say, Palisades, we're kind of -- we're a little bit taller and a little bit narrower, if that helps.

MR. SCHROCK: Semi-scale.

MR. REYES: But not to that extent. So I expect to see a lot of the 3D mixing behavior without any problem.

So that's where we are. So, I would say that geometrically, we have -- we look relatively good. I won't say it's perfect. If we were to design, of course, from scratch, we could match every diameter and every length. But we were in the zone where it varied from maybe length scale from 1.34 to 1.38, so we'll have to evaluate that when it comes to distortions and see if that's a --

MR. WALLIS: The L/D ratio, you'll get something which would be different.

MR. REYES: In our facility.

MR. WALLIS: Yes.

MR. REYES: Yes; for the down comer.

MR. WALLIS: It will be different from the Palisades.

MR. REYES: Right.

MR. WALLIS: So you're consistently off on all of the lengths.

MR. REYES: Right.

MR. WALLIS: The L/D ratio is a --

MR. REYES: Right, right.

MR. WALLIS: It's consistently different.

MR. REYES: Correct, correct, yes. Yes, we could only -- that's right.

Okay; the types of tests -- so that's the geometric similarity, just looking at the physical ratios around the plant. That's not looking at phenomena.

MR. ZUBER: The gap.

MR. REYES: The gap, yes; that's really the gap there.

So we're looking at two types of integral system tests or two categories, I should say: hot leg breaks, and we're looking at the types of breaks where the break energy is going to be similar close to the decay, so we're trying to keep the pressure off somewhat, so it's more of a slow, small break type of transient looking maybe at the top of the hot leg. Main steam line breaks, looking at a whole series of main steam line breaks to try to do, in particular, an asymmetric type of a main steam line break, so we can look at stagnation on one side of the plant versus the other. So we will see if that would occur and under what conditions that would occur.

We can also do some of the separate effects tests, and that might be useful to study the plume behavior a little bit more carefully. We can set up our facility to run in a steady state mode basically; get our initial conditions; done our HPI and then move some very careful measurements of the plume, so that would be helpful for our CSD students trying to calculate something that's maybe not transient.

MR. WALLIS: Can they get 15 minutes of stagnation and maintain it?

MR. REYES: Right, right.

MR. WALLIS: So, you're having to hope it might happen.

MR. REYES: Right; so, we're looking at both tests, this integral and separate effects.

Okay; since Dave already talked about the phenomena ranking, what I'd like to do is jump right into the thermal mixing scaling, so that's way out there on page 18.

So, this was a really -- these are always learning experiences for me. I enjoy it. The literature review on the thermal mixing part of it is very rich. There is a lot of work that's been done in the past, and people have been solving mixing of plumes for a long time. I've got some excellent papers by Bachelor, by Morton. There was a good paper by Turner, by Taylor. They were solving these plume problems way back when, and they didn't have a CFD code, and it was very interesting to see how they went about developing some of these similarities solutions to come up with very useful things.

Bachelor, in one of his papers, talks about they had a problem in World War II, and they wanted to use heaters alongside the runway to clear out the fog, and so, they were developing these heated jets on either side of the runway, basically a tunnel, so that the planes could land

and take off in foggy weather. So, the description of that research effort is really interesting, so I would recommend it. If you haven't looked at that one, I've got a copy of it, if you would like.

So there is a lot of good research that has been done, and a lot of it is related to similarity type solutions and to scaling of plumes, and lots of good pictures showing plumes at different scale lengths and the similarities between those plumes.

This is the overall approach that I have taken on the scaling. I want to scale the thermal fluid mixing behavior in the down comer and the cold leg, and I broke it up in two regions: the top down scaling and then the bottom up process type scaling, and the top down scaling, I was looking at the cold leg in the down comer as a control volume, and I was basing my calculation equations for that control volume on the bottom-up scaling and looking at very specific processes, looking at the high pressure injection flow rates, the back flow phenomena and high pressure injection lines. The onset of cold leg thermal stratification, which was one of the criteria of interest today, and I actually rederived this in a slightly different new and improved form.

First plume modeling, the lock exchange process; at the edge of the cold leg going into the down comer, you've got basically a pipe going into a large area, and that's kind of a classic lock exchange problem, where you have this countercurrent flow, kind of like the opening of the window. When it's a hot room, you open up the window, and you get this countercurrent.

So that's very similar to what you see in the down comer right at the cold leg entrance, or it is the same, and the down comer plume modeling and down comer heat transfer, so I won't be talking about every single one of these phenomena, but I'll try to hit most of them.

MR. ZUBER: What page is that?

MR. REYES: Page 18, and that's kind of a small slide there on this, a little hard to see.

So, I did go back and look at some of the behavior. This is a picture of the CREARE one-fifth scale mixing tests. You can kind of see how this plume developed, and it is because they had very low flows. The -- in the real plant, this would be a 10-inch diameter line with a very low injection flow. What they would do is they use the accumulator line for the injection point, instead of having lots of different penetrations. They use the accumulator line, basically, so we're injecting this cold plume. It comes in the bottom of the pipe. You can see here, it's spreading.

On this side is the loop seal. On this side, not too easy to see, is the down comer wall to the vessel, so they're spreading out this way, a little bit further in time. It's reaching the down comer. You're dropping back to this pump simulator, and even further in time, now, you've got a plume which is hard to see in a down comer, and you've got this countercurrent flow established in the loop seal, so you have some hot water coming this way and some of the cold water coming this way, the heavier water this way and lighter water this way.

So there is a lot of this type of data available. The early CREARE tests were done without a loop seal, and they did do -- they did include flow in this line to try and develop this stratification criteria.

So, this is the -- Dave's already shown you the geometry here that's kind of been -- this picture has been used a lot to describe the phenomena. There are some differences here, so the next slide is a little bit more along the lines of what you would expect to see in a plant like the Palisades plant, okay? And this is the -- basically, you have a side entry condition, so their injector is on the side instead of the top. So that's going to affect them in the mixing behavior right there.

It is a very low flow. You have the -- the cool pump has a lip on it, and that lip acts like a wier wall, and so, in our facility, we've modeled this wall. We've got the height scaled on this volume, actually it's scaled. And so, basically, it limits the amount of back flow into the loop seal. So that's a somewhat different arrangement than we've gotten in the past. So that will be interesting to see the behavior, but that's the type of thing that we're modeling in our facility.

MR. ZUBER: How do you deal with the thermal couplers underneath, down on the boom?

MR. REYES: Yes; so, we have thermal couplers -- oh, that's -- thank you. This figure shows you the thermal coupler placement underneath the cold legs. So this is one hot leg, and these are the four cold legs, and so, these are all of the -- the ones in red are thermal couplers that already existed, and the blue are thermal couplers that we've just added.

And you see, we have concentrated them quite a bit up towards the cold legs, and that gives you an idea of the distribution. So it's kind of an unwrapped vessel. Then, these thermal couplers were down there. As far as scale -- let's see -- this is about -- this would be about -- well, this is about one cold leg diameter here, one cold leg, two cold leg diameters, three, four, so this is about four cold leg diameters here. In Palisades, although they're looking both at the -- they're interested both in the weld material as well as the base material, so it doesn't necessarily have to fall right on a weld, per se, but they have one weld which -- circumferential weld, which is about two cold leg diameters down, and they have another one which is about the center of the rest, which is about five cold leg diameters down.

So, I used this basic drawing here as a control volume. This is going to be my thermal mixing volume to do the top down study and the bottom up analysis, and the way these analyses are performed, you write your balance equations, and what I hope -- the key things I get out of this is how to plot my data and particularly the cool-down rate, and I'll show you -- we've done some REMIX calculations using this result, and you can see that it does collapse. When you plot it in terms of nondimensional time and nondimensional temperature, you're able to collapse the data from the REMIX calculations for Palisades and those for APEX. And so, that's very encouraging.

So that means that this analysis at least gave us the right dimensionless groups.

MR. ZUBER: Do you have a slide for that?

MR. REYES: Oh, yes, yes.

MR. SCHROCK: The Qs now.

MR. REYES: Which one? The Qs?

MR. SCHROCK: I mean --

MR. REYES: Oh, I'm sorry.

MR. SCHROCK: -- the subscripts.

MR. REYES: Oh, okay.

MR. SCHROCK: Q_L, Q_M.

MR. REYES: Right, right; this is the volumetric flow rate for the HPI, volumetric -- the density for HPI. This is loop flow. So I also included the effect of what happens if you have a loop -- let me get my picture data -- Q_L would be -- I guess it was on this picture; yes this picture has the -- so here's Q_L, and if I have the loop flow, so if it's not stagnant; this is hard to see here. This is the hot fluid. This is hard to see here; this is a Q_{HPI}, and then, this is a mixture of Q_M, okay, so, it's a mixed mean type of volumetric thing.

MR. SCHROCK: It would seem to me that there ought to be a parameter something like the ratio of the sensible cooling capacity of the injected cold water against the thermal capacity of the vessel, in which case, the thinness of the vessel --

MR. REYES: Would impact.

MR. SCHROCK: -- would appear as a more prominent difference --

MR. REYES: Right.

MR. SCHROCK: -- between this and the full-scale plant. Does that emerge here?

MR. REYES: Right; yes. I'll show you the group where that appears.

MR. SCHROCK: All right.

MR. REYES: And for awhile, I thought about whether or not it needed to be included in the time scale, because you actually bring that into the time scale, and it turned out to be a small component.

MR. ZUBER: Which one did? The conduction?

MR. REYES: The conduction, yes, and the part of it is because it depends on the metal volume that you use, so if it's a narrow strip of metal just below the plume, it turns out to be a fairly small amount, a small amount of mass compared to the actual behavior on the outside. So that's one of the things that we found, and that's one of the things that came out of REMIX also. You have to input that into REMIX as one of the values, and so, when you look at that, I was surprised that that number didn't influence more.

We did it both for Palisades and for our facility. So you can write a mass balance equation; an energy balance equation, and I wrote the energy balance in terms of --

MR. ZUBER: What does this do for the -- you're cooling as far as -- I mean, the --

MR. REYES: Right.

MR. ZUBER: -- the solid comes very fast through the liquid temperature, and then, it stays.

MR. REYES: Well, this would say that -- so, if the heat transfer from your wall isn't playing as large of a part as I thought it was going to in heating up the plume.

MR. ZUBER: Yes.

MR. REYES: Yes; okay.

So, I wrote this in terms of a dimensionless temperature.

MR. ZUBER: So this would be, to some extent, noncomparative.

MR. REYES: We're saying not the real -- we think this is probably related to the real behavior. Now, we have to try it with some real plumes first, so once we have some measurements, we can see is -- do these approximations work or not? But right now, the contribution due to the metal mass is much smaller than I expected.

MR. ZUBER: It is?

MR. REYES: Yes; we did it also for Palisades, I mean, the calculation. Now, that could be due to the heat transfer coefficient that's being used in REMIX; I don't know. But I'm looking at two heat transfer correlations. One is a Feuster-Jackson correlation. There's another one which was some work done by LaBirdie, who is now one of our -- one of the faculty at OSU, and so, I'll be getting in touch with him, but he did some of the early work with Faith, Fayeth. Yes, I think Fayeth was his professor.

MR. SCHROCK: It's a transient problem

MR. REYES: Right.

MR. SCHROCK: And, I mean, the heat transfer coefficient can't be specified. I mean, it's got to be calculated at every step along the way. Does REMIX do that?

MR. REYES: That's a good question. That's a good question. I think it just gives you the correlation, and then, I don't know if it calculates a velocity propagating down or not. It just seems to -- it's more correlated than this type of experiment.

MR. SCHROCK: I think it's important to scrutinize that REMIX heat transfer coefficient specification. I don't know what it does. But I'm sure that in the real world, it's something that varies -- the hydrodynamic conditions are continuously varying throughout this whole problem practically.

MR. REYES: Right.

MR. SCHROCK: Even when you're in so-called stagnation, you're growing a thermal plume on the wall.

MR. REYES: That's right; yes. That's one of the things we should check. My gut reaction when I saw the calculation was that I thought that the wall would have a bigger role in heating up the plume than what was calculated. But that's just an observation.

MR. ZUBER: How long does it take to do this?

MR. REYES: Oh, very fast. Very fast.

MR. ZUBER: And then, you can get the feedback on the coefficient.

MR. REYES: Right; now, that's right. It's getting into the code and actually figuring out how they input that. These can be written in a dimensionless form, and in so doing, you come up with your time scale, which you put in the place of your shell volume and divide it by your volumetric fill of the HPI, so the focus of the analysis is -- what should happen is that your mass -- for your consistency, what should happen is that your mass balance and energy balance equation should both have the same time scale.

You come up with several dimensionless groups, which are in terms of density ratios, and I've got those here. So, here is the time scale. It's just that a density ratio group, one that describes a loop flow, and that's just the mass flow rate of the loop versus the kind of a mixture, like an outage type of an HPI mass flow rate.

And then, the ones that would play a larger role or could play a larger role is the down comer heat transfer. So, here, you have to come up with an expression for your down comer heat transfer in terms of some heat transfer correlation and divide it by basically a mixture energy transfer.

And then, you have a mixture temperature ratio. Now, for stining condition, all of these Q_Ls would drop out. And REMIX only does the stagnant condition. It doesn't do a calculation with flow.

So, the top down scaling, you produce these five groups, and then, from the bottom up, you try to fill in some of these -- the missing correlations, like the heat transfer coefficient and things like that. One areas is the HPSI flow rate. You want to specify a HPSI flow rate for our facility, and so, we have the same -- basically, all of our flows are going to be -- we're going to operate our facility one-to-one time scale, which will be -- it's a little different from what we've done in the past. We've operated on a half time scale.

Where you do that, all of your flows, all of your volumetric flows go with the volume, so it's one to 276, and that's what we've done here. So, and we've done it with a normalized pressure, so we can program our control system to respond to a given pressure or a given flow rate. So the HPSI event is going to respond like the HPSI in the Palisades plant.

The other aspect, once you do come up with your desired HPSI flow, and this is based on their nominal flow condition; once you come up with your HPSI flow, then, you can start looking at some of the other phenomena related to the HPSI operation. One is the back flow, whether or not you get the back flow in your injection line. Now, these lines are designed such that you have -- the nozzle comes in horizontally on an angle, and you have a check valve immediately after that nozzle. So, the check valve is right there, so it's really designed to prevent significant back flow into that line. I don't know if there's a -- if they get -- experience any chattering or not, but that's what it's designed for.

But flows are low enough to where you would expect to see back flow in the nozzle.

MR. WALLIS: This is where something else -- previously, you had the equation balances; you had -- these things have a way of sneaking in some of the mechanics, which is just sort of for --

MR. REYES: So, that reaction force type testing, yes.

When we compared the HPI fluid member in APEX and Palisades for the whole range of flow rates, if we choose our nozzle ID to be 1.35 inches, we overlay it.

MR. WALLIS: That would be --

MR. REYES: That's right; so, there's a little blue dot here, which is Palisades, and you can see up here, we hope we can reach that flow range, so they fall on top of each other. So we're satisfied that we can model any important back flow in that line pretty well. So that was one positive thing.

The other big criterion which comes in the bottom-up is this onset of thermal stratification, and that was a real interesting problem, because I dug into it quite a bit. Dave had asked me when he looked at Theophanus' criteria whether it made sense that the criteria should be based on a cold leg diameter.

[Pause.]

MR. REYES: The problem that's being addressed, basically, is you can have stratified flow, heavy fluid on the bottom, a lighter fluid on top, and what flow conditions, if there are relative velocities, would you expect the fluids to mix? So, intuitively, you would expect that the length scale for that to scale that would not be the entire cold leg diameter. It would be the length -- or what has been done in the past, it would be one of the lengths, either the light fluid length or the heavy fluid length. So that got me stirred up.

MR. ZUBER: The depth?

MR. REYES: The depth; the depth. That's a good way to put it.

So, this is the correlation that was used in the previous PTS study. Theophanus derived this -- he basically said that -- where he got this equation from was that the

Frude number of the mixture should equal one, and that would be like the down -- for stratified flow or for a mixed condition. So that was stated a priori. There was no basis for that, I mean, no additional information on that other than you kind of think of, you know, whether a pipe flows full or not, you think of a Frude number equal to one.

Based on a perfect mixing assumption that came up with this ratio of these betas, which is thermal expansion coefficients, and you've got this one-plus the loop volumetric accelerate over the Q_{HPI} base to the negative 3/2 power. He compared this to data that was obtained in the CREARE one-fifth scale and modified the correlation so the effect of this data ratio here is to make this exponent just a little bit larger, and so, he said go for a -7/5 exponent, so it's 1.4 instead of 1.5, and that would fit the data better from CREARE. And as a result, this is the criteria that was used.

Now, this Frude number here is kind of a mixed Frude number. It's based on the HPI length scale and the cold length mixed scale. That was one of the things that was kind of confusing.

It's defined as follows: so, you're using the HPI volumetric flow rate, but you're using the flow area of the cold length, okay? So, it's this kind of a mixed bag there. And then, you use the diameter of the cold leg, delta roll over roll. So this is the definition for this superficial Frude number, and the not superficial Frude number is equal to one plus Q_L over Q_{HPI} and raised to the -7/5. That would be the boundary, and that's what this boundary is here. So this is Theophanus' prediction. And this is some of the early data. We've got some calculations that -- we looked at some ROSA data and some APEX data. It wasn't really -- we had some steam in our line, so it wasn't exactly the case, but it did seem to fall in the right -- the five per sides of the line.

We also had some CFX calculations for an AP600 type of a system which sort of fell pretty close to the line, so we felt like that particular correlation was working reasonably well, but I still wasn't too pleased with this length scale, thinking it should be the depth.

So I went back and looked at several papers, and there was some work that was done by Gardner in 1973 looking at hydraulic jumps, and so, I said well, this would be a good way to analyze this problem if we did a hydraulic jump analysis. So that's what I did and came up with a new correlation, and I'll show you how that works. You have two stations. You have a light fluid flowing over a heavy fluid. This is a uniform velocity here; a uniform velocity here, and my idea is that over a certain -- these two stations are far enough apart such that a hydraulic jump occurs, and you have a nice uniform mixture velocity coming out.

So you're basically mixing everything up. You also see that in dilution problems. They study similar things. And you have this mixture velocity and your initial incoming velocities. And I defined these area fractions, so the area of the light fluid here at station one over the total area is alpha. The area of this light fluid here at station two over an area would be an alpha two. So the idea is that in a sense, you're keeping the constituents -- the identity of the constituents, in a sense, because you're maintaining this area.

However, if you look at it in terms of volume, you'll see that you get the same result in terms of mass of hot fluid to a total mass, and you wind up with a very similar kind of result. So this seems to have a fairly wide application.

MR. ZUBER: There are some data from Farouk working on something -- I don't have a name -- Bureau of Standards from the early sixties, and you have flow that uses a very similar approach.

MR. REYES: Okay; maybe this is already in the literature or something; the National Bureau of Standards.

MR. ZUBER: No, no, no, following a student of -- no, this is from the Bureau of Standards.

MR. WALLIS: I have a picture of the one we're coming in trade in the -- you're coming from the --

MR. REYES: Well, this is where the -- so, you have to use your imagination now, okay?

MR. WALLIS: Now, on the next page, you have Bernoulli's equation applied to something which goes from continuous to discrete.

MR. REYES: Yes; let me talk about the interpretation of this. If you have two emiscible fluids, okay, you might look and say and say oh, you have one on the water, and you can actually get some type of them behaving like this. Or if you have air in water, you might look at bubbles in a liquid. Because that's kind of where I started with this, and the more I thought about it, the more I realized, well, the way in which you treat this, you can treat it, in an average sense, as a mixture over here, and if you want to look at the head terms on this side, you could say, well, it's a row G times an H, you know, times some type of a fraction. And so, that's kind of where I was going with that.

MR. WALLIS: Your analysis is really for stratified to stratified. It goes from different stratified; that would make sense.

MR. REYES: And that is correct; that is really correct. So, in essence, it's just like the hydraulic jump going from one height to another height, but the difference is that VM. That makes a big difference, that mixture velocities. Now, I'm saying that both phases are going to travel or both fluids are going to travel the same mixture.

MR. WALLIS: Okay; you need some other piece of information.

MR. REYES: Right; and that turns out to be the key to --

MR. WALLIS: If you don't have that, you can't solve the problem. You need another piece of information.

MR. REYES: Right.

MR. WALLIS: You need something else.

MR. REYES: Correct; I just put the gavel down and said this is going to be -- removing out the mixture velocity. So you're ahead of me, so you're already on the next page.

So you can write an equation at each station, for the heavy fluid and for the light fluid, and you're saying, well, the energy is conserved. You can write the continuity equation, and really, you only need to write one, because you can relate -- I can relate this mixture velocity in terms of the volumetric flow, which is what I do next for a mixture.

If you do that, I'll just talk about the process in a little bit. The idea is if you eliminate the delta-p using these two equations, you write your mixture velocity in terms of a volumetric flow rate, so it's the DL plus VH over the flow area gives you an average velocity for the mixture, and that gives you a governing equation. You can reduce those two equations basically to this one using the continuity equation, to this one here.

And now, it's starting to look a little familiar. So this is the density of the hot fluid, the volumetric flow rate of the -- excuse me, the heavy liquid, the volumetric flow rate of the heavy liquid, G-delta-thorow times this length scale or diameter times this area fraction squared times these terms here, and you get a similar type of a thing here for the light fluid.

Now, you have to make some type of an assumption here. You want to have a hydraulic jump, and so, you're modifying the limiting condition so that you make a very simple critical condition assumption. You say that, well, alpha two is going to equal alpha one. And under those conditions, that's going to be basically your maximum -- I don't know if relative velocity is the correct term, but your maximum set of velocity conditions that can occur without a change in area fraction. So it's as if you're just at the precipice of making the jump, but you're trying to satisfy those conditions.

MR. WALLIS: It says alpha two equals alpha one, and nothing happened.

MR. REYES: Say it again? That's right; if -- on the one hand, you've got this V mixture on that one side, and on the other side, you've got basically a separated flow. If you said alpha two is equal to alpha one, and you didn't do anything about that; we make an assumption about the velocity.

MR. WALLIS: It's pretty hard for me to imagine how two fluids flow side by side without changing their area suddenly come to the same velocity. It doesn't seem feasible.

MR. REYES: Right; so, that's why it's basically the critical condition. It's not the actual condition.

So, let me show you what that does. When you make that assumption, it does two things: it changes this equation here. Of course, you can use this to plug in alpha two equals alpha one; it's not a real difficulty. It also changes your continuity equation, because now, all of a sudden, you have a relationship to relate the flows at the inlet to the flows at station one to the flows at station two.

So, when you do that, you make that simple substitution, alpha two equals alpha one --

MR. WALLIS: Is this equation on 121 in my book?

MR. REYES: I believe that's probably right. So you've seen this before.

[Laughter.]

MR. REYES: But wait, there's more.

[Laughter.]

MR. REYES: You can write it in terms of volumetric flow rates or velocities, and this is where you probably see more like due delta roll over -- times an area. And, of course, you can write them in terms of the Frude number, by Frude heavy, Frude light equals one.

This really is the stratification criteria. You can rewrite -- I can take this now with the critical condition, I can take this equation and reformat it in the way which will look very similar to Theophanus. But the fact of the matter is this is the stratification criteria right here. We've had it all along for many, many years, this equation has been known. But the fact of the matter is that this is really it.

And so, the length scales, then, are the heavy fluid and the light fluid, those are the true length scales for the problem. What's interesting is when you apply some of these assumptions I can show you: one assumption -- this next one is kind of a -- I'll put it up real quick. If you change your coordinates for the hydraulic jumps so that VH is zero, and you look at a rectangular geometry, you get this result from that previous equation, of course, which can be compared to this final Wallis --

MR. WALLIS: No, we got the first one, and we had to fudge it with a factor of 0.5 to make it --

MR. REYES: Oh, I know why that is. So, the next version of this will explain that point.

But if you do the -- if you apply that stratification criterion to the previous equation, you come up with a sum of the Frude numbers squared equals one. Then, if you use the continuity equation that comes from that critical condition, you wind up with an equation which is very, very similar to the original one for Theophanus. You have one plus Q_L over K-strike to the -3/2, so it's the same next point, compared to what was there before, but you do get something different up front, okay?

So now, our two criteria will diverge, which always adds a lot to the dramatic tension of things. The two criteria diverge somewhere, and nine is going to be a function -- it will depend on density ration, and it seems to have -- but this, I'm sorry, has to be QH -- you have all QHes here or QI, just to make it consistent with Theophanus. So same exact term there; some difference in the terms here.

So, I have to go through and evaluate -- where does that make a difference? The next plot shows the difference here. They do converge. As you go further out, as your loop flow increases, of course, they seem to converge, and I'll show you on a long scale a little bit better. But up here, this one will vary. This is the criterion that I developed; it will vary with density ratio, so you'll see differences due to the density ratio. And it is addressing an issue which was a problem for something that Theophanus had been working on, and that was he developed two codes, actually. It was a REMIX and a NEWMIX code, and the NEWMIX code was designed for high injection flows, which would be high values of QH.

I think this is -- I don't have the data, but unfortunately, the CREARE data goes about to here, point blank, so I need some data in this area. So it would be nice to test it out to see if that works, but for the conditions that we're studying, we're actually over here, where the two correlations converge quite well. So the next figure just shows that.

Looking at a different density ratio here, this is log-log scale; that's why there seems to such a precipice over on this end. This is looking at a typical density ratio of row light over row H of about 0.7, so they are very similar when you get further out here, and they are quite different on that end.

And on this side, if, for the case where, of course, the heavy fluid is much, much heavier than the light fluid, and if you assume it to be zero, they both go to one, and that's what you get there. Now, for the Palisades plant, we had that condition -- where we're looking at, it doesn't really make a very large difference. So basically, they're almost parallel at this point, and this is the range of conditions that would be applicable to the injection flow rate that I showed you earlier on. So the difference doesn't affect too much at all.

And the good thing about that, then, is, of course, that when you're scaling these things, what you do to provide a good comparison is if you preserve the superficial fluid number, and you preserve this Q_L to Q_H ratio, keep those to one in the facility of an APEX and Palisades, where Q_L is the loop vacillation flow rate, you should get good matched behavior as far as the onset of stratification. So that will work for either criterion. So as long as I preserve that, whether Theophanus' criteria is correct or my new one is correct --

MR. ZUBER: You want to get some data into the region that is different --

MR. REYES: Well, I think later on, when we go -- if we do some higher injection flow rates, you know I'm going to get into that area just to see how well that compares.

So here's the results. Looking at the criteria and applying it now to Palisades plant, when their pumps are on, as you'd expect, you know, this is the Palisades Q_{HPI} data, and this is the superficial Frude number versus the ratio of volumetric flow to HPI flow. It's going to be in the well-mixed regime, and that's what you'd expect to see. And this is the criteria here.

MR. WALLIS: By orders of magnitude.

MR. REYES: Yes, oh, yes, it's way, way up there. So that was no surprise.

When you trip the pumps, and you go into decay, I was surprised because the flow was fairly low, and now, on that one, this is at 2.5 percent decay power. You see that the data from the pump gets closer to the stratification condition. And, of course, if you drop the decay power --

MR. KRESS: That's why the decay power ended up on that PIRT chart as being important.

MR. REYES: Yes.

MR. WALLIS: It's what's driving this.

MR. KRESS: It's what's driving the circulation.

MR. REYES: It's what's driving the circulation.

MR. KRESS: Yes, so it determines when you get to a --

MR. REYES: Right.

When you go to 1.5 percent decay power, you predict that you may have periods of stratification even when you're at decay power, and you've got enough circulation.

MR. WALLIS: What time is this in the accident that you get down to 1.5?

MR. REYES: It's still under analysis.

MR. WALLIS: So you're interested in this as being a problem way out there? An hour after --

MR. REYES: Right; now, some of the transients that were studied in the previous study were a hot zero power type transients. So, you're already at some low decay power.

MR. WALLIS: The whole thing is depressurized, isn't it? Maybe not; it depends on the break size.

MR. REYES: Right; and there were so many assumptions, conservative assumptions that were made that it was --

MR. WALLIS: For small breaks.

MR. REYES: And then, of course, at 1 percent decay power, we expect to see a -- if the positive HPI ranges is at these pressures, it would be stratified.

The other thing, as far as the stratification criteria, and this does show a lot of data; I didn't point that out, but this is the Palisades; this is the APEX, so it's the blue and white thing. They just fell right on top of each other.

MR. WALLIS: Palisades isn't data, is it?

MR. REYES: No, no, I'm sorry, yes; well, neither is the APEX. Right now, these are just calculations. So, for the Palisades calculations and for the APEX calculations, it's one on top of the other.

MR. ZUBER: For the REMIX calculations?

MR. REYES: Right; now, so, this was for stratification criteria. Now, to look at the behavior in the plume or in the down comer, we did two cases, and at two different pressure conditions and different cold leg conditions, and what we're doing is relating a pressure in APEX to a pressure in Palisades, and we're looking at a corresponding flow rate, Q_{HPI} flow rate that would go with those corresponding pressures, okay? So these are injection temperatures.

Their injection temperature is 87 degrees is their nominal requirement. So that's higher than -- we actually did more cases where we looked at in the case of APEX injecting at 87 degrees and Palisades at 87 degrees as well as 60 degrees. Sixty degrees is easier for us to operate at that condition, but we could go to 87 degrees with a little bit of effort.

So, REMIX calculations, so there are two cases. Here's case number one, and we're looking at the Palisades. We're looking at the temperature in the plume at different elevations in the down comer. The two blue lines, this is the temperature at the cold leg line for APEX. This is the temperature at the cold leg line for Palisades. Now, this is in terms of dimension of temperature, and this temperature comes out of the top down scaling analysis, and versus the dimensionless time, and that's the same time constant that came out of the top down scaling analysis and versus dimensionless time, and that's the same time constant that came out of the top down scaling analysis.

MR. ZUBER: Are they the same?

MR. REYES: They're slightly different, so I've turned out -- if you took the ratio of our time constants, ours was about 0.8 something, so it's not quite one-to-one.

So, now, this is basically taking and predicting temperatures inside the plume, and this is the cold leg center line; the orange -- it's a little hard to see -- orange and orange. It's two diameters down, and then, the brown is five cold leg diameters into the down comer. So what we're seeing is that they don't exactly match, but to give you a feel for the time constant, this is about 7,000 seconds, 8,000 seconds in real time, so it goes fairly far out.

So there are some differences here, but in general, they match reasonably well for this case number one. As you get to the higher pressure, this is a lower pressure case. As you get to the higher pressure, we saw better agreement. So case two was done at a higher pressure, and if you see it starting to narrow down quite a bit; this is about 7,000 seconds.

So, when you plot them in dimensionless terms, you can actually collapse the data pretty well. Some of the distortions, well, one of the things that we were expecting to see was -- we were expecting to see more of a distortion because of the wall effect, and so, that's something that needs to be analyzed more carefully.

MR. WALLIS: It's very difficult to see comparisons between APEX 2D --

MR. REYES: Yes.

MR. WALLIS: -- from there. I don't know where they are.

MR. REYES: Okay.

MR. WALLIS: Are they on top of each other or something? It's so close.

MR. REYES: Here, they're pretty much on top of each other, and then, they start to deviate here. This is --

MR. WALLIS: Okay; so, the 2Ds and the 5Ds are both there.

MR. REYES: Yes; unfortunately, the colors are a little bit -- well, I would say this is going to be the 5D up here, because you expect it to be higher up.

MR. WALLIS: I see two lines instead of four lines, so presumably --

MR. REYES: So, two of them --

MR. WALLIS: Are on top of each other.

MR. REYES: This is --

MR. WALLIS: I see four lines instead of six lines. I see four reddish-colored lines.

MR. REYES: Right.

MR. WALLIS: I see two reddish-colored lines, although there are four --

MR. REYES: Let me explain; these two that match here, these are the two Palisades at five and two.

MR. WALLIS: Oh, so --

MR. REYES: Yes, five and two. So, what's happened there is that you've gotten out to a certain distance.

MR. WALLIS: This is like what Dave was saying.

MR. REYES: This is what Dave was saying.

MR. WALLIS: Out to two; the five is the --

MR. REYES: Yes; and then, these are five and two for APEX.

MR. WALLIS: Oh, okay.

MR. REYES: Okay? And then, these are the two blue with the cold leg center lines.

MR. WALLIS: Zero and --

MR. REYES: Right.

MR. WALLIS: -- zero.

MR. REYES: So that's the type of behavior that we're seeing based on REMIX calculations.

MR. WALLIS: So, let's see now. This is saying that the cold leg centered temperature is not so different from the temperature in the down comer.

MR. REYES: Right; yes, for these cases, that's right. So, what REMIX does is you have an injection temperature, and then, you have mixing occurring --

MR. WALLIS: I thought the whole problem was --

MR. REYES: -- in the cold legs.

MR. WALLIS: -- that the temperatures were supposedly very different if there was a plume.

MR. REYES: Well, they're different, but you have quite a bit of mixing.

Now, this was, in this case, REMIX allows flow in both directions. So we would have to set up our problem so that we have the -- we have that weir wall on one side. We'd have to set it up so that we can --

MR. WALLIS: Doesn't the vessel still have -- why aren't the red curves starting out hot with the other one cold? Or am I somehow confused?

MR. REYES: So, these are just fluid temperatures, and I'm -- that's a good -- timewise --

MR. WALLIS: I was expecting to see a cold temperature and a hot temperature, and they all seem to be sort of close to each other.

MR. REYES: They're very tight, yes.

MR. KRESS: These don't include heat transfer to the walls.

MR. REYES: They do. They're --

MR. KRESS: But the mixing is -- sort of overwhelms that?

MR. REYES: That's right; when I mentioned earlier on that I was expecting to see more of an effect on the wall.

MR. WALLIS: The dimensionless -- the way you dimensionalize them, nondimensionalize them different for the blues and the reds, which is why they look the same. They're both sort of forced to go up in 01. So, the actual temperatures themselves are quite different.

MR. REYES: Right.

MR. WALLIS: So it's sort of misleading.

MR. SCHROCK: What is this dimensionless time scale? I wasn't able to find that.

MR. REYES: That comes in the back of the top down scaling.

[Pause.]

MR. REYES: So, this is the time constant. Oh, that's a good point. This volume here, that's going to be the active volume of the control volume, so in REMIX, they give you a specific formula.

MR. SCHROCK: Fluid volume.

MR. REYES: Fluid volume, right; they give you a specific formula that says you take the cold leg length of the portion of the loop seal and one-quarter of the down comer.

MR. WALLIS: This is sort of a mixed reactor with a volume of the vessel and the flow rate of the --

MR. REYES: Exactly right. And so, they use that, then, as a -- if you did a perfect mixing, of course, you would just have an exponential decay kind of a thing and in terms of the same time constant.

MR. WALLIS: I was sort of puzzled by the last -- the one with the temperatures.

MR. REYES: Oh.

MR. WALLIS: I thought the convection water had to be colder than that.

MR. REYES: Oh, I see.

MR. WALLIS: You fixed CL center; what is that?

MR. REYES: That's the cold leg center line.

MR. WALLIS: Well, does that mean that you've actually got hot water off there by now, and the cold water is below it?

MR. REYES: That's a good question; that's a good question.

MR. WALLIS: If you looked at the cold leg bottom --

MR. REYES: It seems to be -- yes.

MR. WALLIS: Quite different, wouldn't it?

Anyway --

MR. REYES: Well, that's a good question, and I agree with you. That should have been more.

MR. WALLIS: Well, the message is that APEX is like Palisades.

MR. REYES: Correct.

MR. WALLIS: Whatever we're looking at.

MR. KRESS: I was guessing that APEX cold leg center was just the point that the cold leg, where it goes in, that little point right at the bottom, just as you first go in and meet the wall.

MR. REYES: The wall.

MR. KRESS: That's what I thought you meant.

MR. REYES: Oh; I think it's --

MR. KRESS: So, it would be zero height there or zero depth.

MR. REYES: I think in the code, 0.0 is actually the center of the --

MR. KRESS: It's actually the center?

MR. REYES: The center of the cold leg.

MR. SCHROCK: It seems to me there are two features that don't come in here. One is the fact that the reactor has this massive wall, and therefore, the start energy in that vessel is really big compared to anything that you have in APEX.

MR. REYES: Right.

MR. SCHROCK: Does it show up in this dimensionless time? And I don't see how it factored into the dimensionless temperatures --

MR. REYES: Right.

MR. SCHROCK: -- either.

The other thing is that your APEX is designed for saturation temperature at 300 psi compared to -- what is the temperature difference there is about 150 degrees or --

MR. REYES: Yes, it would correspond to --

MR. SCHROCK: So, the delta-t driving the heat transfer is like twice as great in the reactor as compared to APEX.

MR. REYES: Right; the difference is in the fraction, in looking at the -- so, I looked at it both ways, including the time constant which includes the effect, the volume of the mass. It turns out that that volume of that mass is very small, because what you're looking at is just the volume of mass directly under the plume as opposed to the -- that the way this is modeled, one-fourth the down comer fluid volume, all the cold leg volume and the loop seal volume. So that number actually turns out to be physically small. I can show you the -- I don't have them with me, but I can send them, of course, to you.

Now, my gut feeling was that I should see more of an effect, but these are just code calculations right now, so fluent might -- or one of the CFD codes might predict something different, but it's got to depend on the H that you pick.

MR. ZUBER: Does REMIX really calculate the conductions?

MR. REYES: It's one of the claims is that you input all of your metal mass according to their --

MR. ZUBER: Okay; you can see what the --

MR. REYES: Yes; they use an H which is based on Feuster-Jackson, and they come up with a temperature --

MR. ZUBER: They do 1D calculations.

MR. REYES: 1D calculations.

MR. ZUBER: Conduction?

MR. REYES: Right.

MR. ZUBER: In the metal.

MR. REYES: Correct, yes.

MR. ZUBER: You don't see the effect on the wall. The difference in the --

MR. REYES: Right; and I agree. So that's something we could look into, of course, much further, but we'd like to use maybe one of the CFD codes to try to do that.

MR. ZUBER: CFD codes will not address -- they will not calculate the --

MR. REYES: Yes, they have that. The new ones have that, yes.

Okay; so, let's conclude this part of it here. So, let me summarize the results here.

MR. SCHROCK: I guess another way of looking at it, Jose, is penetration depth for the conduction problem is the same -- that the metal is the same.

MR. REYES: Well, let's see.

MR. SCHROCK: So, the penetration depth compared to the wall thickness at any point in time would be much greater in APEX than it is in the reactor.

MR. REYES: Right; now, we do have -- our vessel is all stainless, and the conductivity is pretty low on that.

MR. WALLIS: I mean, it doesn't penetrate further than a certain distance. As long as the wall is much thicker than that, it doesn't matter.

MR. REYES: It's in here.

MR. WALLIS: Anyway, you're going to sum it all up.

MR. REYES: Right; that's one of the goals. That's something that I identified already and said that this something is not quite --

MR. WALLIS: So you're going to address, then, these two questions: can you predict the overall sort of transient and the flow rates in the whole loop well enough to know when you get stagnations, and the other thing is can you model the boom in the down comer accurately enough for whatever purposes. Those are the sort of the two key goals.

MR. REYES: Those are the key goals.

As far as my personal concerns of how well the experiments will go, the measurement points, you can never get enough measurement points in a down comer, especially things like velocity. It's very difficult to come up with velocities when you're at pressure, and we looked at some of the probes that are available commercially, and they won't -- unfortunately, they won't do the temperatures that we wanted to look at, so we're still looking to see what's a good way to measure the velocity.

MR. WALLIS: I think your CFD people ought to consider different turbulence models, because this doesn't do a good job on this kind of lines of flows.

MR. REYES: Well --

MR. WALLIS: Confined jets, and this is a kind of confined jet as well.

MR. REYES: Right.

MR. WALLIS: So there are certain situations where Kay-Epson is not -- there are other models which are -- this shouldn't be so difficult; it is, after all, a single phase flow.

MR. REYES: Well, it's a single phase flow. It should -- well, that's what these codes were developed for, I mean, these CFD codes.

MR. WALLIS: Well, I think as far as the down comer goes.

MR. REYES: Right.

MR. WALLIS: Because the whole loop thing has to --

MR. REYES: Right, that's the difference, right.

Well, I'm going to conclude there. I can't find my conclusion slides. They got mixed in with this stuff, so you can read through there. We've modified the facility to include the loop seals. Now, it's just based on geometric similarity and trying to meet this stratification criteria as far as the h-dry nozzle. We believe we can model the onset of h-dry back flow. We can model the thermal stratification in the cold legs.

We have a new criterion which I'd like to get some test data on the other end to see if that works or not.

We've got our time constants for the mixing behavior, and I have a note here that I should check the effect of the conduction volumes.

And as far as remaining scaling, I still need to complete the documentation on the secondary side blow-downs, the main steam breaks and then produce one large table with all of the pi groups so that I can evaluate them and present the distortions in kind of a unified way. So that's still something that's lacking with regards to this analysis.

Any questions?

MR. WALLIS: Well, my impression from both presentations is that we've given you a bit of feedback, but really, you're so much at the beginning of this that I'm not sure we can help you much until you start to get the results, and this looks like a good way to proceed generally speaking. We have to get some results.

MR. REYES: Okay; well, I'm open to any turbulence models you might have or any other analysis ideas.

MR. ZUBER: I think better about the -- now than --

MR. REYES: Okay; good.

MR. WALLIS: Well, we still need some good feeling that when these guys do their academic jobs that it's going to be well-integrated into whatever is done here.

MR. ZUBER: It depends on how they're going to use it and for what purpose.

MR. WALLIS: So, what does the committee want to do? Any more questions? Any more presentations from the staff?

MR. BOEHNERT: That's it?

MR. ELTAWILA: I'd like just to close. I want to thank Jose and Dave for their presentation. I think, before I get into that, Paul pass on an integrated schedule for the PTS issue resolution and rulemaking process. I just want to let you know that we are part of an integral team that's working on the PTS, and there is a cooperation from the industry at work to provide the staff with the information to be able to come up with the resolution of that issue.

We were asked to provide pressure, temperature and heat transfer calculations, a very simple request that was requested from us from the team that's working on PTS. We thought that if we come here to you and provide you with RELAP5 or a TRAC calculation, we're going to be harassed about the applicability of this code to this transient. So we took a different approach. We said let's try to use some of the facility that we have here to try to understand some of the physics that's happening in the facility and use the experimental data, the scaling rationale and the codes and try to put a story together about the actual behavior of the plant.

If we fail to make that message clear, I hope by the time that Jose finished, I think it's clearer right now; we would have been much better prepared if we had a few weeks to digest the information that's coming out of Jose and things like that, but we're trying to do the best with what we have right now.

So, the -- again, the emphasis of the program is just to provide them with this information so they will be able to do an integral assessment of the PTS. Another thing that's different from the original analysis that was done in 1985 that we are going to have an integral assessment of the uncertainty, talking about the thermal hydraulic uncertainty fracture mechanics and PRA and integrated together. So that's why some of the experiment work is being pursued right now.

Thank you.

MR. WALLIS: Thank you.

And now, I think it's been very useful that we've learned what you're doing. We're going to keep in touch as you work on this problem, which seemed to me too early for us to recommend that any presentation be made to the full ACRS. We're not ready for anything like that, are we?

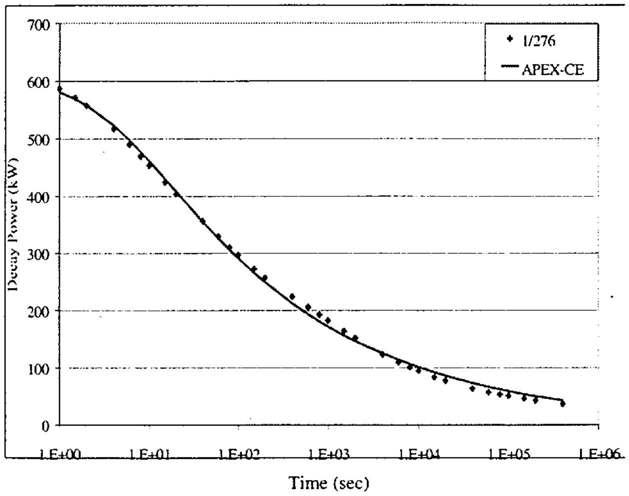
MR. ELTAWILA: We've -- yes, I think all the presentation about PTS is coordinated as one presentation. There will be no single presentation of thermal hydraulics.

It's an overall project. And there are some milestones here; you can see them that we are supposed to continue.

MR. WALLIS: Right. Well, maybe we could go off the record, and then, we could have a discussion among ourselves about what we've learned today. Would that be appropriate to do that now? Just caucus before we disappear for the day? So, let's close the record. I'll close the meeting. Thank you very much.

[Whereupon, at 4:15 p.m., the recorded portion of the meeting was concluded.]

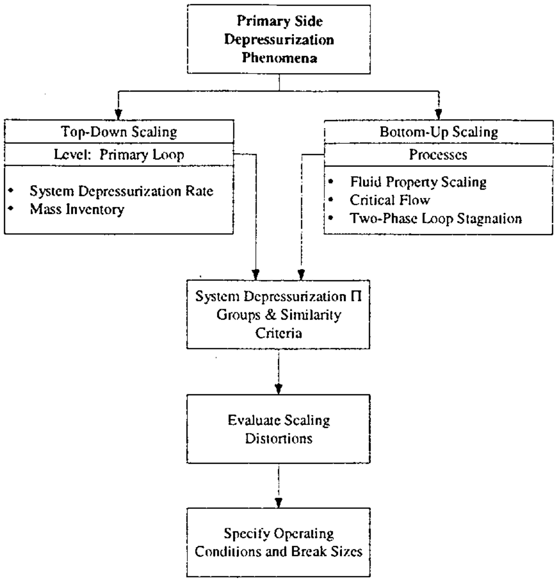
APEX-CE Decay Power



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.**

System Depressurization Scaling



Primary Side Depressurization Phenomena

Top-Down Scaling

Level: Primary Loop

- System Depressurization Rate
- Mass Inventory

Bottom-Up Scaling

Processes

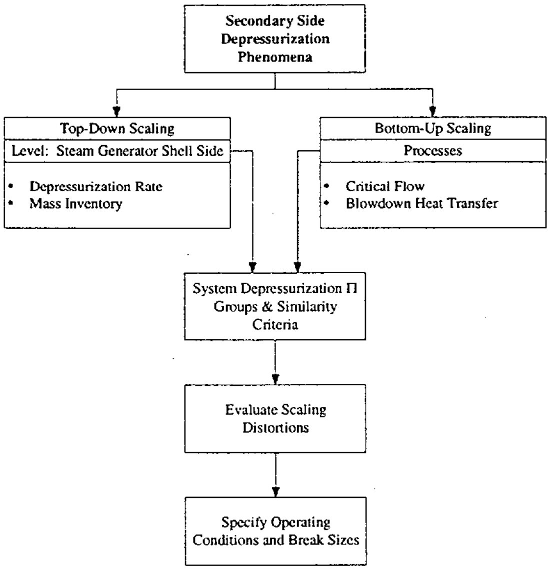
- Fluid Property Scaling
- Critical Flow
- Two-Phase Loop Stagnation

System Depressurization Π Groups & Similarity Criteria

Evaluate Scaling Distortions

Specify Operating Conditions and Break Sizes

System Depressurization Scaling



Secondary Side Depressurization Phenomena

Top-Down Scaling

Level: Steam Generator Shell Side

- Depressurization Rate
- Mass Inventory

Bottom-Up Scaling

Processes

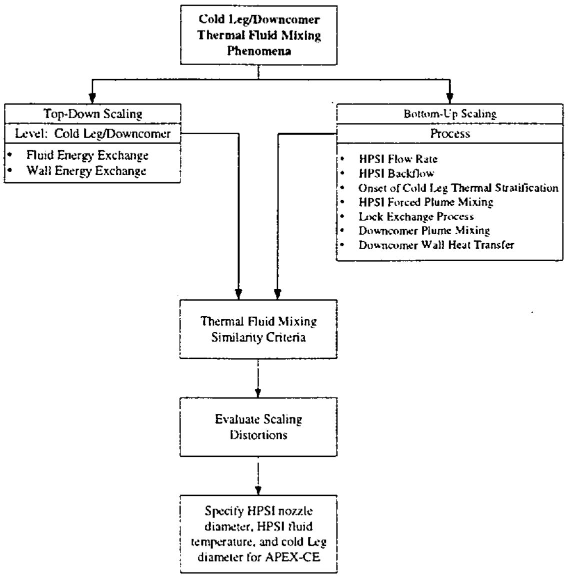
- Critical Flow
- Blowdown Heat Transfer

System Depressurization Π Groups & Similarity Criteria

Evaluate Scaling Distortions

Specify Operating Conditions and Break Sizes

Thermal Mixing Scaling Analysis



Cold Leg/Downcomer Thermal Fluid Mixing Phenomena

Top-Down Scaling

Level: Cold Leg/Downcomer

- Fluid Energy Exchange
- Wall Energy Exchange

Bottom-Up Scaling

Process

- HPSI Flow Rate
- HPSI Backflow
- Onset of Cold Leg Thermal Stratification
- HPSI Forced Plume Mixing
- Lock Exchange Process
- Downcomer Plume Mixing
- Downcomer Wall Heat Transfer

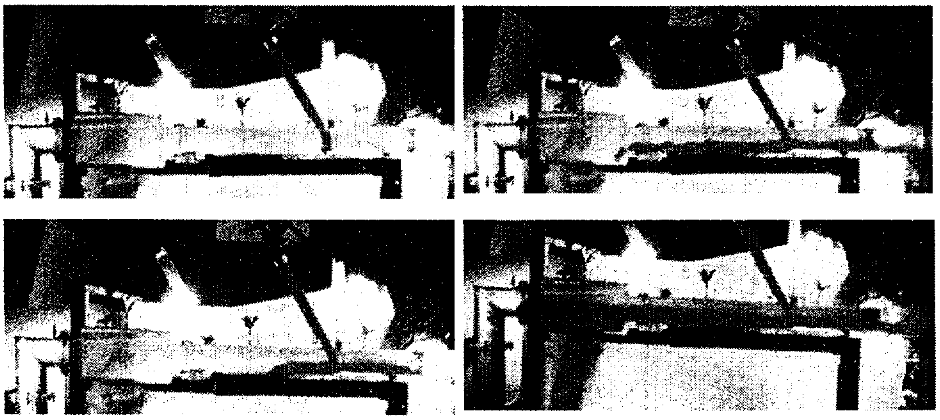
Thermal Fluid Mixing Similarity Criteria

Evaluate Scaling Distortions

Specify HPSI nozzle diameter, HPSI fluid temperature, and cold Leg diameter for APEX-CE

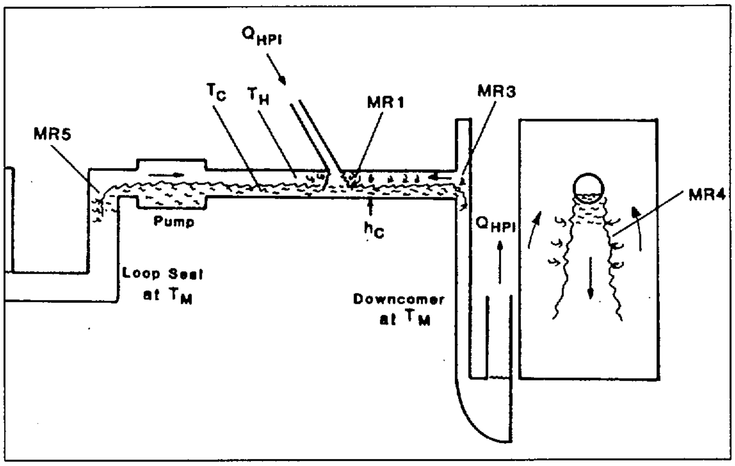
Nuclear Engineering & Radiation Health Physics
Oregon State University

CREARE 1/5 Scale Mixing Tests



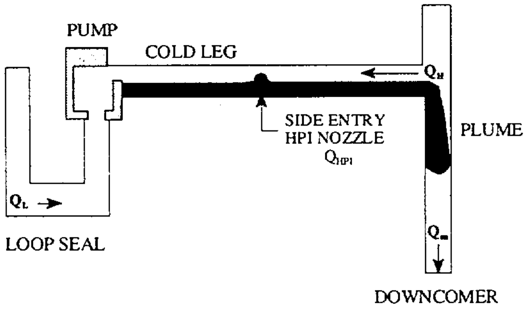
Nuclear Engineering & Radiation Health Physics
Oregon State University

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:**

$$V\frac{d\rho_m}{dt} = Q_{HPI}\rho_{HPI} + Q_L\rho_L - Q_m\rho_m \qquad (6.1)$$

- **Energy Balance:**

$$V\frac{d\Theta}{dt} = \frac{q_{DC}}{\rho_m C_P(T_{LO} - T_{HPI})} - Q_{HPI}\frac{\rho_{HPI}}{\rho_m}\Theta - Q_L\frac{\rho_L}{\rho_m}\frac{(T_m - T_L)}{(T_{LO} - T_{HPI})} \qquad (6.7)$$

  - **where**

$$\Theta = \frac{(T_m - T_{HPI})}{(T_{LO} - T_{HPI})} \qquad (6.6)$$

Dimensionless Balance Equations

- **Mass Balance:**

$$\tau_{HPI}\frac{d\rho_m^+}{dt} = \Pi_\rho Q_{HPI}^+ + \Pi_L Q_L^+\rho_L^+ - \Pi_m Q_m^+\rho_m^+ \qquad (6.16)$$

- **Energy Balance:**

$$\tau_{HPI}\frac{d\Theta^+}{dt} = \Pi_q\frac{q_{DC}^+}{\rho_m^+} - \Pi_\rho\frac{Q_{HPI}^+\Theta^+}{\rho_m^+} - \Pi_L\Pi_T\frac{\rho_L^+Q_L^+}{\rho_m^+}(T_m - T_L)^+ \qquad (6.21)$$

Characteristic Time Scale & Π Groups

- **Mixing Time Constant:**

$$\tau_{HPI} = \frac{V}{Q_{HPI,O}} \tag{6.17}$$

- **Density Ratio:**

$$\Pi_\rho = \frac{\rho_{HPI}}{\rho_{m,o}} \tag{6.18}$$

- **Loop Flow Rate Ratio:**

$$\Pi_L = \frac{Q_{L,O}\rho_{L,O}}{Q_{HPI,O}\rho_{m,o}} \tag{6.19}$$

Nuclear Engineering & Radiation Health Physics
Oregon State University

Characteristic Time Scale & Π Groups

- **Mixture Flow Ratio:**

$$\Pi_m = \frac{Q_{m,o}}{Q_{HPI,O}} \tag{6.20}$$

- **Downcomer Heat Transfer:**

$$\Pi_q = \frac{q_{DC,O}}{\rho_{mo} Q_{HPI,O} C_P (T_{mo} - T_{HPI})} \tag{6.22}$$

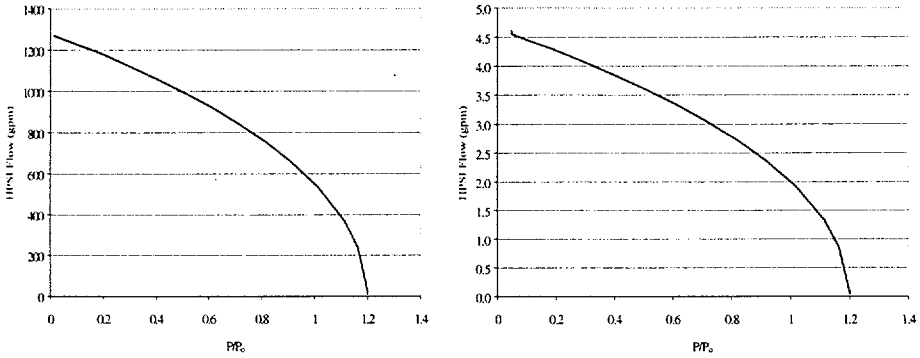
- **Mixture Temperature Ratio:**

$$\Pi_T = \frac{(T_m - T_L)_o}{(T_{mo} - T_{HPI})} \tag{6.23}$$

Nuclear Engineering & Radiation Health Physics
Oregon State University

Bottom-Up Scaling

HPSI Flow Rate



Palisades APEX-CE

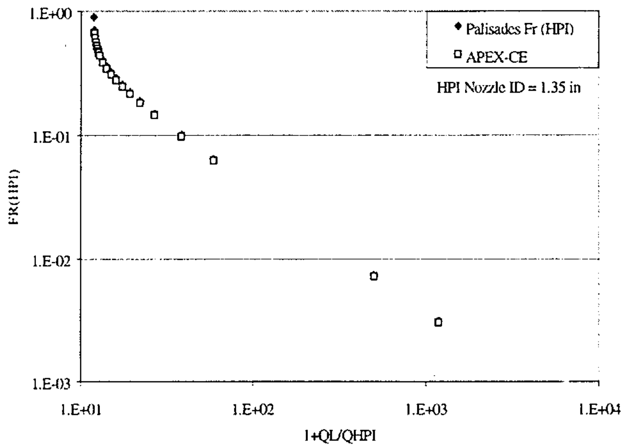
Buoyant Backflow into the Horizontal HPSI Line

- **HPI Froude Number:**

$$(Fr_{HPI})_R = 1 \tag{6.24}$$

$$Fr_{HPI} = \frac{Q_{HPI}}{a_{HPI}\left[gD_{HPI}\frac{(\rho_{HPI} - \rho_{CL})}{\rho_{HPI}}\right]^{1/2}} \tag{6.25}$$

Buoyant Backflow into the Horizontal HPSI Line



Nuclear Engineering & Radiation Health Physics
Oregon State University

Onset of Cold Leg Thermal Stratification

- **Theofanous (et al.):**

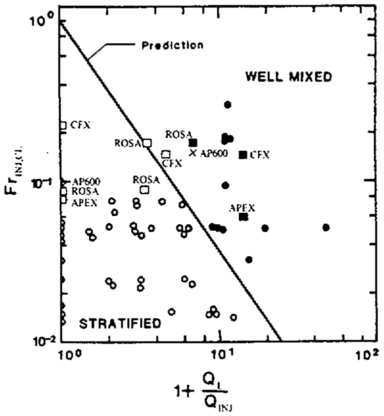
$$Fr_{HPI/CL} = \left[\frac{\beta_m}{\beta_{HPI}}\right]^{-1/2}\left[1 + \frac{Q_L}{Q_{HPI}}\right]^{-3/2} \qquad (6.27)$$

  - **which was approximated by:**

$$Fr_{HPI/CL} = \left[1 + \frac{Q_L}{Q_{HPI}}\right]^{-7/5} \qquad (6.28)$$

Nuclear Engineering & Radiation Health Physics
Oregon State University

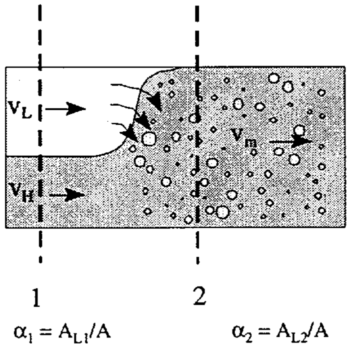
Thermal Stratification Criterion



$$Fr_{HPI/CL} = \frac{Q_{HPI}}{a_{CL}\left[gD_{CL}\frac{\rho_{HPI}-\rho_{CL}}{\rho_{HPI}}\right]^{1/2}} \quad (6.29)$$

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.**



Hydraulic Jump Analysis

- **Continuity Equation for Heavy Fluid:**

$$\rho_H v_H (1-\alpha_1) A = \rho_H v_m (1-\alpha_2) A \qquad (6.35)$$

- **Bernoulli's Equation for each fluid:**

Heavy Fluid →

$$P_1 + \frac{\rho_H v_H^2}{2} + \rho_H g D(1-\alpha_1) = P_2 + \frac{\rho_H v_m^2}{2} + \rho_H g D(1-\alpha_2) \qquad (6.37)$$

Light Fluid →

$$P_1 + \frac{\rho_L v_L^2}{2} - \rho_L g D\alpha_1 = P_2 + \frac{\rho_L v_m^2}{2} - \rho_L g D\alpha_2 \qquad (6.38)$$

Hydraulic Jump Analysis

- **Governing Equation:**

$$\frac{\rho_H Q_H^2}{g\Delta\rho D A^2(1-\alpha_1)^2}\left[\frac{2-(\alpha_1+\alpha_2)}{2(1-\alpha_2)^2}\right] + \frac{\rho_L Q_L^2}{g\Delta\rho D A^2\alpha_1^2}\left[\frac{(\alpha_1+\alpha_2)}{2\alpha_2^2}\right] = 1 \qquad (6.39)$$

- **Critical Condition:**

$$\alpha_2 = \alpha_1 \qquad (6.40)$$

  - **Maximum relative velocity that can occur without a change in area fraction.**

Hydraulic Jump Analysis

- **Stratification Criterion:**

$$\frac{\rho_H Q_H^2}{g\Delta\rho D A^2(1-\alpha_1)^3} + \frac{\rho_L Q_L^2}{g\Delta\rho D A^2\alpha_1^3} = 1 \qquad (6.41)$$

$$\frac{\rho_H v_H^2}{g\Delta\rho D(1-\alpha_1)} + \frac{\rho_L v_L^2}{g\Delta\rho D\alpha_1} = 1 \qquad (6.42)$$

$$Fr_H^2 + Fr_L^2 = 1 \qquad (6.44)$$

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)**

$$Fr_\Delta = 0.5\left(1 - \frac{h_L}{H}\right)^{\frac{1}{2}}$$

Hydraulic Jump Analysis

- **New stratification criterion:**

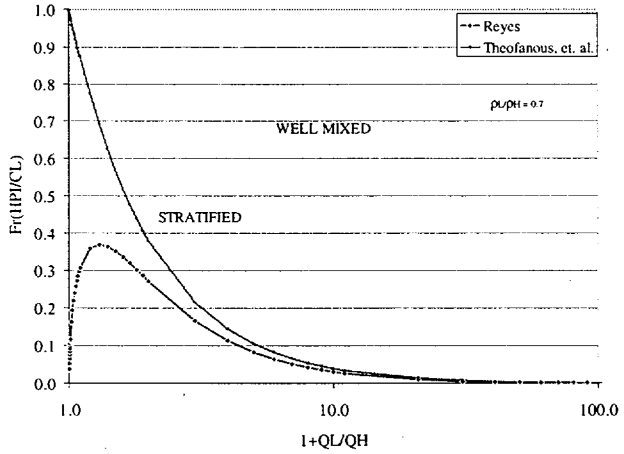
Reyes ⟶

$$Fr_{HPI/CL} = \left[1 + \frac{\rho_L Q_H}{\rho_H Q_L}\right]^{-1/2}\left[1 + \frac{Q_L}{Q_{HPI}}\right]^{-3/2} \quad (6.46)$$

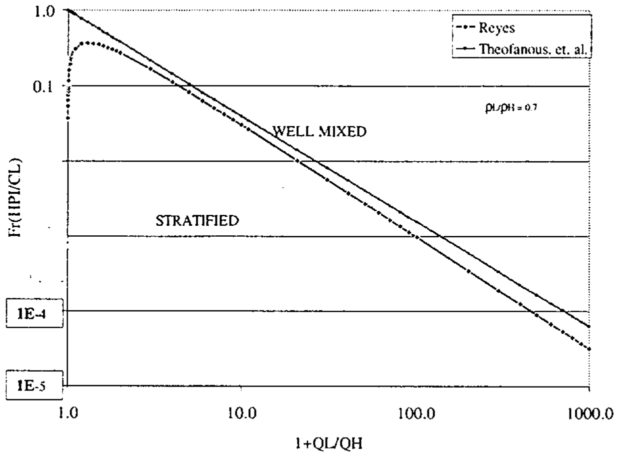
Theofanous (et al.) ⟶

$$Fr_{HPI/CL} = \left[\frac{\beta_m}{\beta_{HPI}}\right]^{-1/2}\left[1 + \frac{Q_L}{Q_{HPI}}\right]^{-3/2} \quad (6.27)$$

Comparison of Criteria

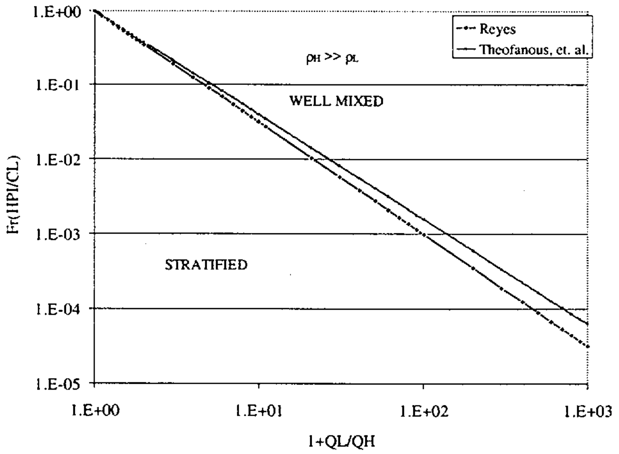


Comparison of Criteria



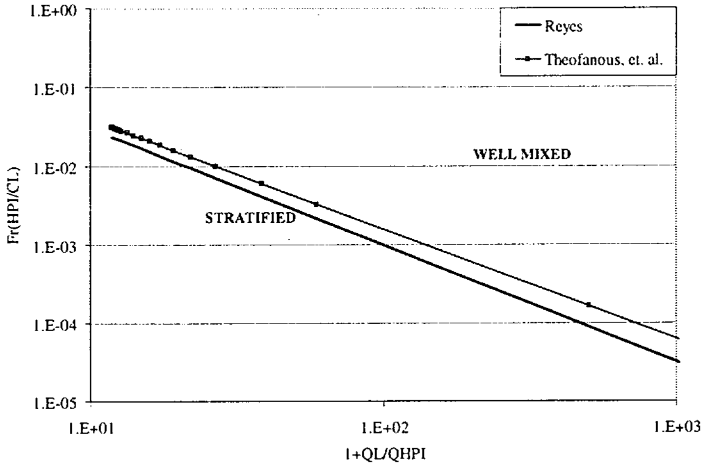
Nuclear Engineering & Radiation Health Physics
Oregon State University

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

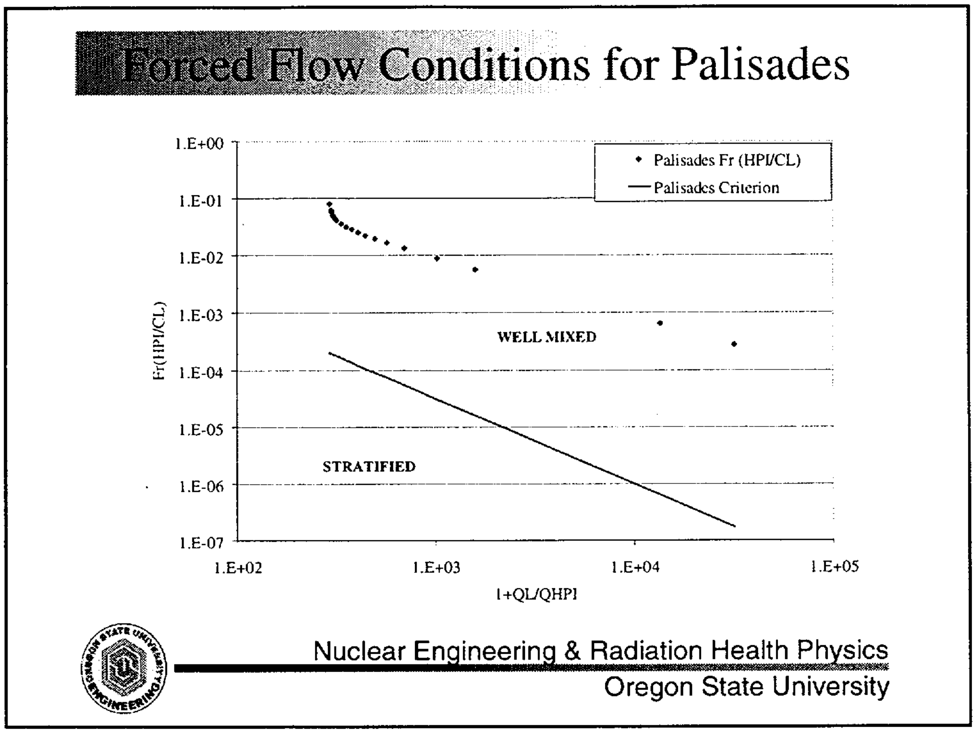
- **Thermal Mixing in the Cold Leg:**
  - **To preserve the onset of thermal stratification in the cold leg, requires:**

$$(Fr_{HPI/CL})_R = 1$$

$$(Q_L/Q_{HPI})_R = 1$$

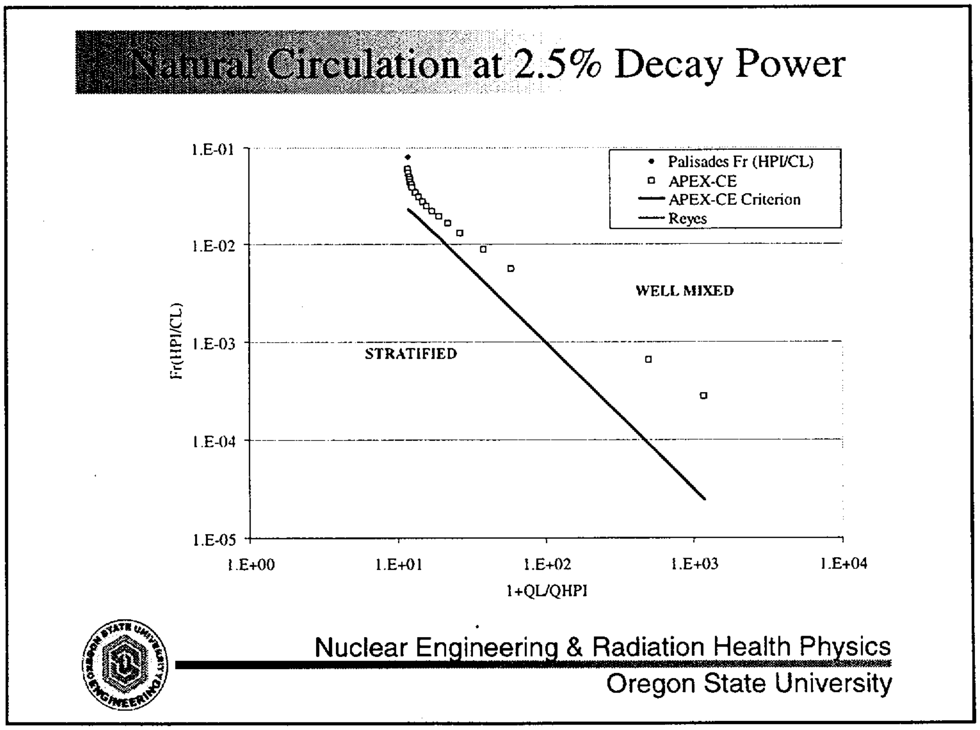
  - **where Q_L is the primary loop natural circulation flow rate.**

Nuclear Engineering & Radiation Health Physics
Oregon State University



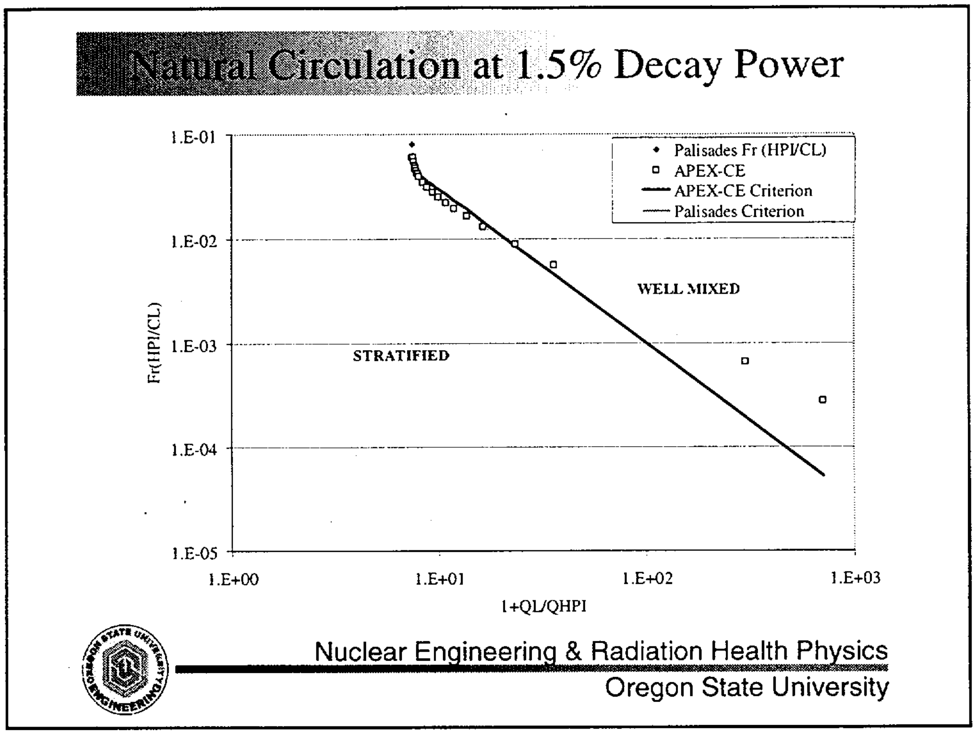
Forced Flow Conditions for Palisades

Nuclear Engineering & Radiation Health Physics
Oregon State University



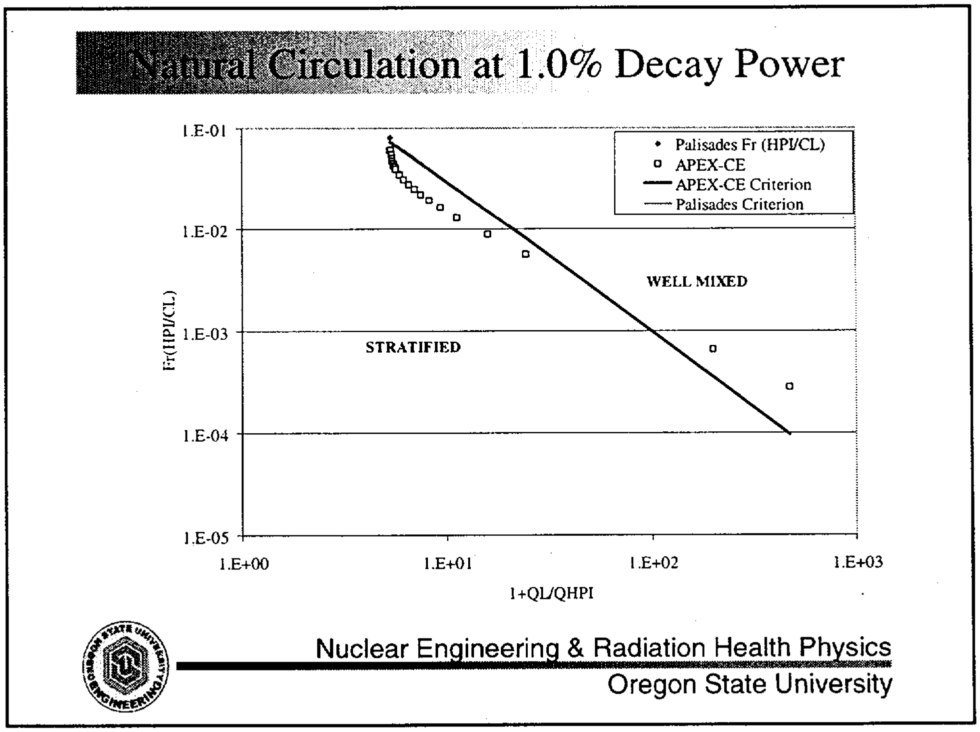
Natural Circulation at 2.5% Decay Power

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

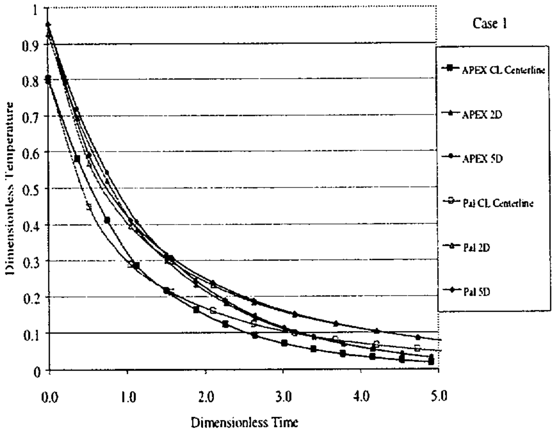
Nuclear Engineering & Radiation Health Physics
Oregon State University

REMIX Calculations

	Pressure (psia)	Cold Leg Temperature (°F)	Injection Temperature (°F)	Injection Flow Rate (ft^3/s)
Case 1				
APEX-CE	90	320	60	2.25×10^{-3}
Palisades	315	421.8	87	0.62
Case 2				
APEX-CE	290	414	60	1.07×10^{-3}
Palisades	1020	546.4	87	0.297

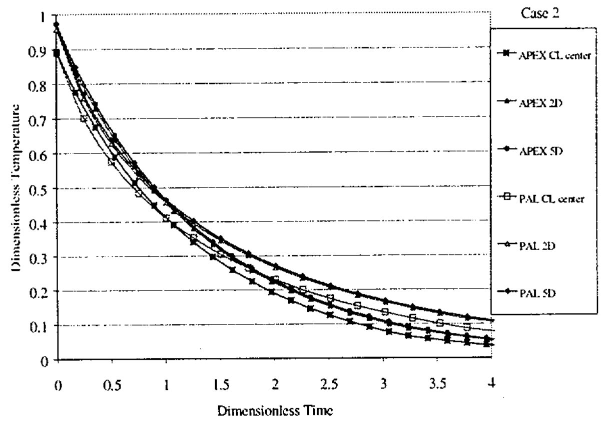
Nuclear Engineering & Radiation Health Physics
Oregon State University

REMIX Plume Temperature Calculation



Nuclear Engineering & Radiation Health Physics
Oregon State University

REMIX Plume Temperature Calculation



Conclusions

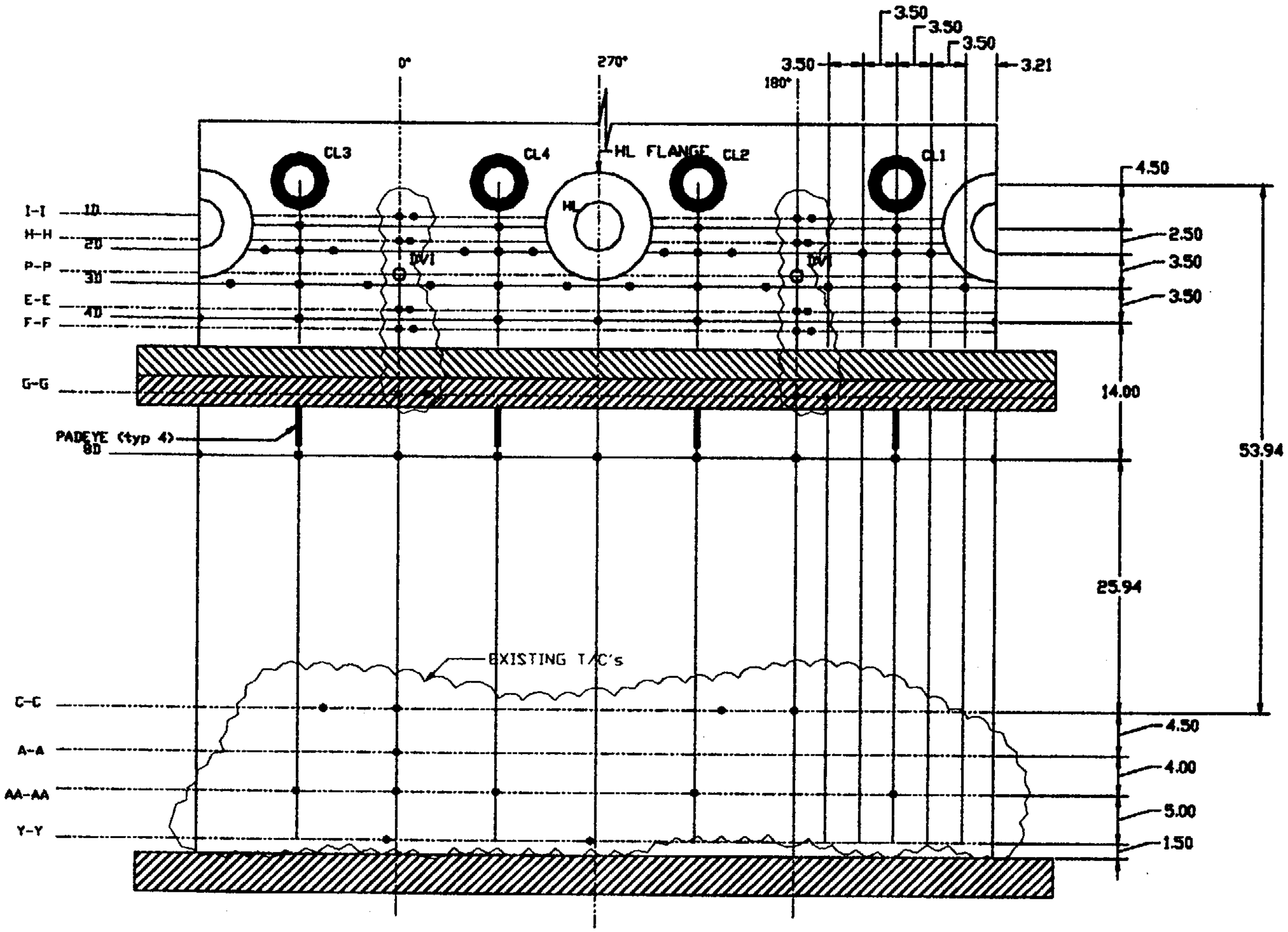
- **OSU has modified APEX to simulate the Palisade's 2x4 PWR. This includes the addition of an HPI line on each cold leg, cold leg loop seals, and additional T/C rakes.**
- **APEX-CE is geometrically similar to Palisades.**
- **APEX-CE operations will match the range of Fr_{HPI}, $Fr_{HPI/CL}$ and Q_L/Q_{HPI} 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.**

Conclusions (*continued*)

- **Detailed Downcomer mixing behavior can be studied using separate effects tests in APEX-CE.**
- **Time constants and characteristic Π groups have been obtained for the natural circulation, primary system depressurization, and thermal mixing scaling analyses.**

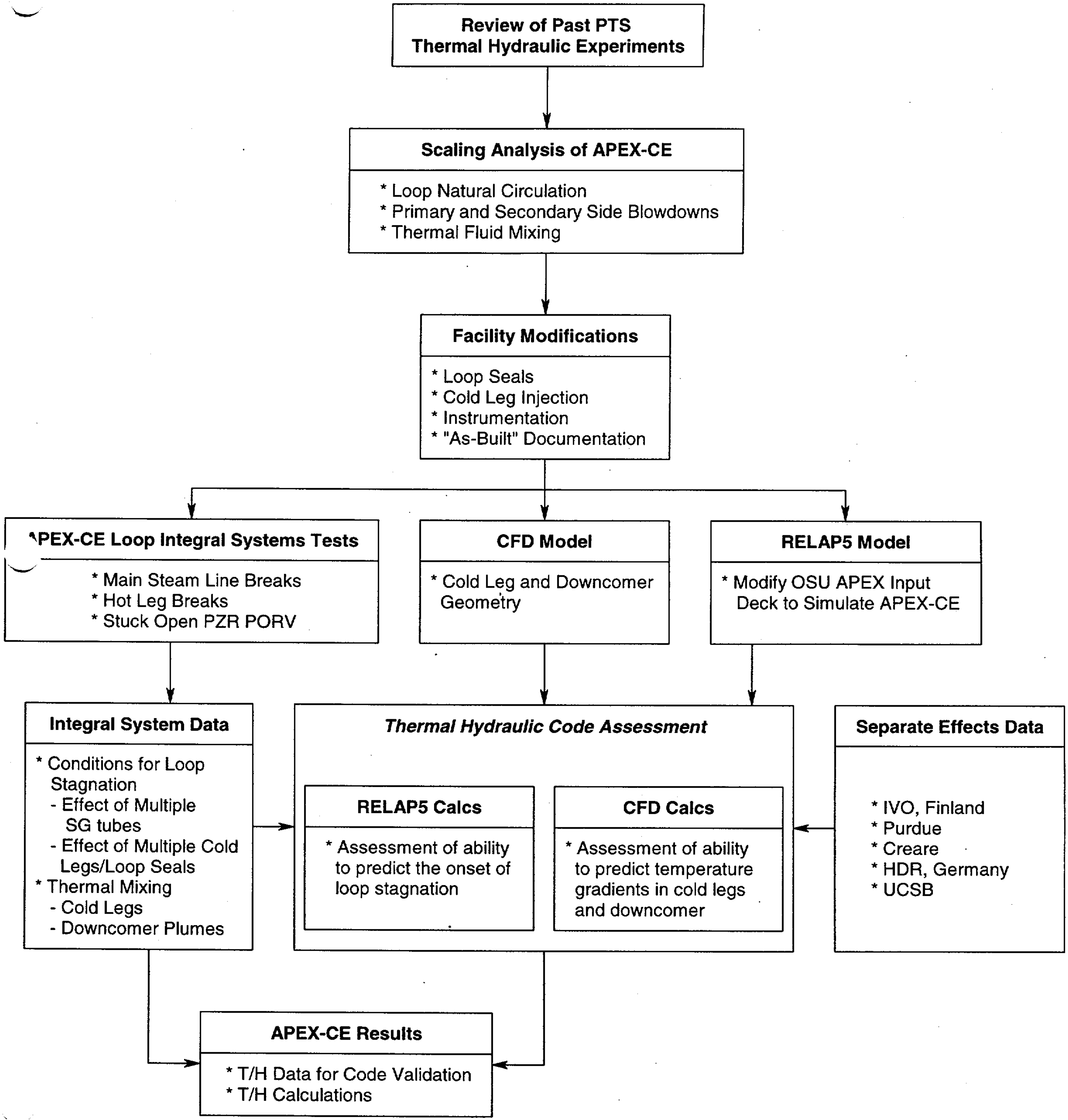
Remaining Scaling Effort

- **Complete secondary side blowdown scaling analysis.**
- **Complete evaluation of all Π groups.**
- **Complete documentation.**



EXISTING THERMOCOUPLES

Layer	Tag #	Degree
E-E	TF-151	186.2
	TF-152	180
	TF-134	0
	TF-135	6.2
F-F	TF-153	180
	TF-154	188
	TF-132	0
	TF-133	8
H-H	TF-149	180
	TF-150	186.2
	TF-164	0
	TF-165	6.2
I-I	TF-147	180
	TF-148	188
	TF-166	0
	TF-167	8
G-G'	TF-155	180
	TF-156	191.3
	TF-130	0
	TF-131	11.3
C-C	TF-157	212
	TF-158	180
	TF-128	0
	TF-129	32
A-A	TF-126	225
	TF-127	315
	TF-162	45
	TF-163	135
AA-AA	TF-172	0
	TF-173	270
Y-Y	TF-118	22.5


Review of Past PTS Thermal Hydraulic Experiments
Scaling Analysis of APEX-CE
* Loop Natural Circulation
* Primary and Secondary Side Blowdowns
* Thermal Fluid Mixing
Facility Modifications
* Loop Seals
* Cold Leg Injection
* Instrumentation
* "As-Built" Documentation
APEX-CE Loop Integral Systems Tests
* Main Steam Line Breaks
* Hot Leg Breaks
* Stuck Open PZR PORV
CFD Model
* Cold Leg and Downcomer Geometry
RELAP5 Model
* Modify OSU APEX Input Deck to Simulate APEX-CE
Integral System Data
* Conditions for Loop Stagnation
- Effect of Multiple SG tubes
- Effect of Multiple Cold Legs/Loop Seals
* Thermal Mixing
- Cold Legs
- Downcomer Plumes
Thermal Hydraulic Code Assessment
RELAP5 Calcs
* Assessment of ability to predict the onset of loop stagnation
CFD Calcs
* Assessment of ability to predict temperature gradients in cold legs and downcomer
Separate Effects Data
* IVO, Finland
* Purdue
* Creare
* HDR, Germany
* UCSB
APEX-CE Results
* T/H Data for Code Validation
* T/H Calculations

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

Mike Paulus
Official Reporter
Ann Riley & Associates, Ltd.

T1

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 Boehnert is the Cognizant ACRS Staff Engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the *Federal Register* on 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
- Offical 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 9th 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 stablity, PWR MSLB, etc. due to lack of assessment

Assessment

- Pointed out in first round RAIs 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

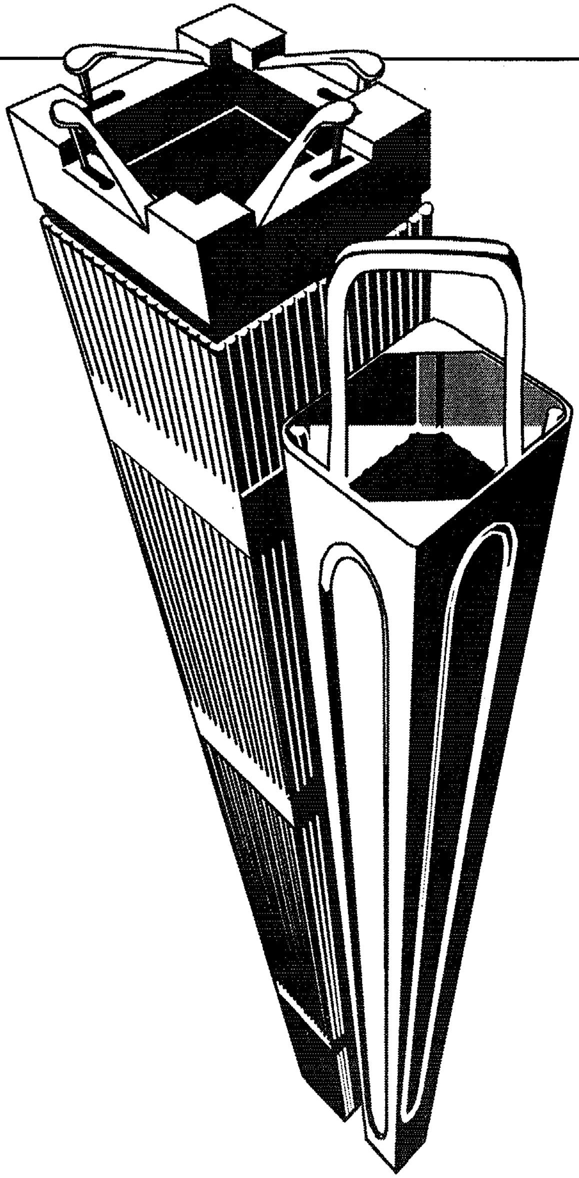
7/8/98	RETRAN-3D submitted for review
12/4/98	NRC accepts RETRAN-3D for review
4/27/99	First round RAI
5/21/99	Response to first round RAI
8/25/99	Second round RAI
10/22/99	Response to second round RAI
3/6/00	Submittal of additional information - Follow up on 12/16/99 meeting - Respond to all known issues - Withdraw certain code options

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

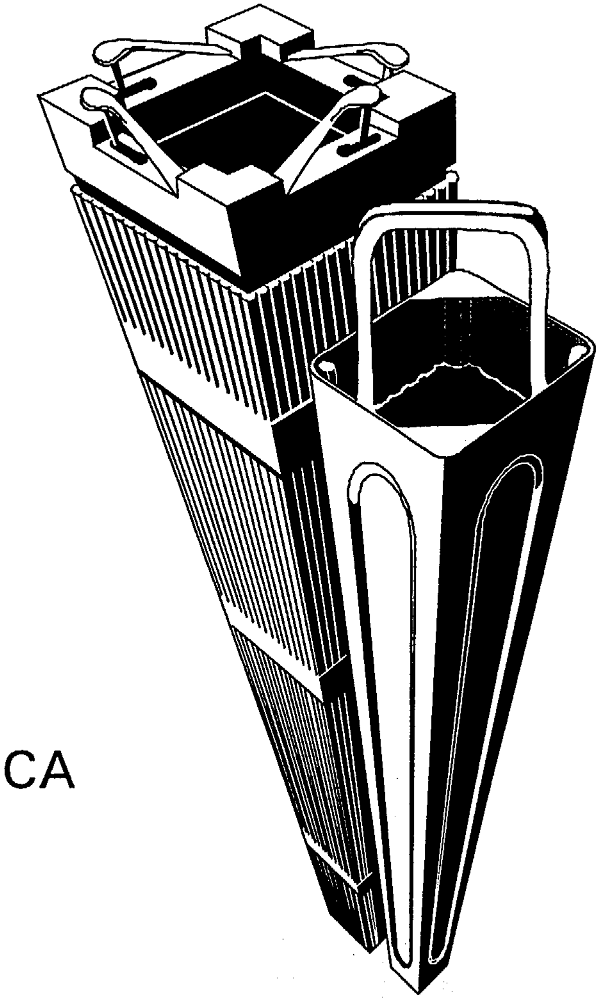
Jerry S. Holm, Manager
PWR Product Licensing

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
- Offical 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 9th 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 <u>only</u> 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 stablity, PWR MSLB, etc. due to lack of assessment

Assessment

- Pointed out in first round RAIs 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

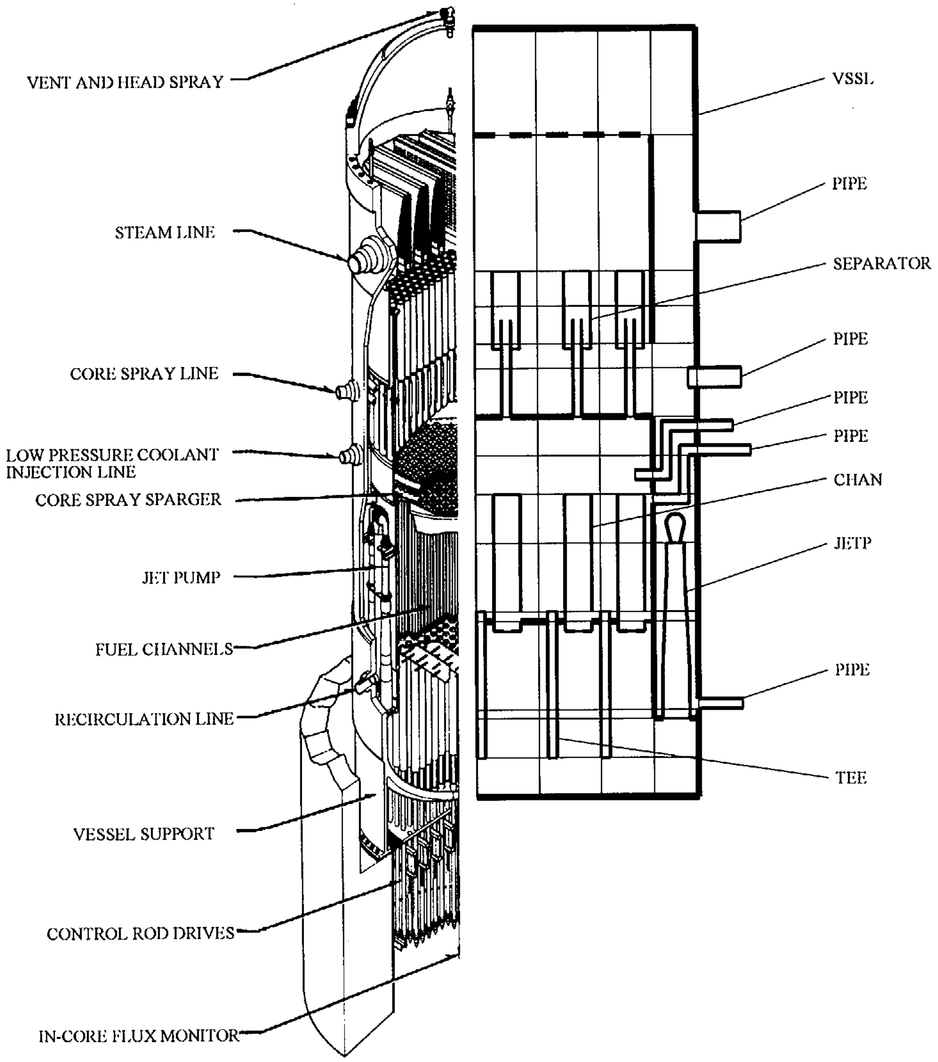
J. G. M. Andersen

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 - ΔCPR 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

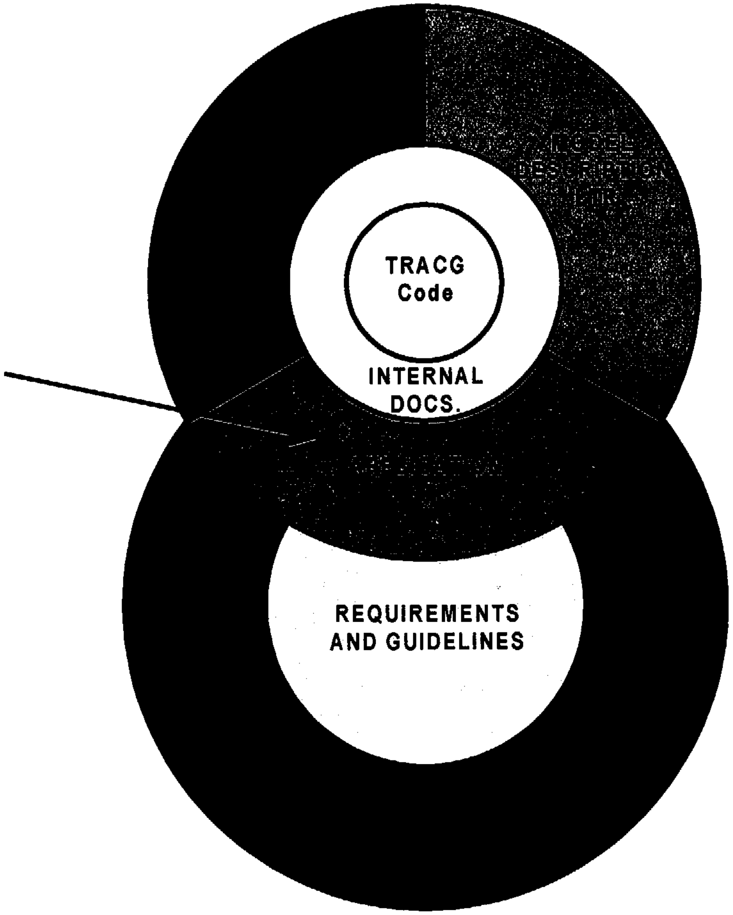
Comparison to Current Approved Methodology

	ODYN / TASC	TRACG
Scope	• Calculation of operating limit minimum critical power ratio	• Calculation of operating limit minimum critical power ratio
Model	• ODYN – Simulation of core average power response. - One dimensional kinetics and hydraulic model for reactor core - Collapsed nuclear data from GE 3D core simulator (PANACEA) • TASC – Simulation of hot channel transient CPR response. - One dimensional thermal hydraulic model	• TRACG – Three-dimensional simulation of core power and CPR response. - Three dimensional kinetics consistent with GE 3D core simulator (PANACEA) - Parallel channel hydraulic model for core including hot channel
Data and Model Uncertainty	• Model uncertainty determined from comparison to plant data • Model uncertainty verified by statistical methodology (propagation of errors)	• Model uncertainty determined by statistical methodology (ANOVA or Order Statistics) • Model uncertainty verified by comparison to data using statistical methodology
Application Methodology for Combined Uncertainty	• Nominal calculation - Best estimate models - Tech. spec. for most plant parameters • Combined uncertainty - Model uncertainty, Power and Scram speed	• Nominal calculation - Best estimate models - Best estimate or tech. spec. plant parameters • Combined uncertainty - Model and plant parameter uncertainties

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

[redacted]

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

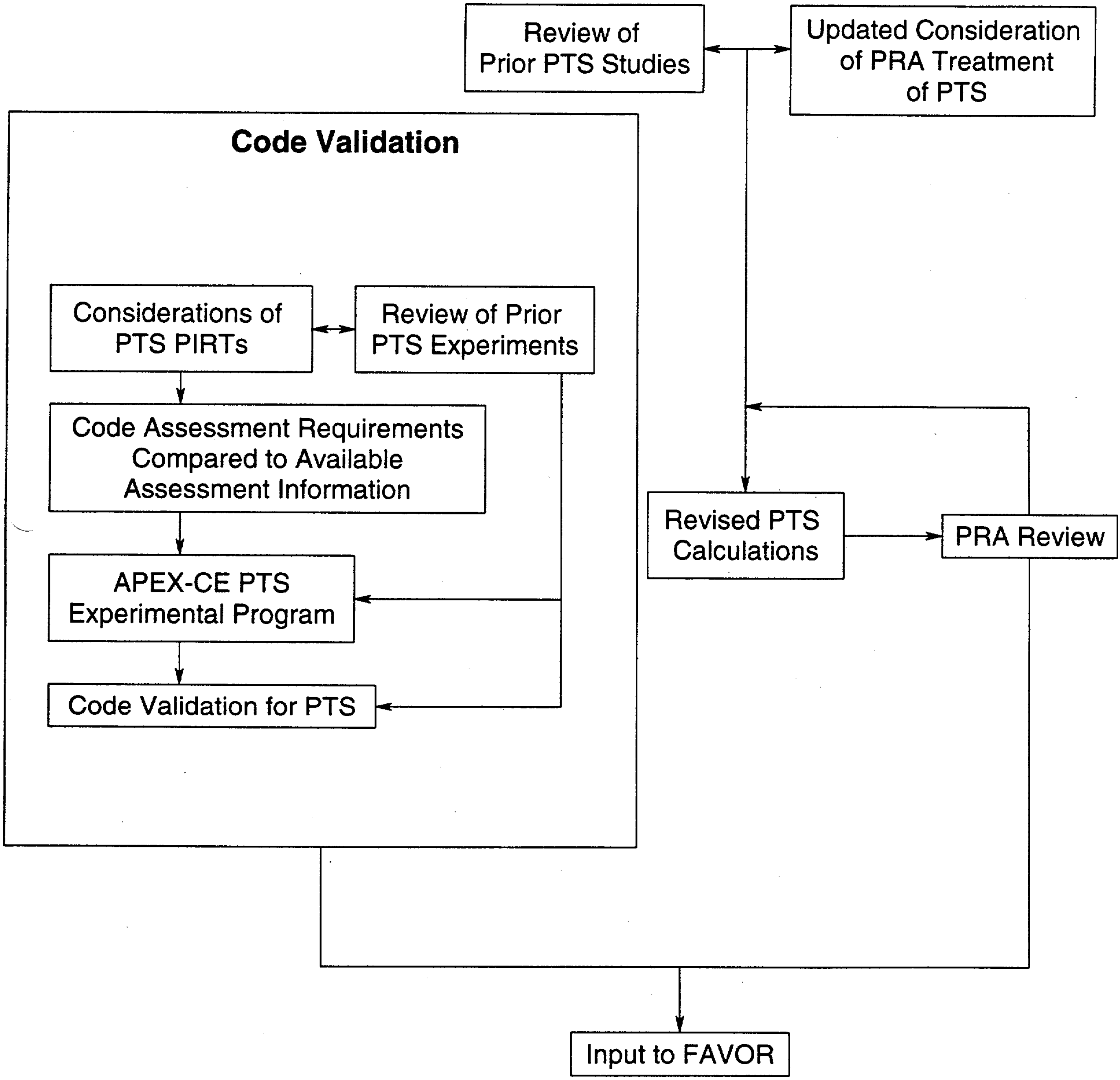
Thermal Hydraulic Phenomena Subcommittee
Advisory Committee on Reactor Safeguards

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.

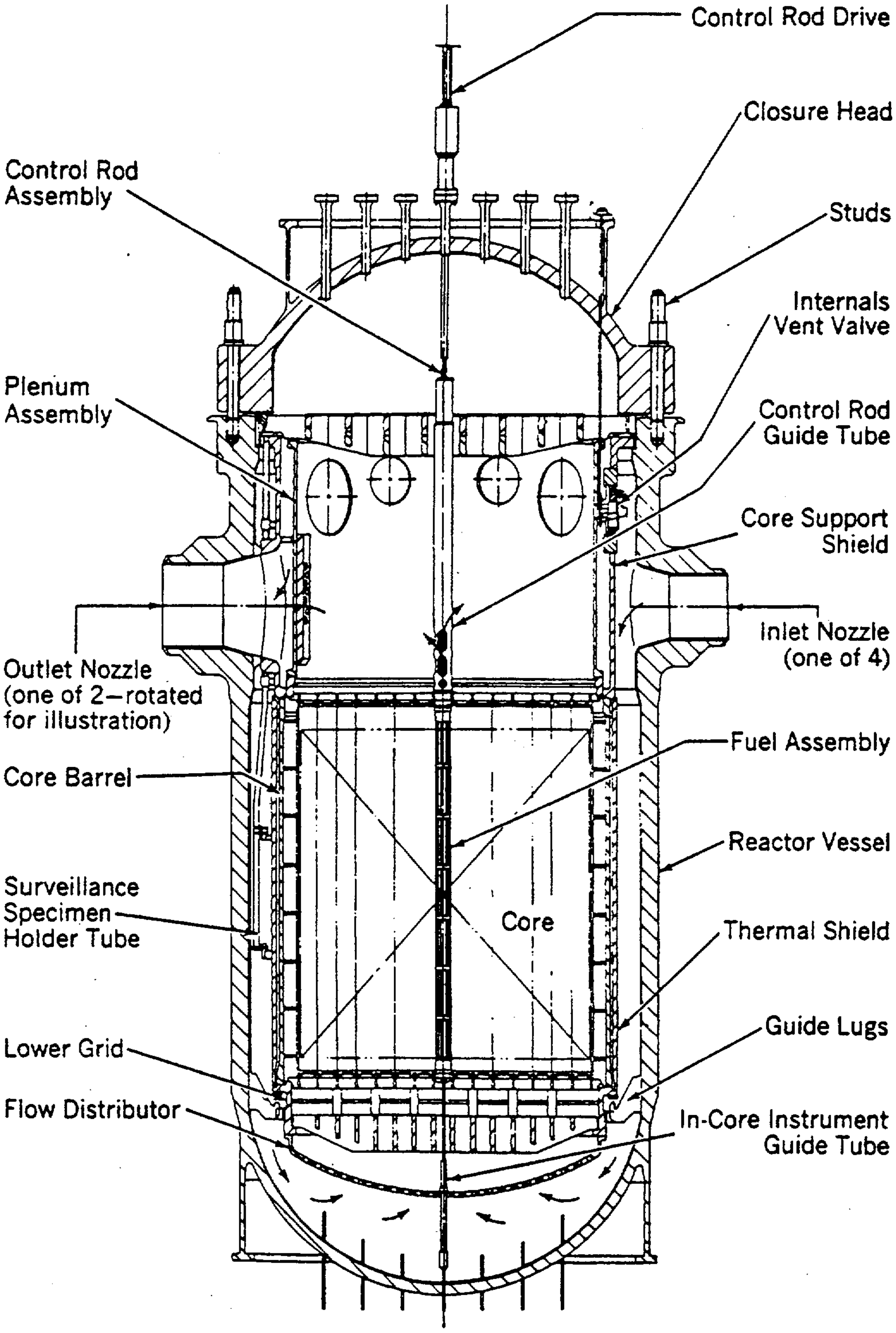
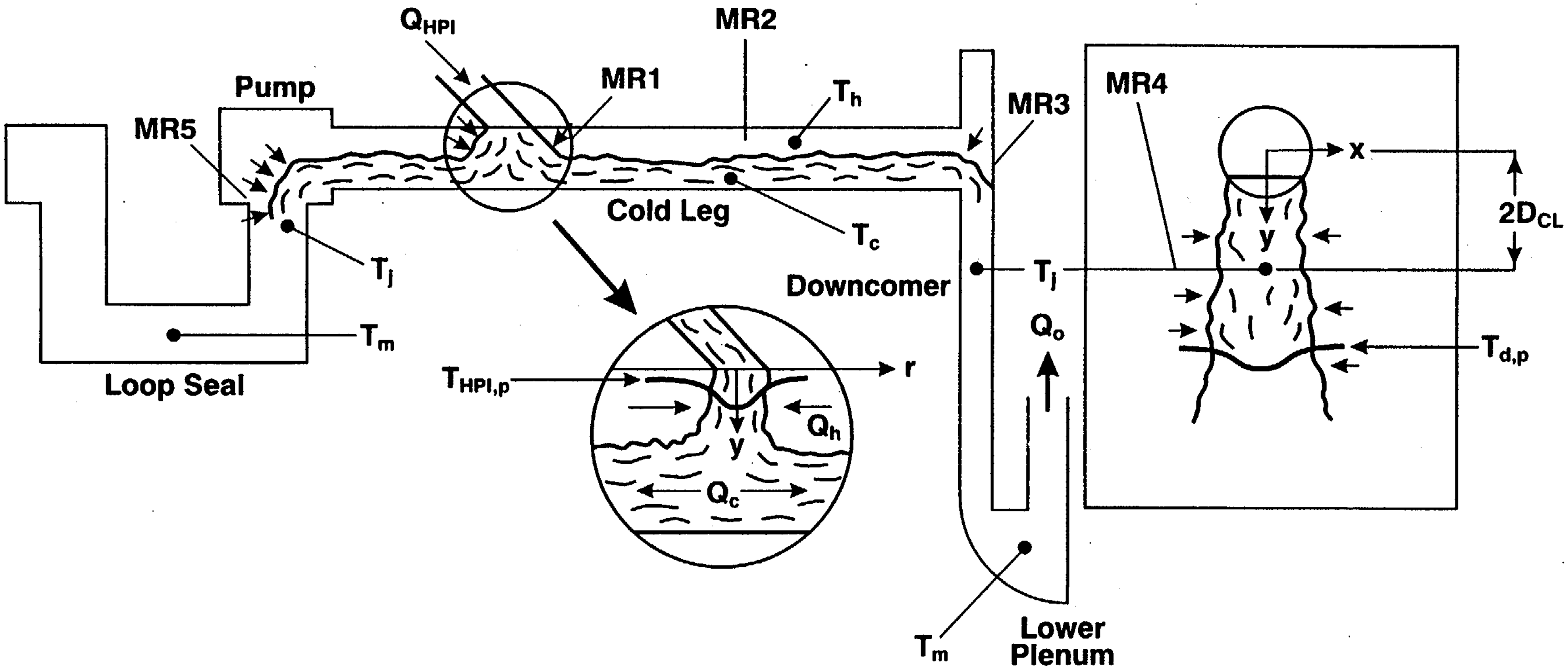


Figure 2.2 Detail of Oconee-1 PWR vessel.



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)

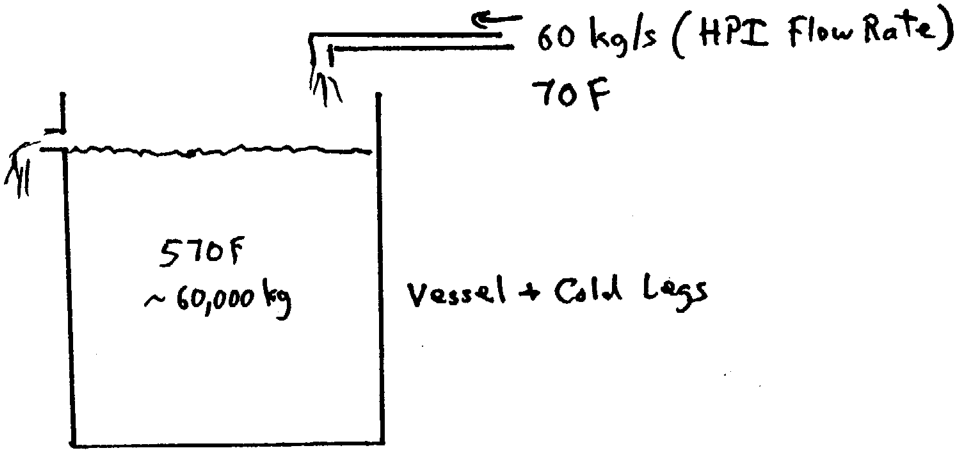
Characteristic Time Scales

- 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^3 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.

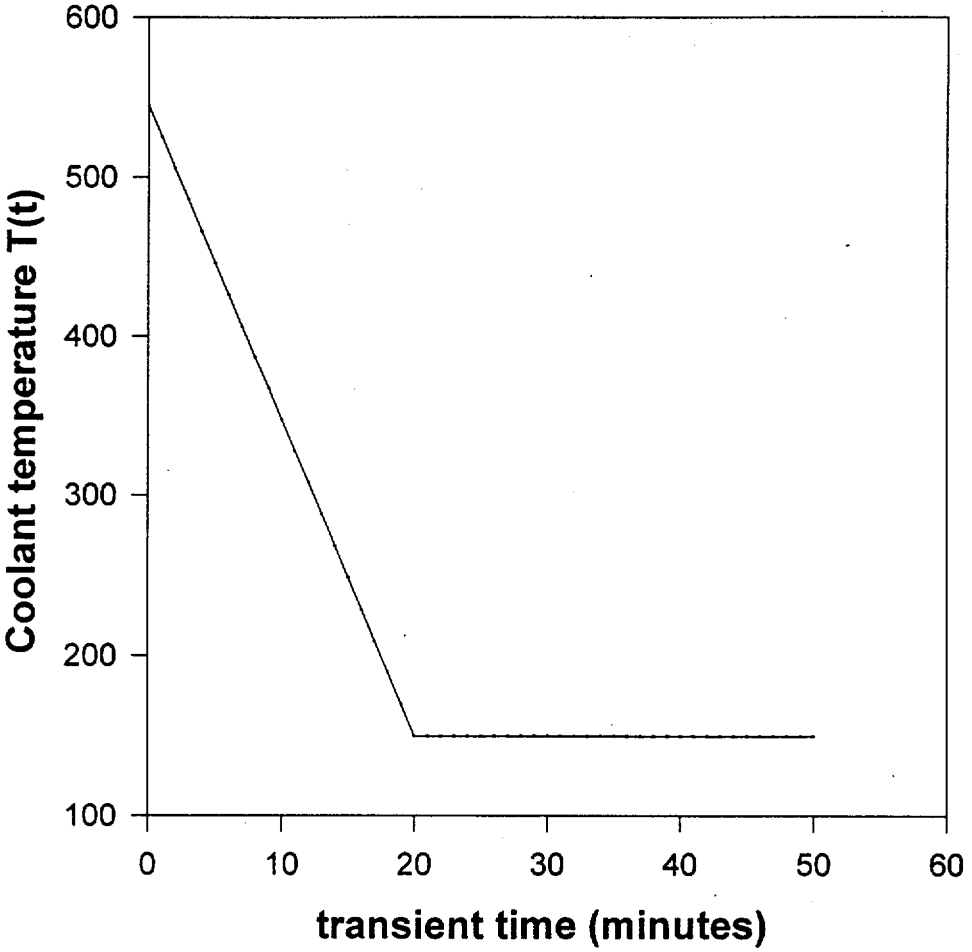


Figure 1 - Thermal transient for case 1

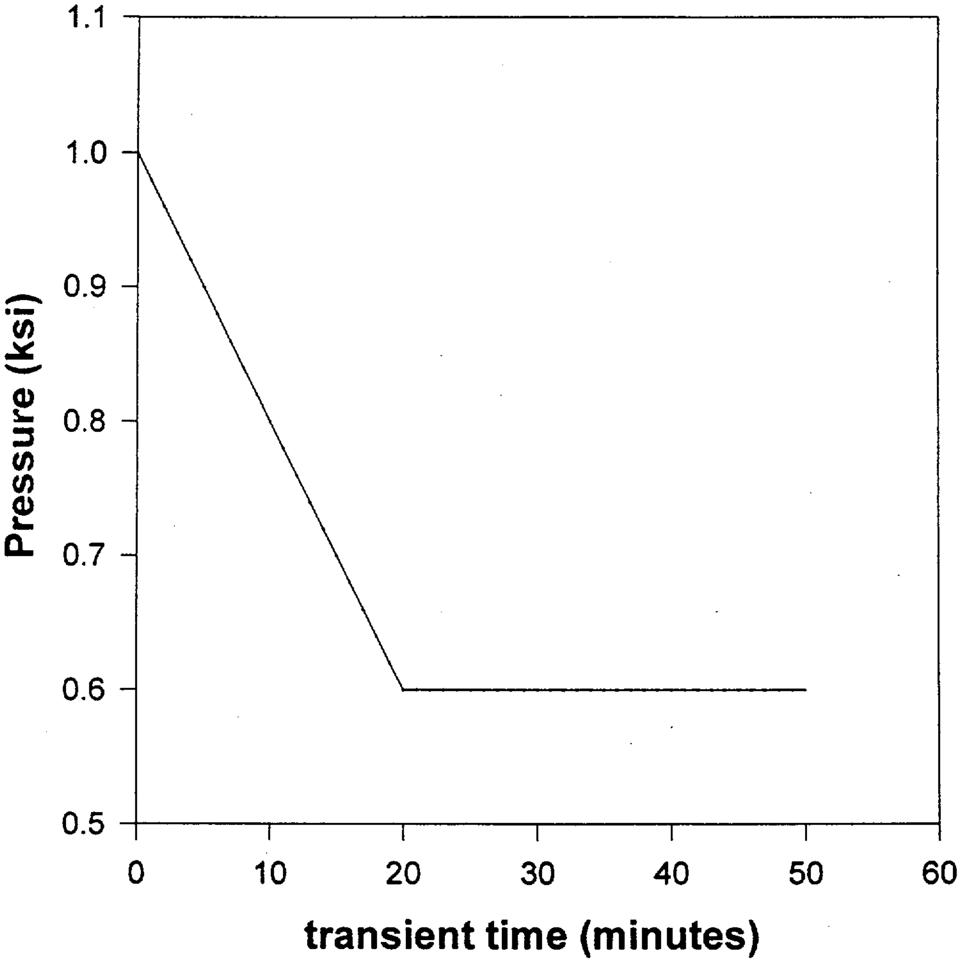


Figure 2 - Pressure transient

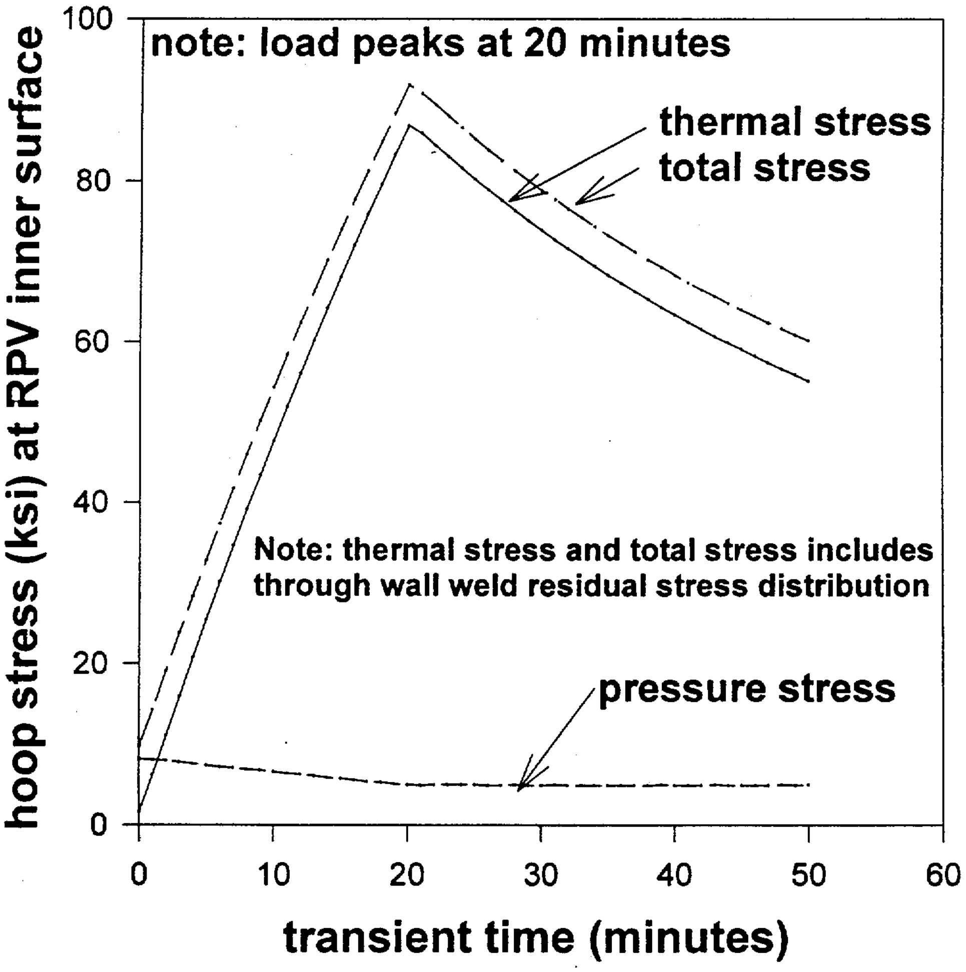


Figure 3 - Circumferential (hoop) stress

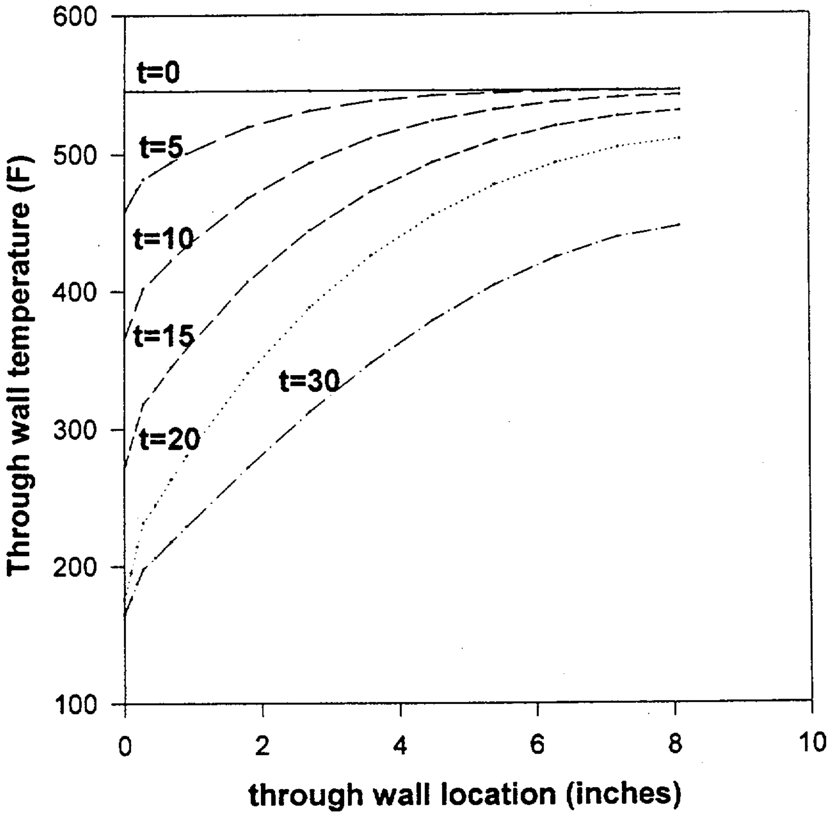


Figure 4 - through wall temperature at various transient times

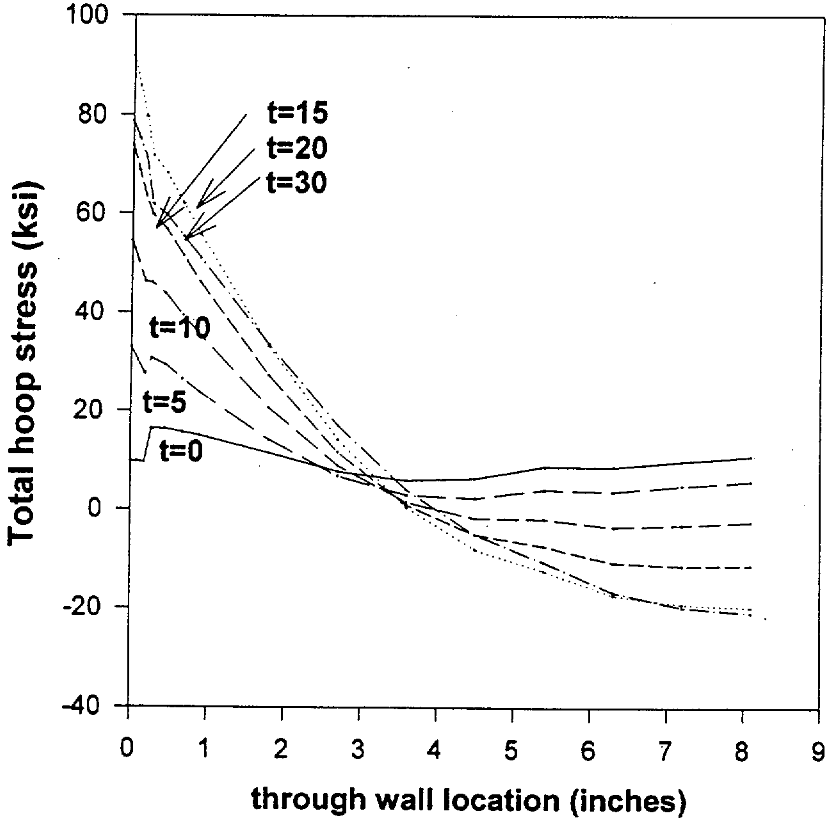


Figure 5 - through wall hoop stress at various transient times

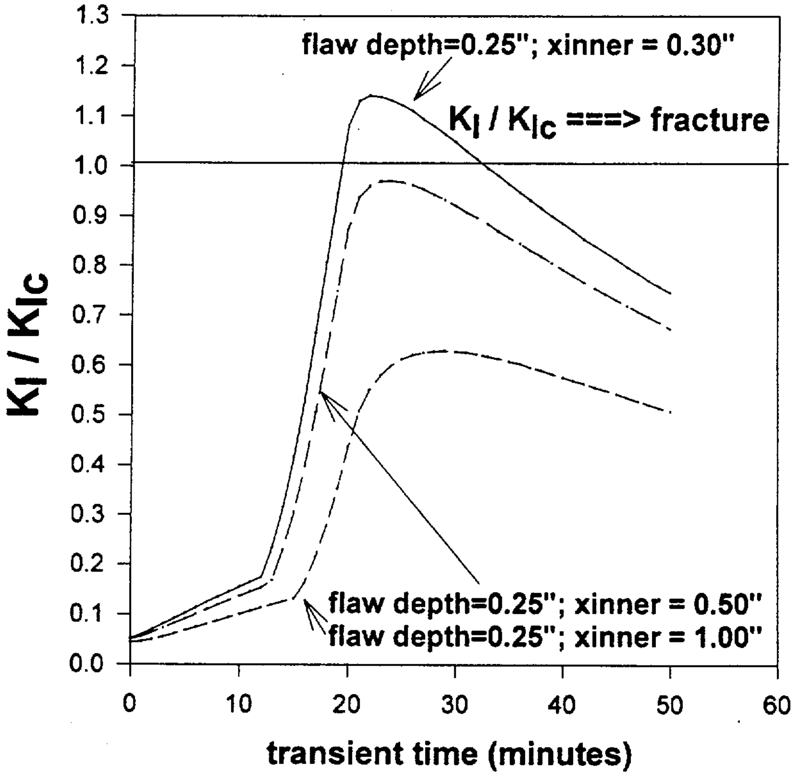


Figure 6: Kratio (K_I / K_{Ic}) for various embedded flaw geometries evaluated at RT_{NDTs} = 270 F (PTS screening criteria for axial welds / plates)

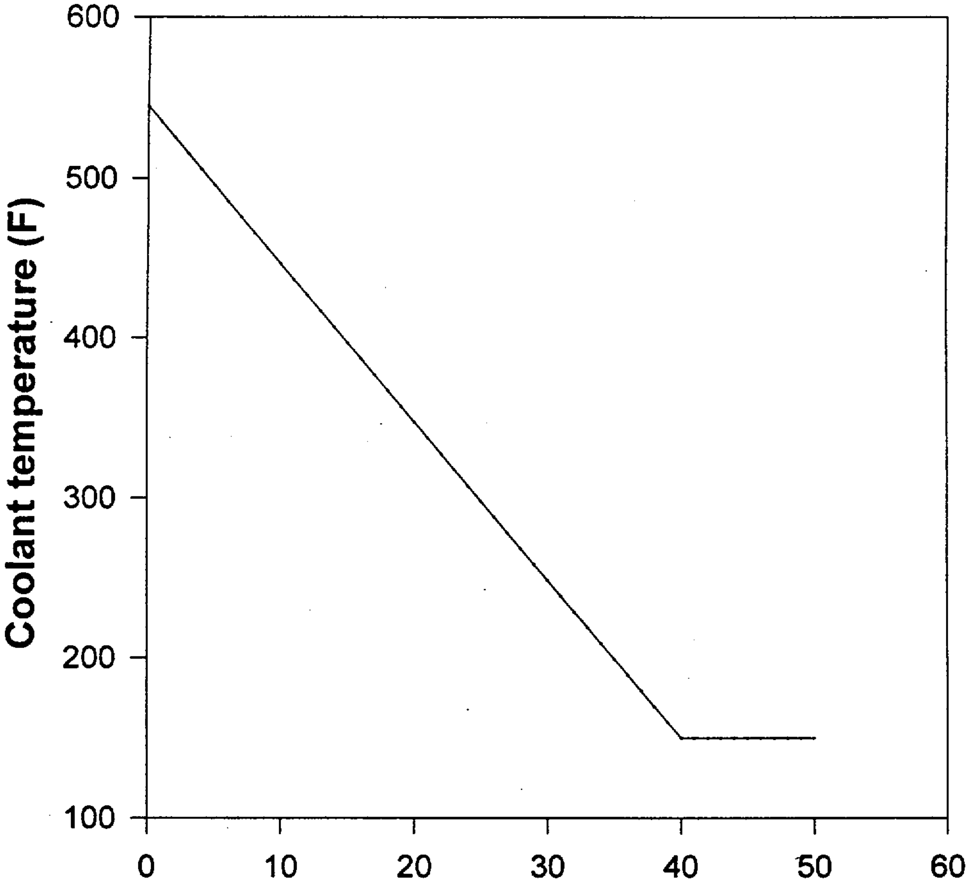


Figure 1 - Case 2 thermal transient

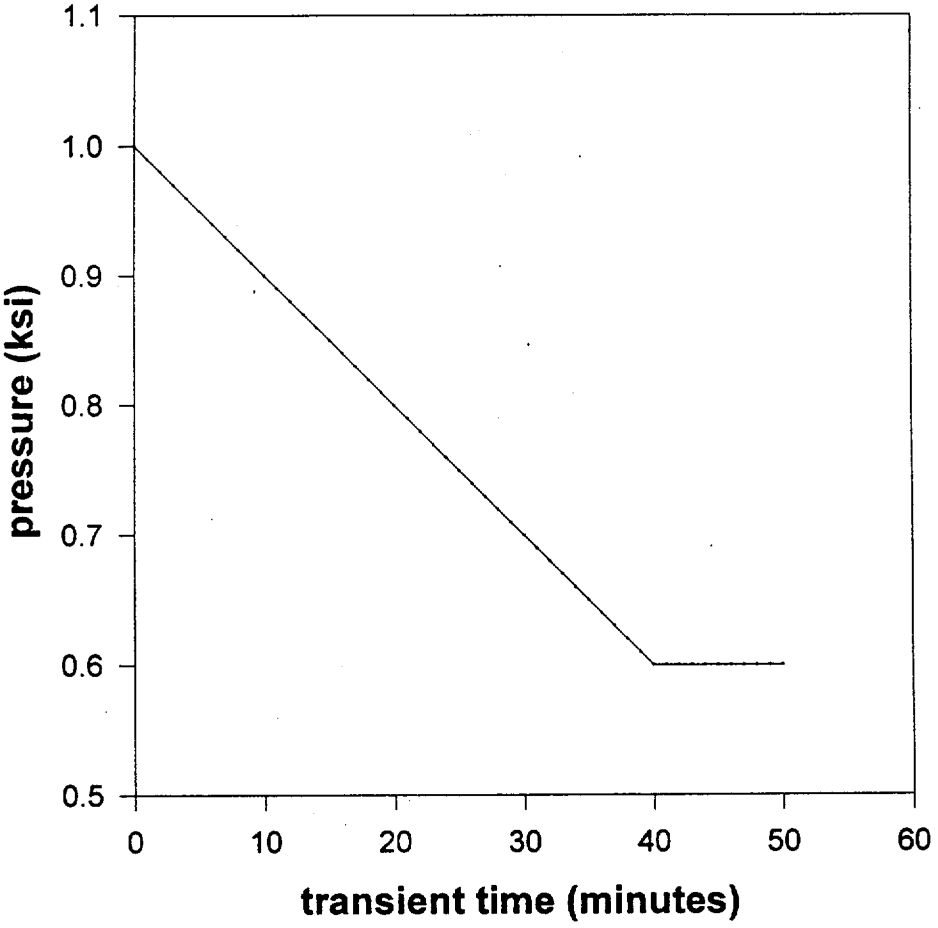


Figure 2 - Case 2 pressure transient

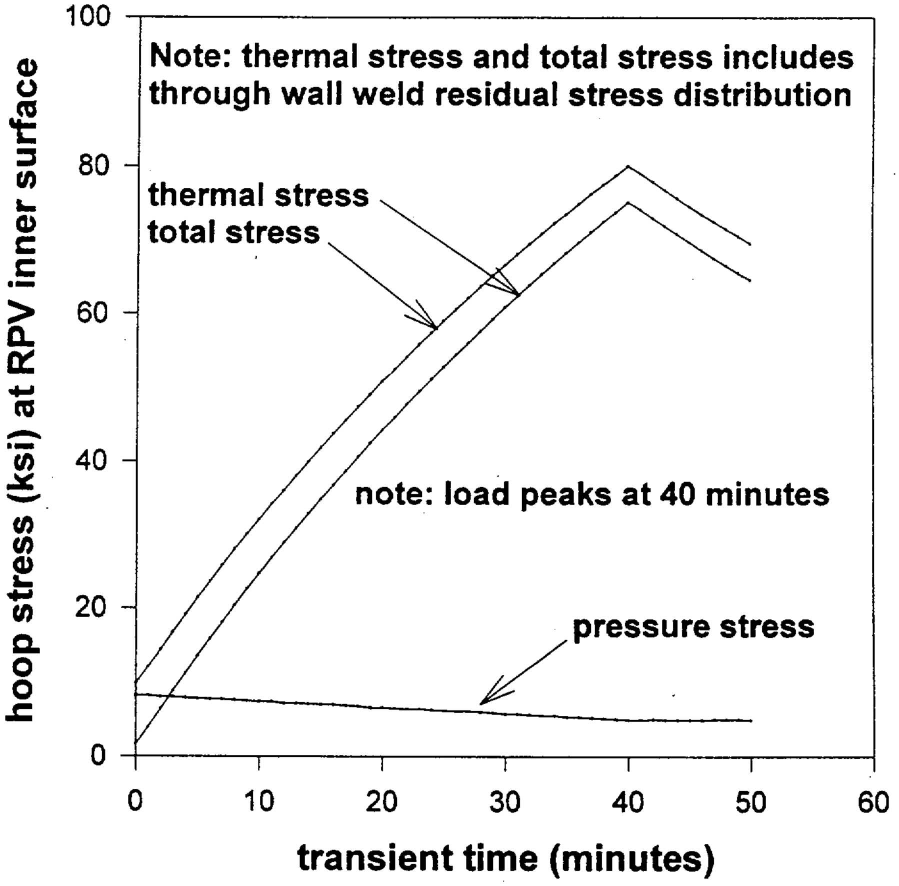


Figure 3 - Case 2 circumferential (hoop) stress

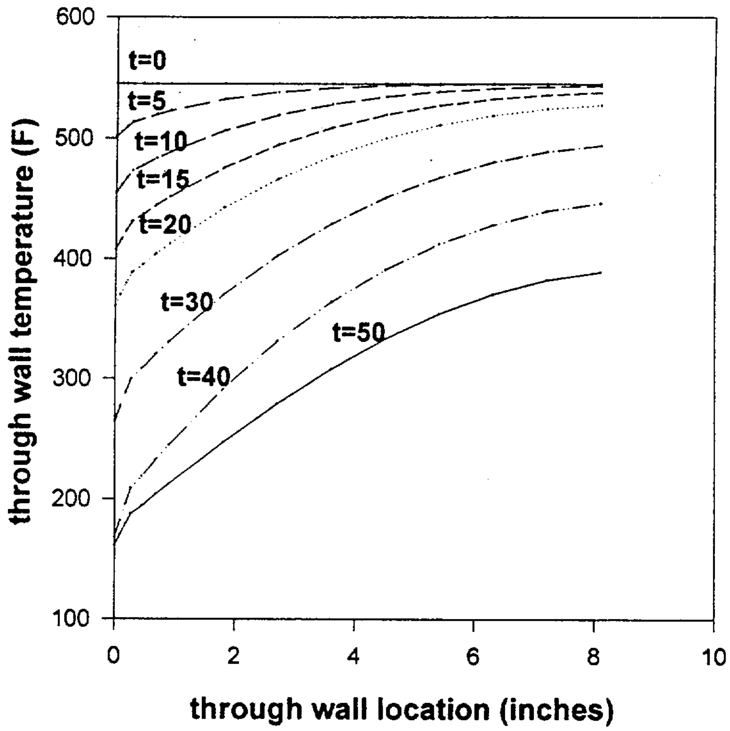


Figure 4 - Case 2 through wall temperature at various transient times

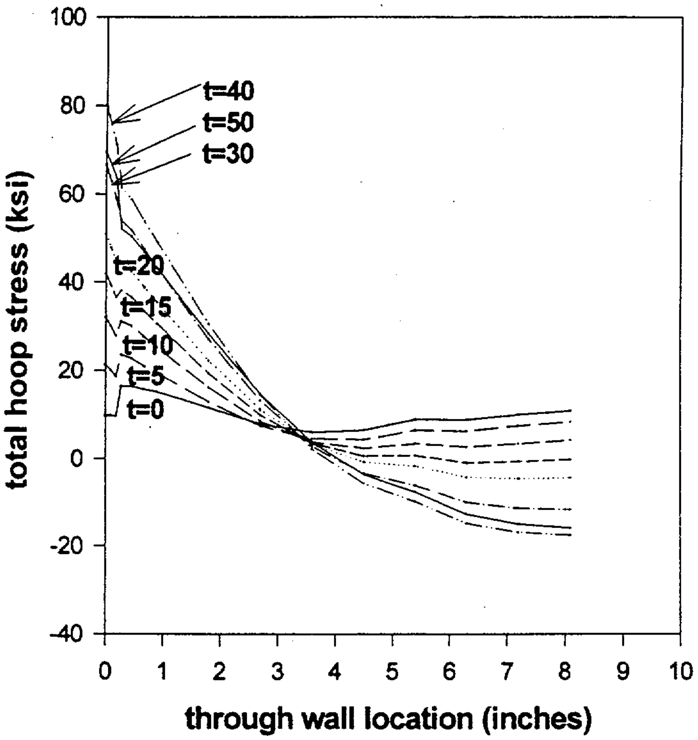


Figure 5 - Case 2 through wall hoop stress at various transient times

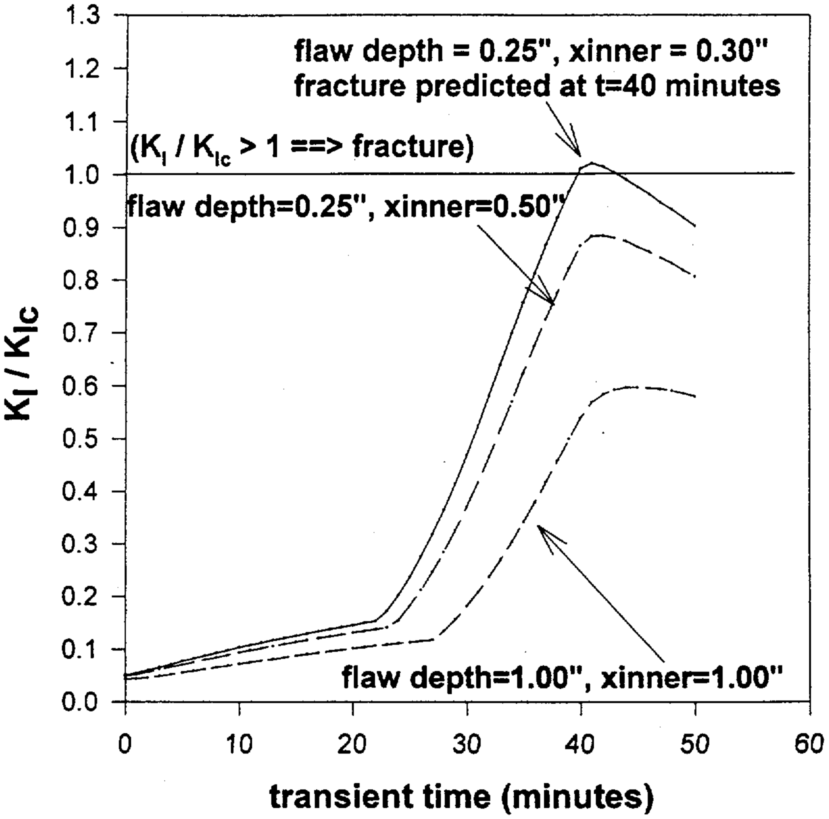


Figure 6 - Case 2 Kratio (K_I / K_{Ic}) for various embedded flaw geometries evaluated at RT_{NDTs} = 270 F (PTS screening criteria for axial welds / plate)

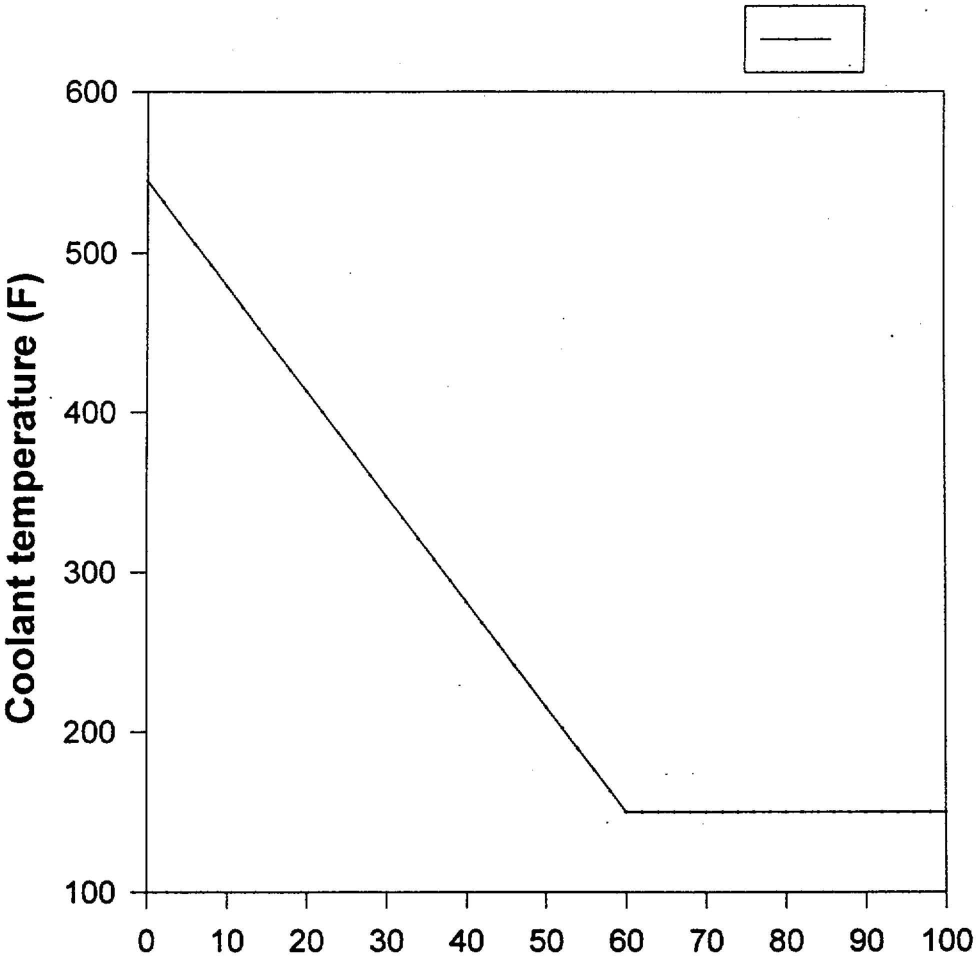


Figure 1 - Case 3 thermal transient

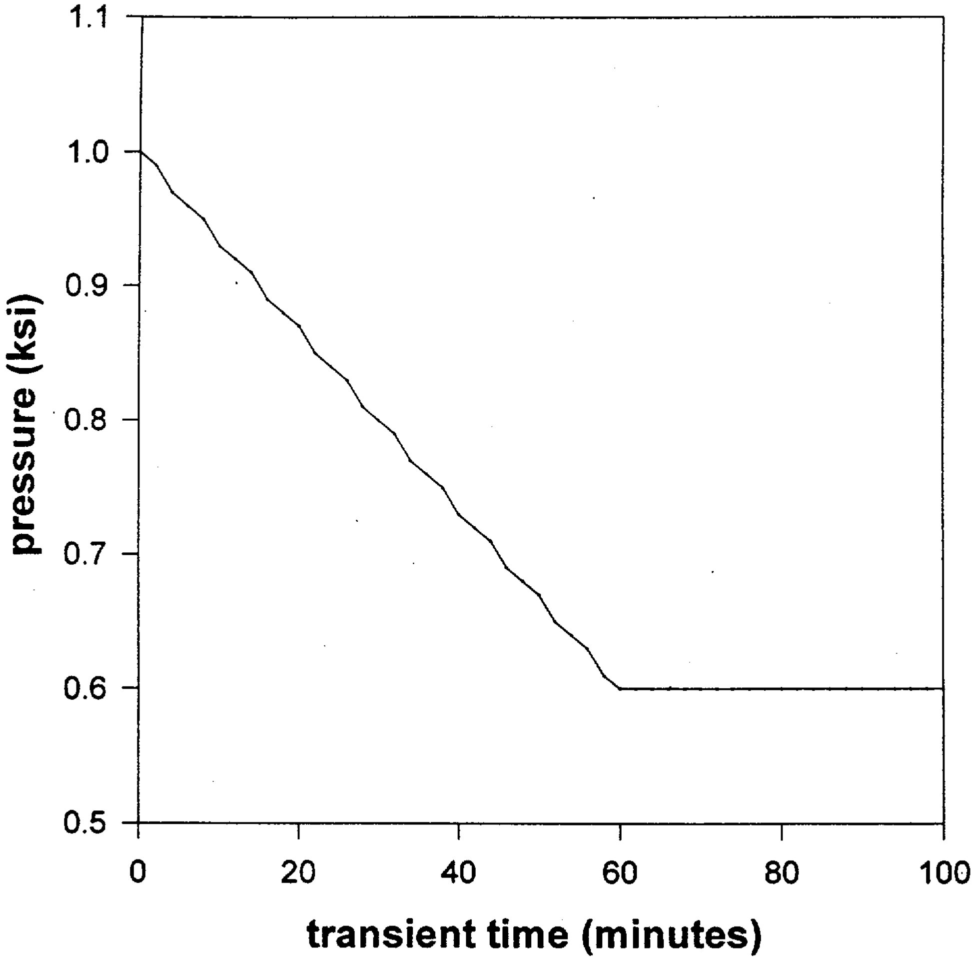


Figure 2 - Case 3 pressure transient

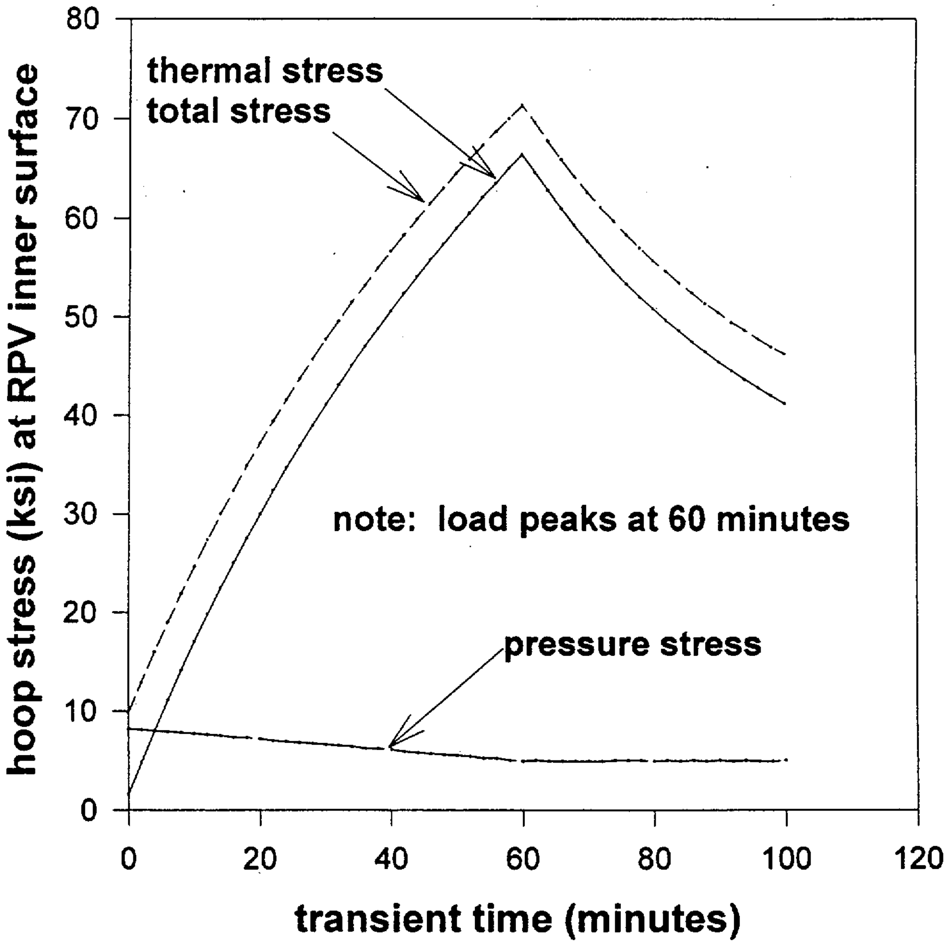


Figure 3 - transient 3 circumferential (hoop) stress

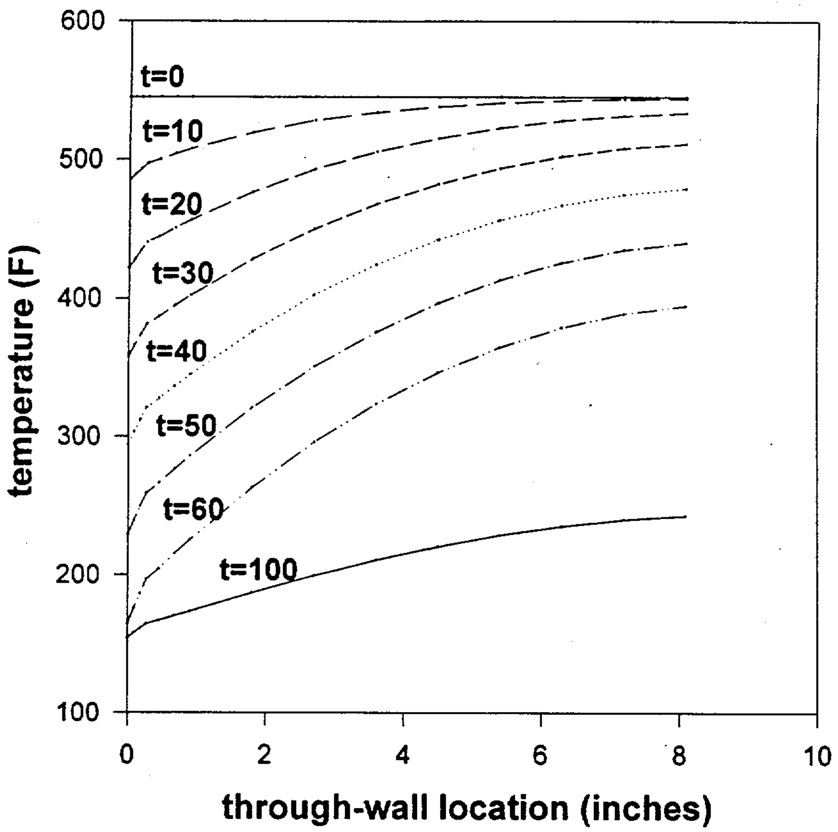


Figure 4 - Case 3 through wall temperature at various transient times

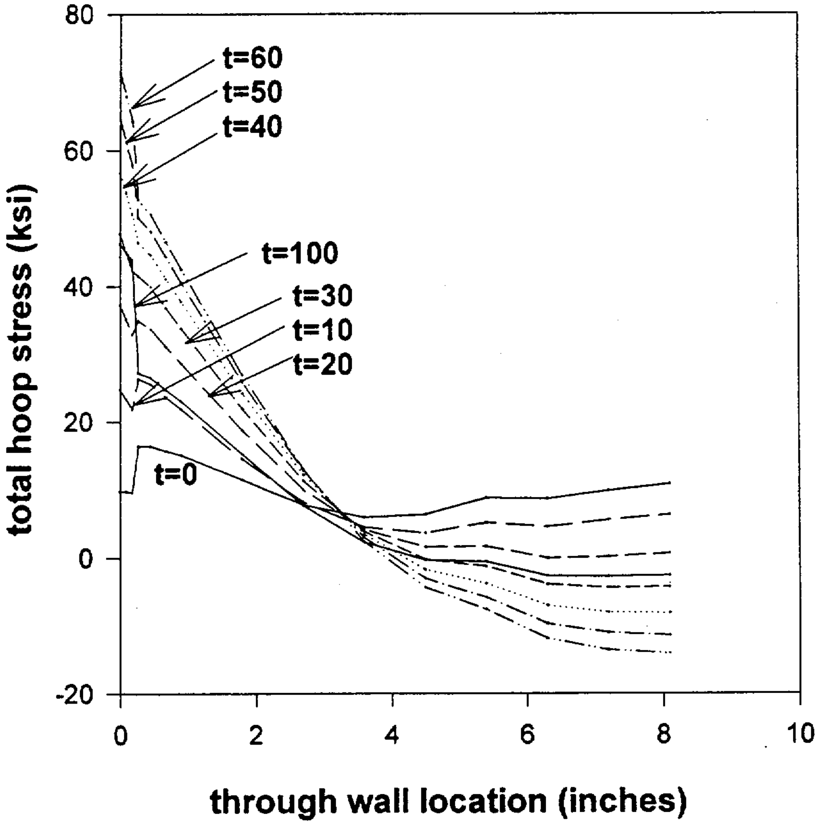


Figure 5 - Case 3 through wall hoop stress at various locations

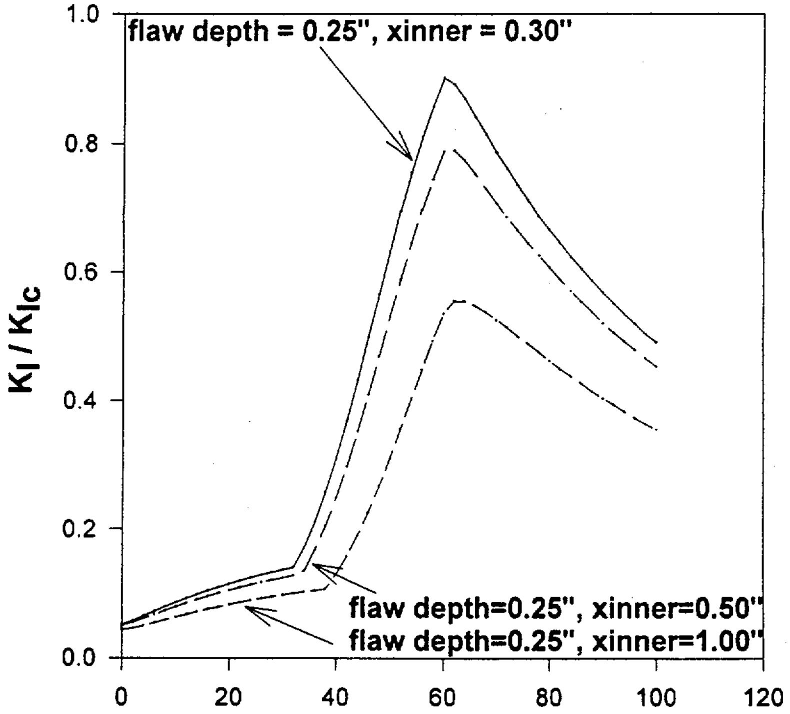


Figure 6 - Case 3 K ratio (K_I / K_{IC}) for various embedded flaw geometries evaluated at RT_{NDTs} = 270 F (PTS screening criteria for axial weld/plate)

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 (Country)	Organization/Sponsor	Scale	Downcomer Geometry	No. of Cold Legs	HPI Location (Orientation)	Loop Flow
CREARE (USA)	CREARE, Inc./EPRI	1/5	Planar	1	Top (60° & 90°)	Yes
Japanese	Mitsubishi Heavy Industries, Ltd./ Kansai Electric Co., Inc.	1/3	Planar	1	Top (45° & 90°)	Yes
IVO (Finland)	Imatran Volma Oy/ IVO	2/5	Semiannular	3	Bottom	Yes
IVO (Finland)	Imatran Volma Oy/ U.S. NRC	2/5	Semiannular	3	Top	
PURDUE (USA)	Purdue Univ./ U.S. NRC	½	Planar	1	Top and side	No
CREARE (USA)	CREARE, Inc./ U.S. NRC and EPRI	½	Planar	1	Top (90°)	No
UCL/TRAC (Belgium)		½	Planar	1	Top and downcomer	
SAI (USA)	SAI/EPRI	1/1	Planar	1	Top	Yes
HDR (Germany)	Battelle Institute/BMTF	1/4-1/1	Annular	1	Top and side	Yes
UPTF (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 ~3 CL diameters below CL
- Westinghouse and CE plants with low Fr_{HPI} allow backflow into HPI injection line
- B&W with high Fr_{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

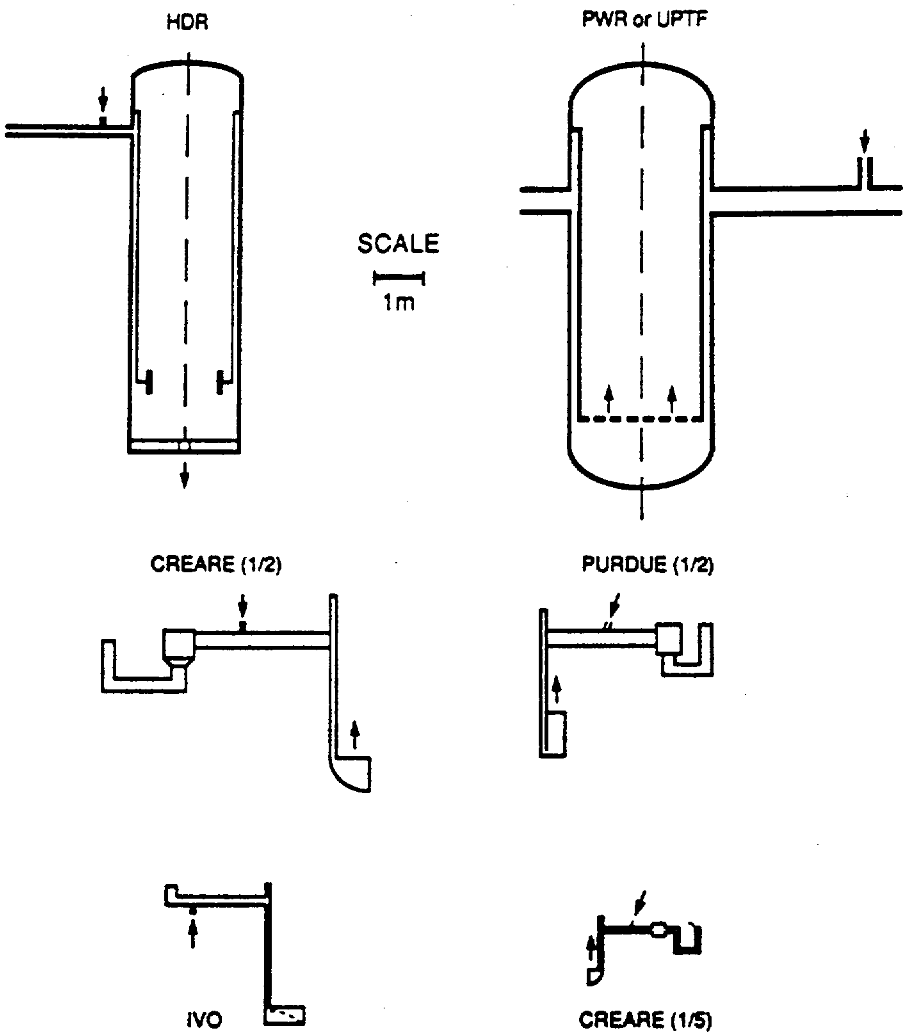


Fig. 2 Relative sizes of various integral test facilities in comparison to full scale commercial PWR.

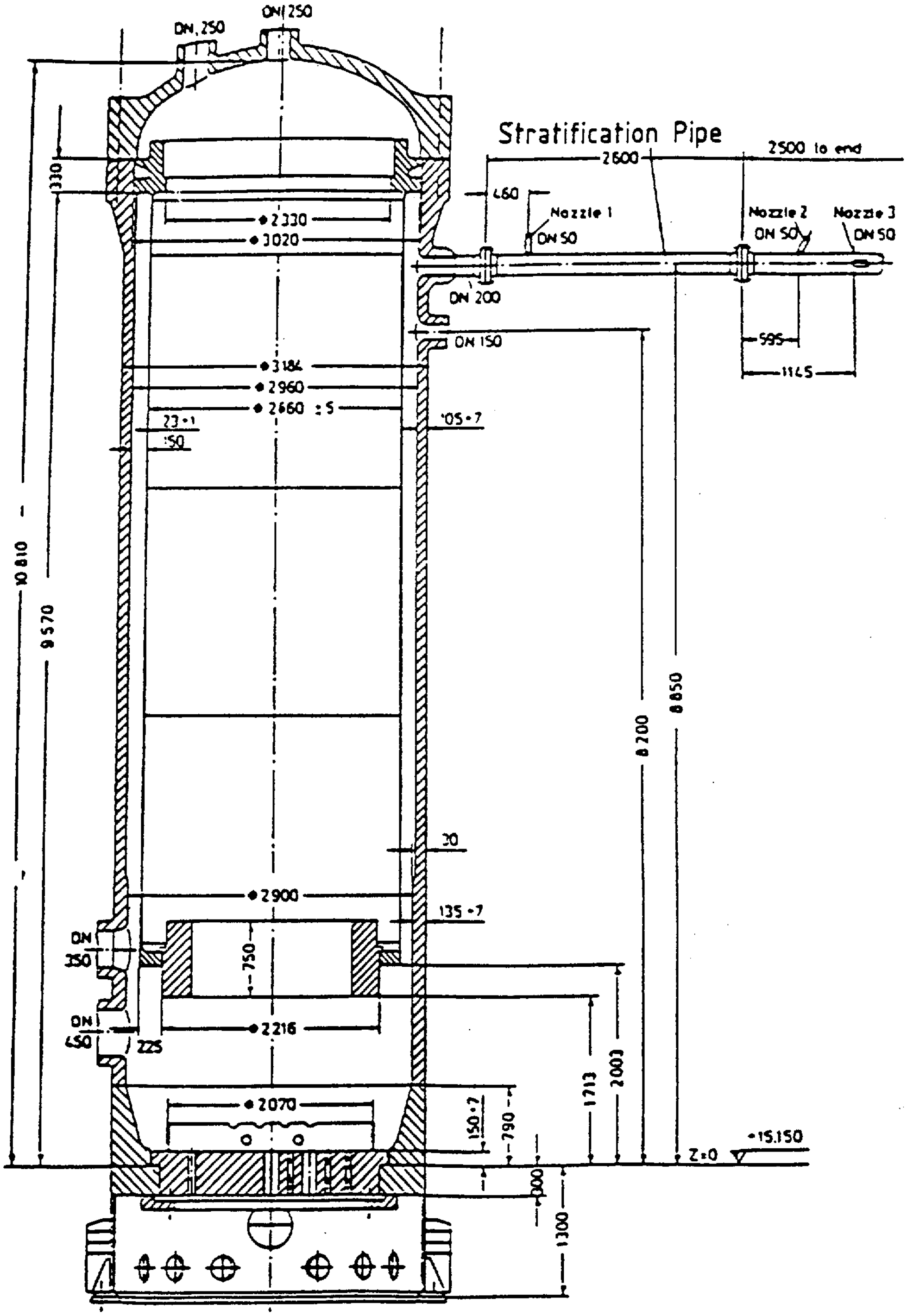


Fig. 1. Cross-section of the HDR-pressure vessel.

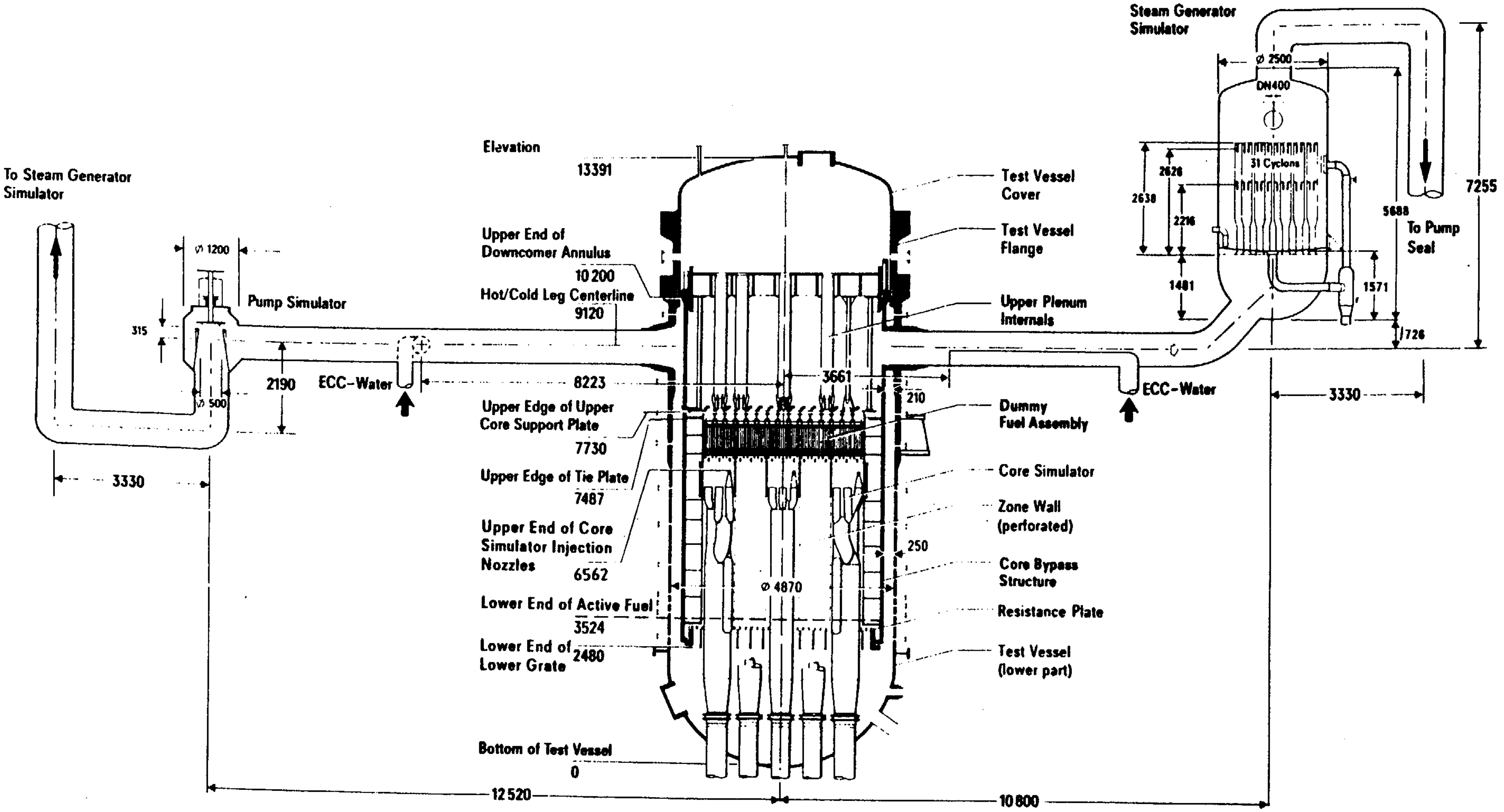


Fig. 3: Major Dimensions of UPTF - Primary System

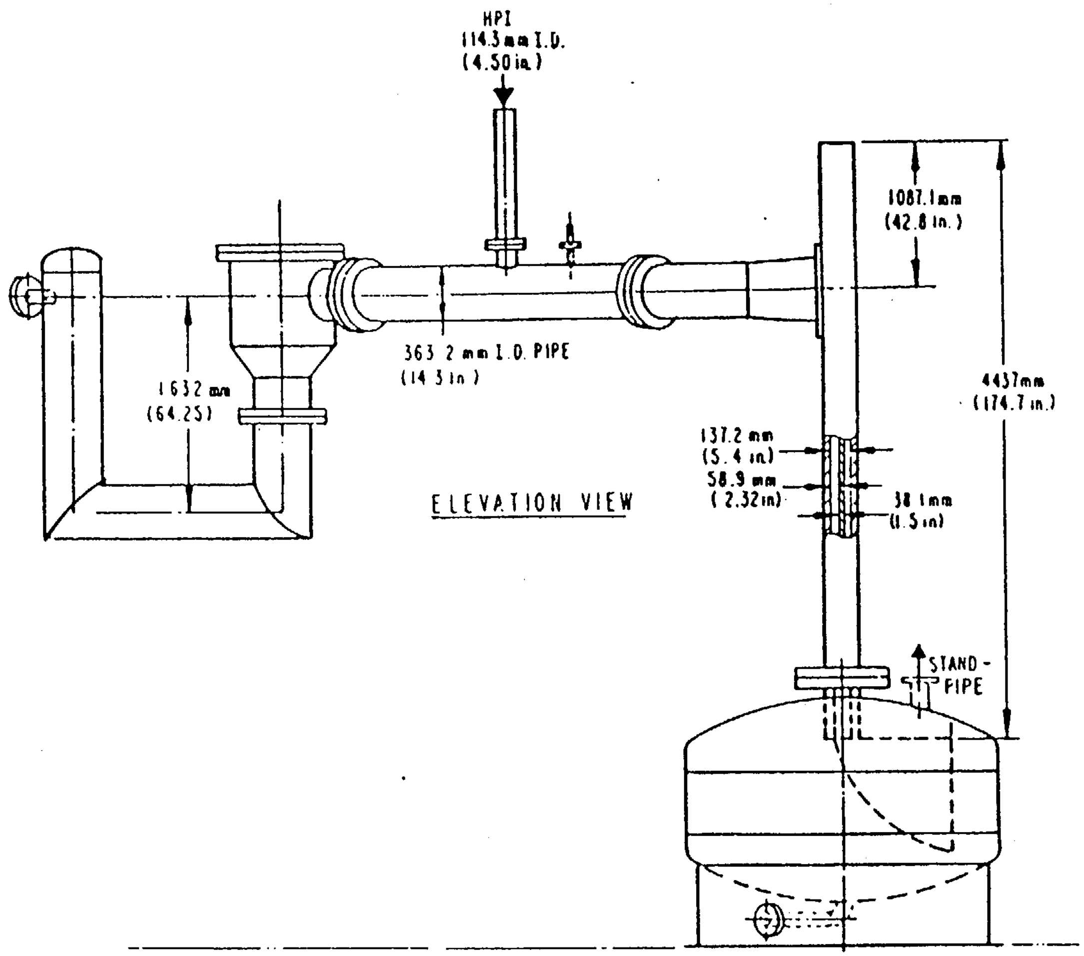


Figure 5.32 Schematic of CREARE ½-scale test facility

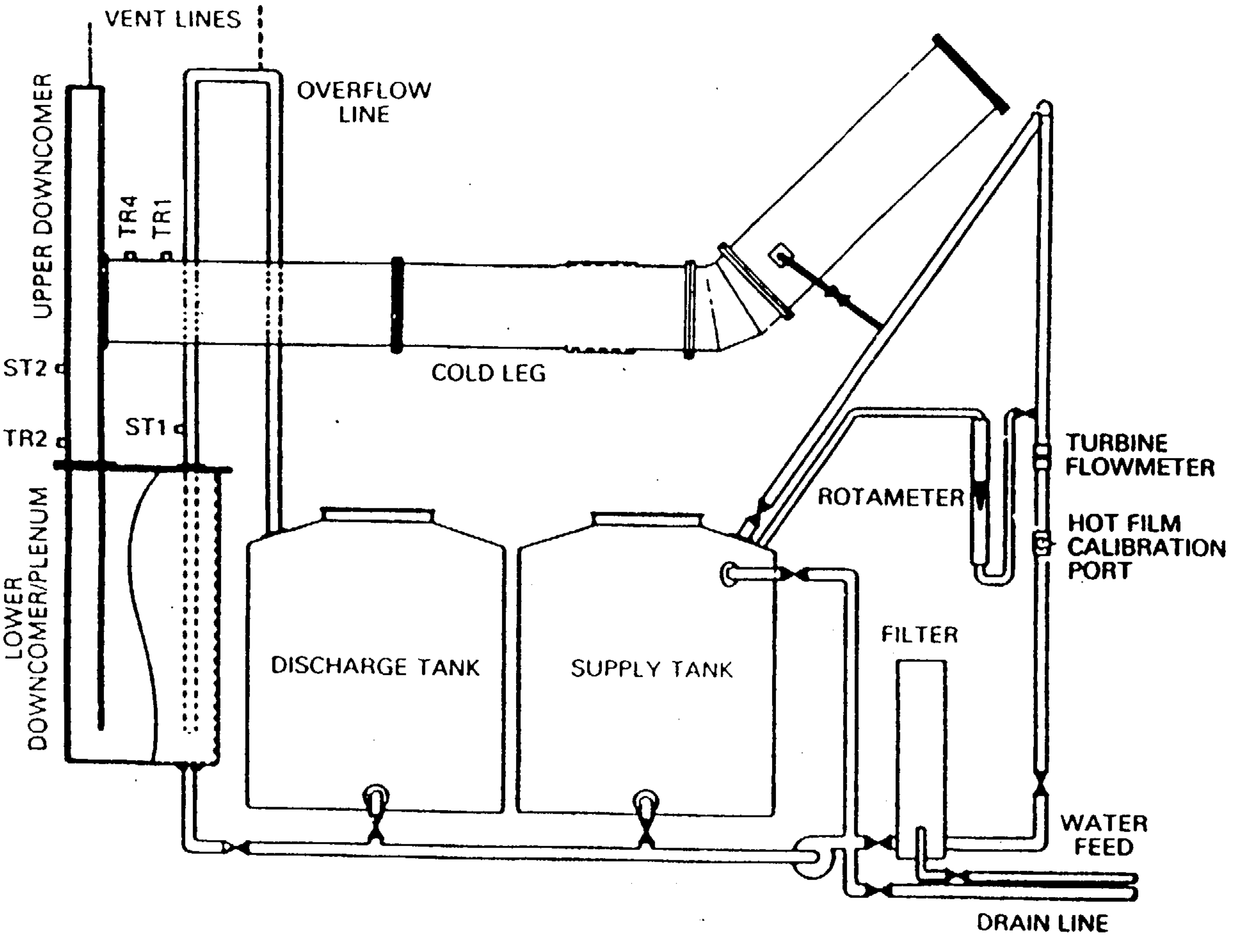
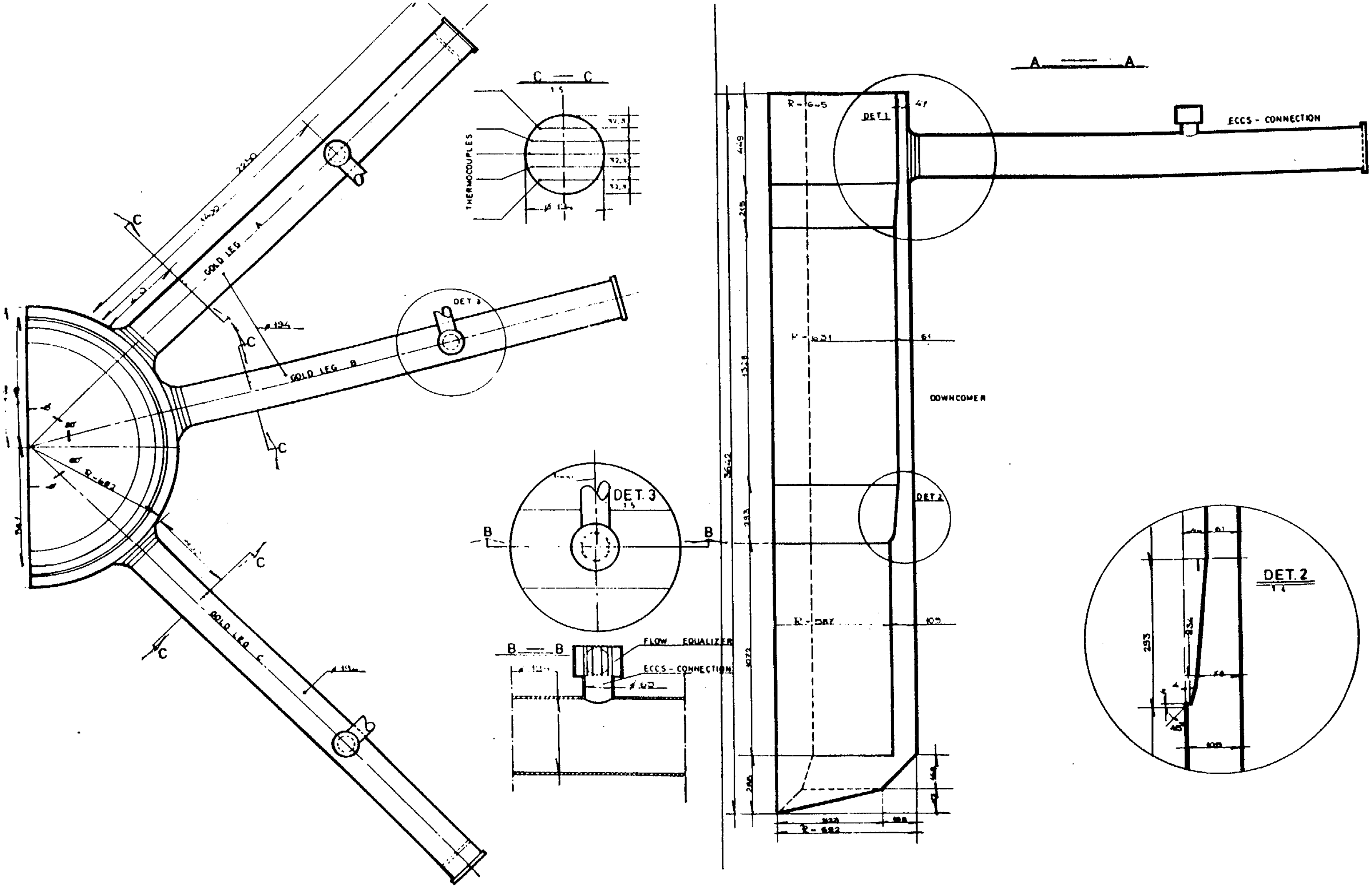
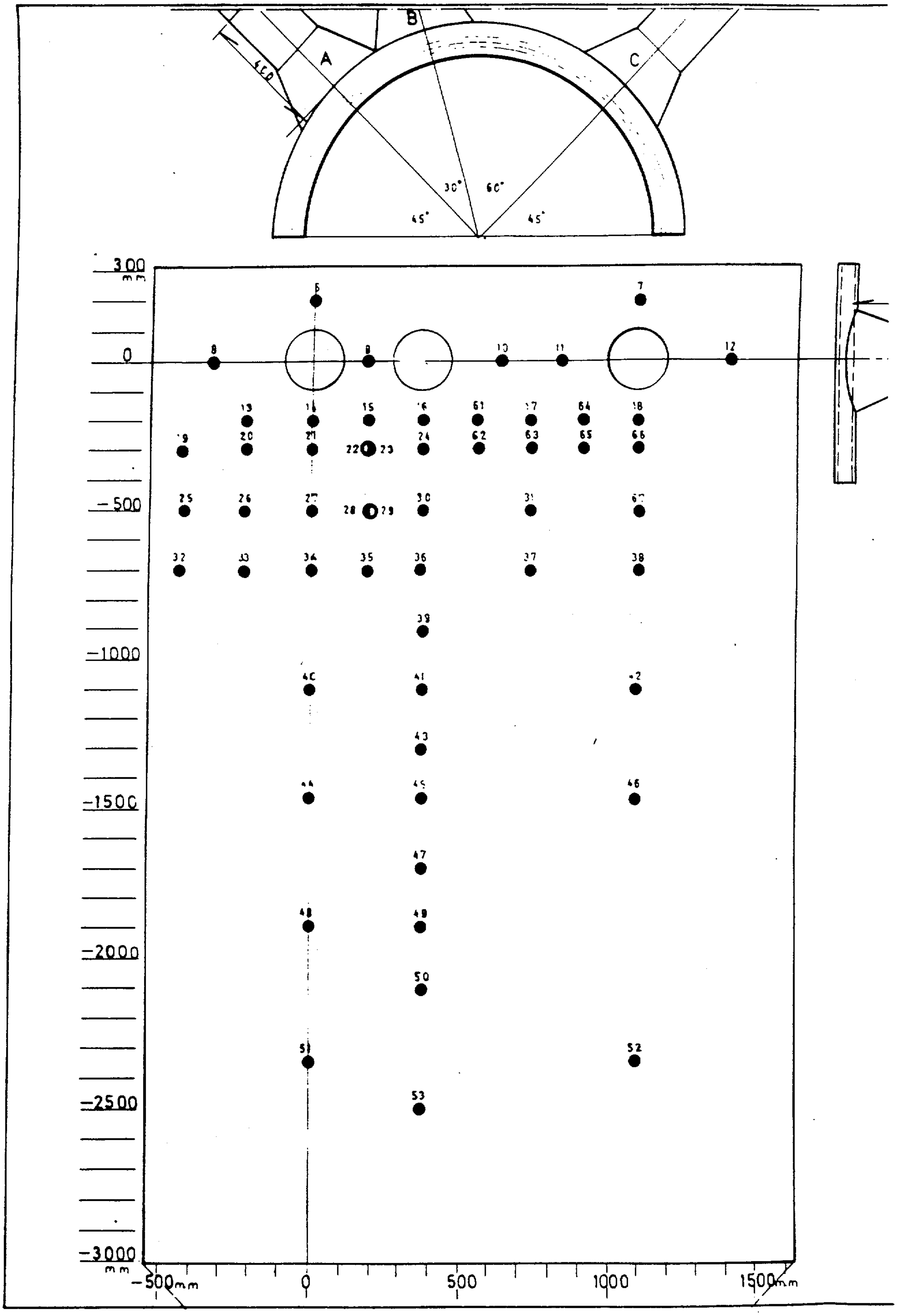


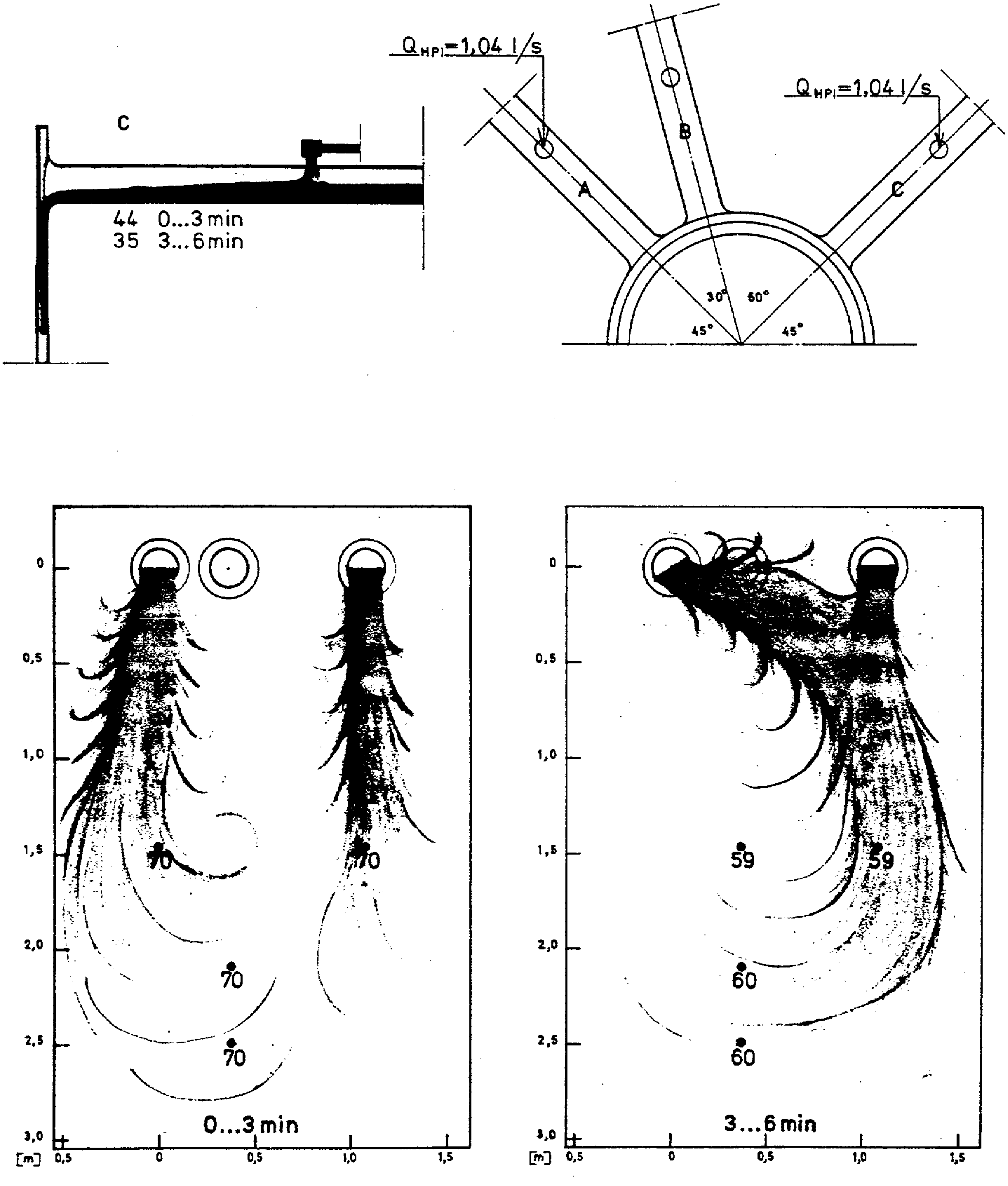
Figure 5.42 Schematic view of PURDUE's 1/2-scale facility (configuration B&W)


A — A
ECCS - CONNECTION
DET.1
DET.2
DOWNCOMER
R - 645
R - 631
R - 582
R - 682
3642
449
245
1328
293
1072
286
47
61
105
DET.2
293
234
C — C
THERMOCOUPLES
DET.3
B — B
FLOW EQUALIZER
ECCS - CONNECTION
COLD LEG A
COLD LEG B
COLD LEG C
DET 3
2250
1430
R - 682
C
B

IVO



IVO Downcomer TC Locations



Drawing 8a
Interaction and mixing of two HPI plumes in the downcomer during the test #112

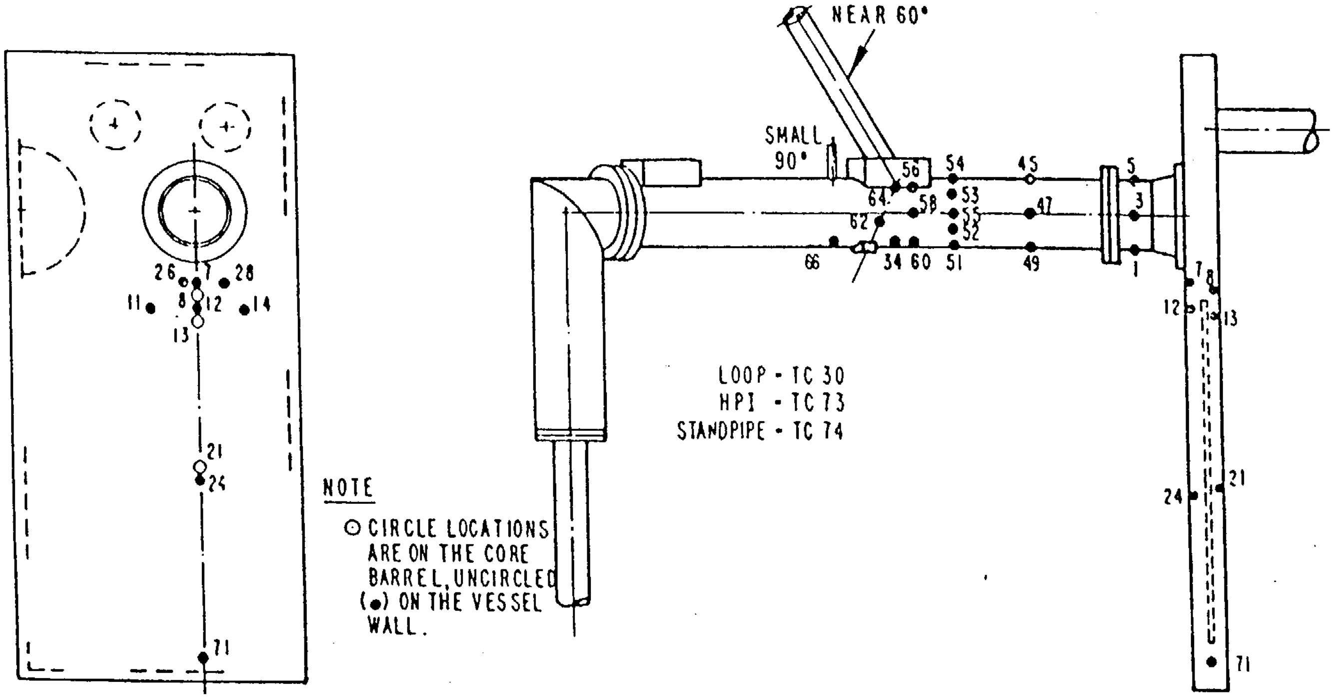


Figure 5.1 Schematic of CREARE 1/5-scale (MIX3) test facility

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, RELAP
2	Stuck open PORV	Failure to run back main feedwater; reactor coolant pump trip	TRAC, RELAP
3	**Turbine bypass valves fail open (2/4)**	**from full power, w & w/o failure of steam generator level control, restart reactor coolant pumps and throttle HPI**	**TRAC**
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	**2-inch hot leg break**	**Located in pressurizer surge line, reactor coolant pumps trip, systems operate as intended**	**TRAC, RELAP**
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	**Turbine bypass valves fail open (4/4)**	**from hot standby, w & w/o failure of steam generator level control, restart reactor coolant pumps and throttle HPI, hot standby initial conditions**	**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

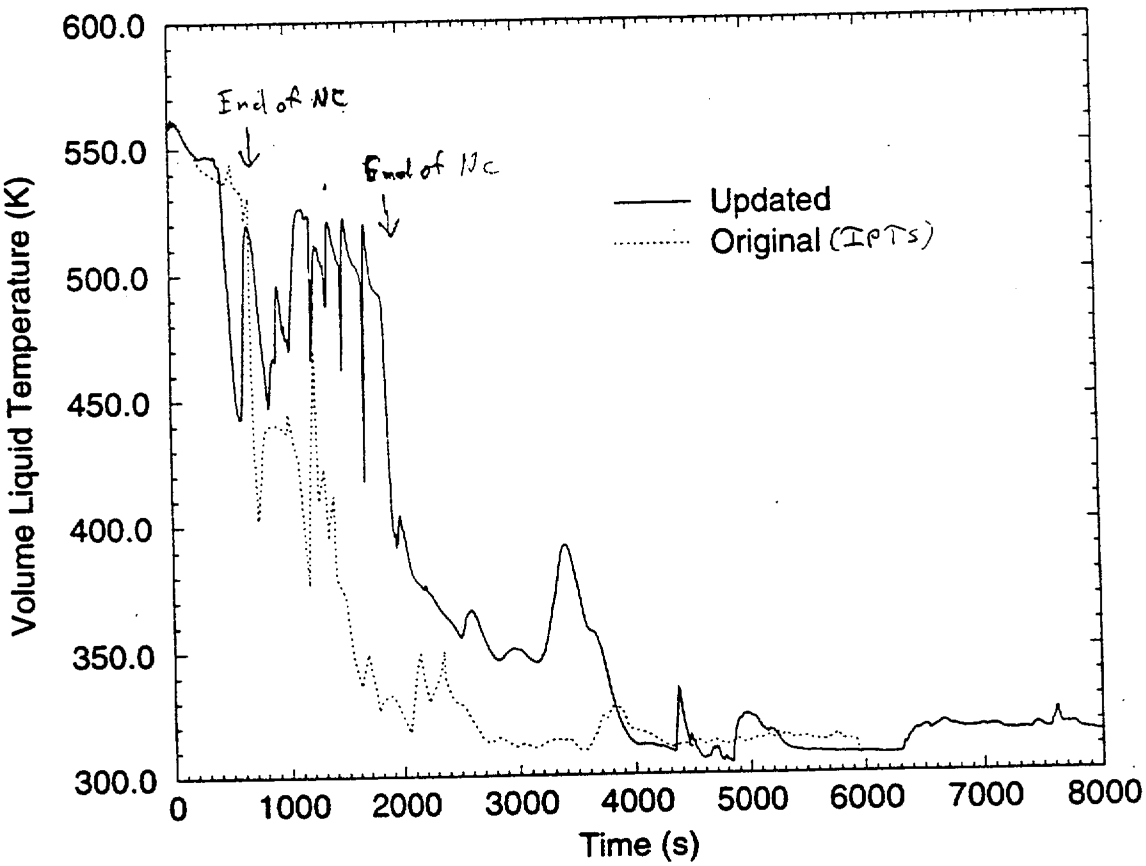


Figure 4-20. Loop A Cold Leg fluid temperature for the HL SBLOCA calculations.

HB Robinson

Importance of Reactor Coolant Pump Operation
(also loop flow stagnation)

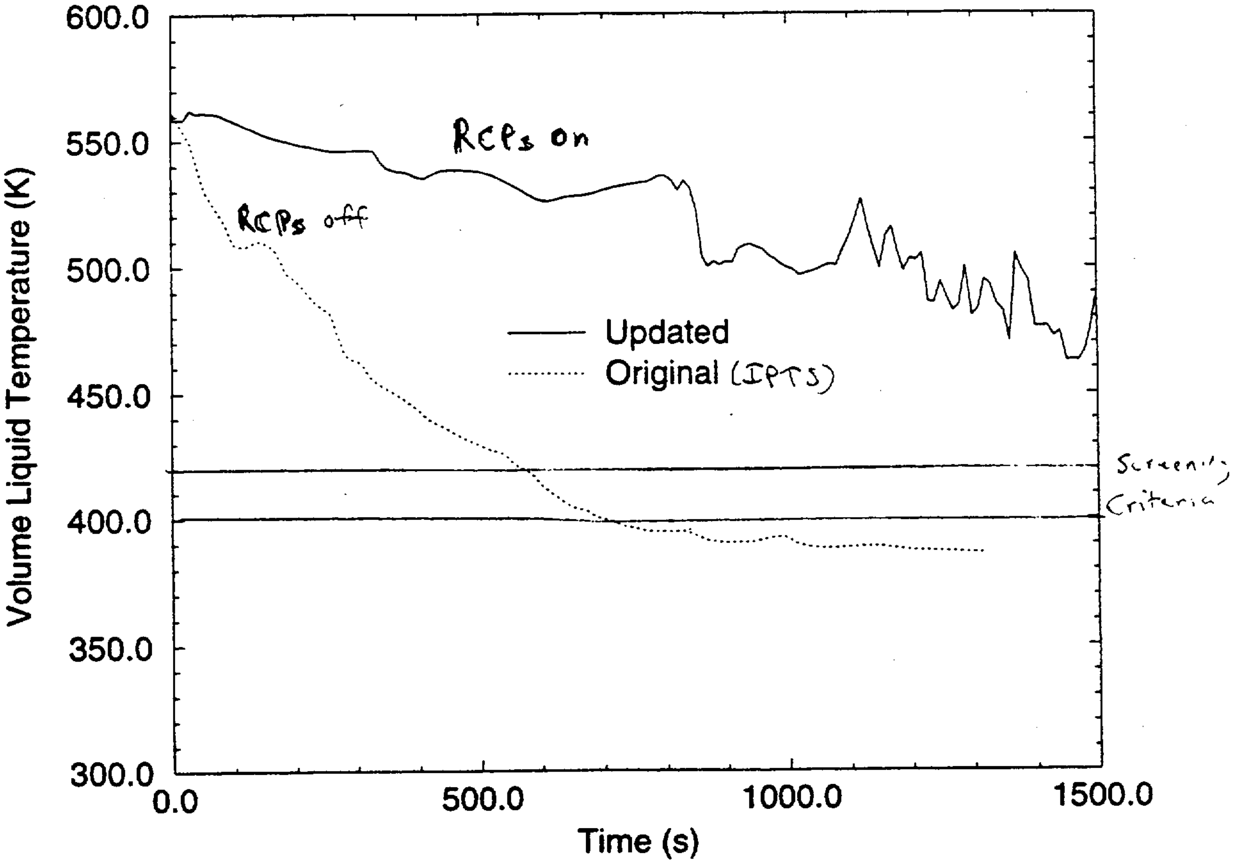


Figure 4-5. Downcomer fluid temperature for the MSLB calculations.

HB Robinson

Importance of Injection Flow Rate

300F = 422K
270F = 405K

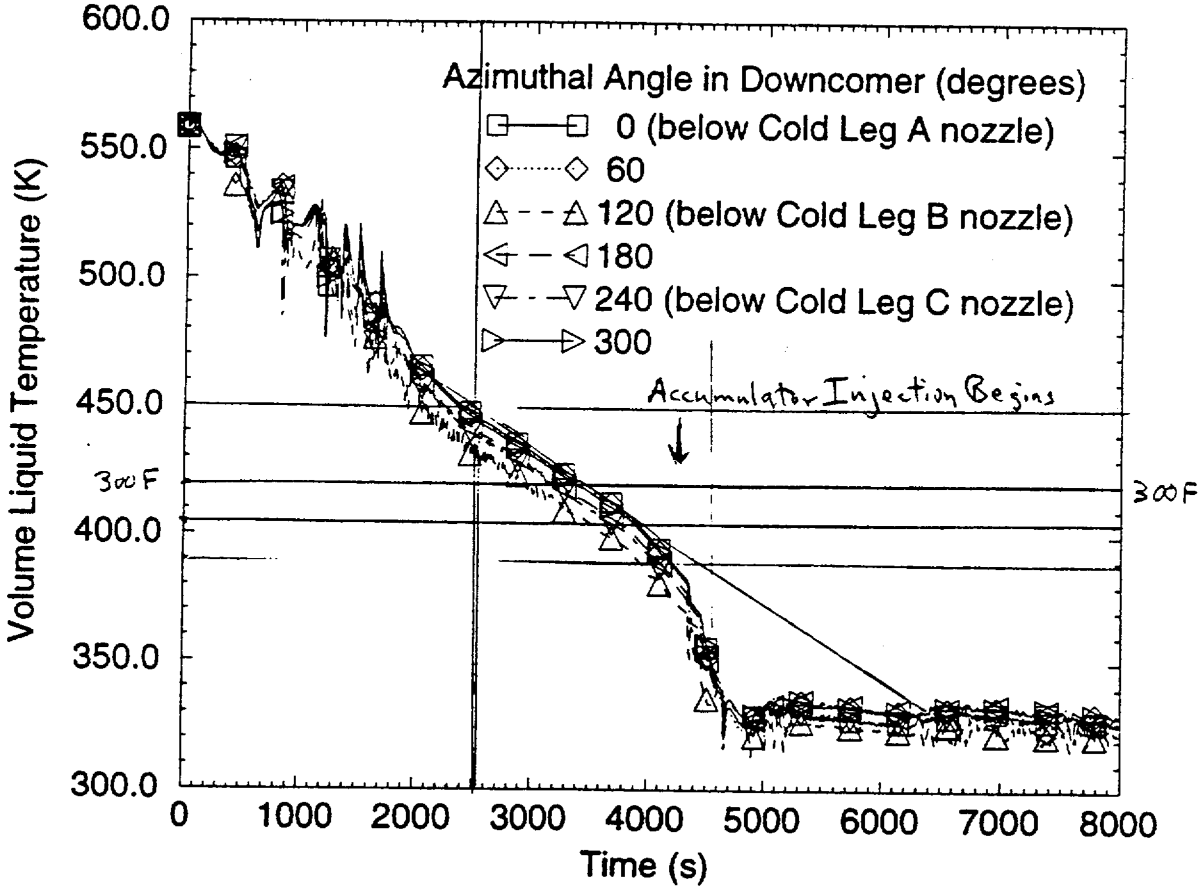


Figure 3-37. Hot leg SBLOCA fluid temperature in the azimuthal downcomer cells at the top of the core active length.

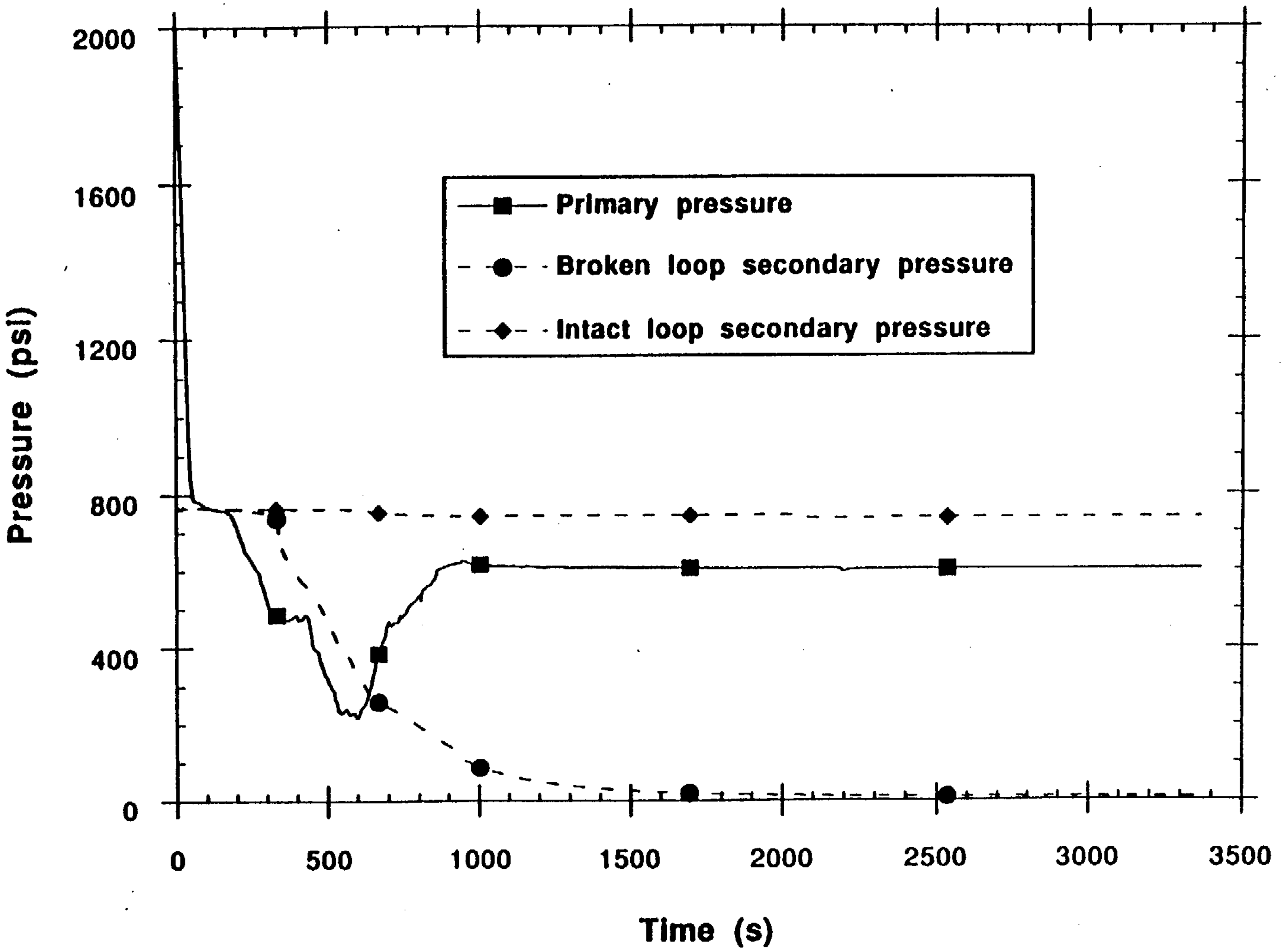


Figure 4 Primary and secondary pressures from the Yankee Rowe SBLOCA run #1.

Importance of Injection Flow Rate

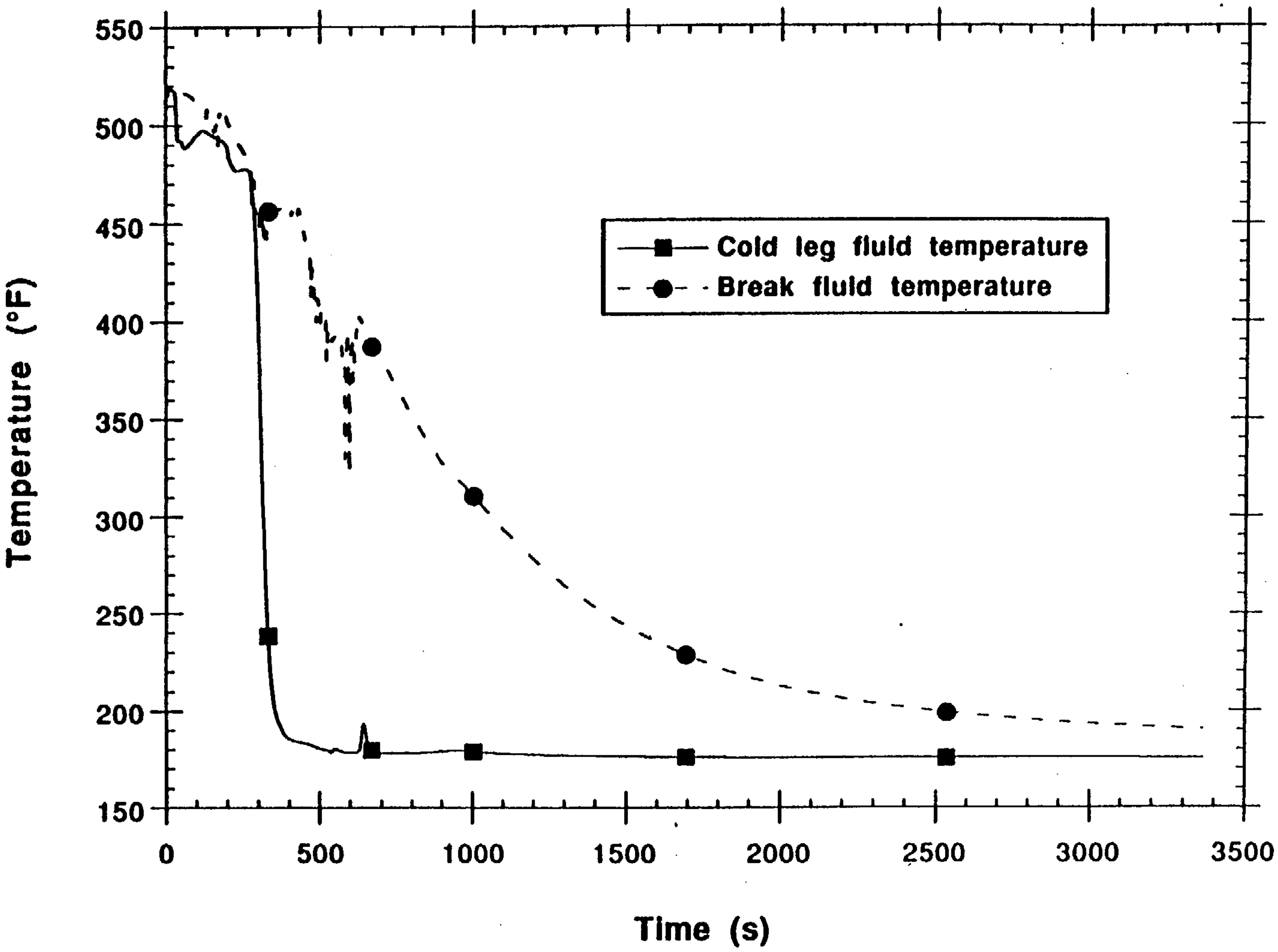


Figure 5 Broken loop fluid temperatures for Yankee Rowe SBLOCA run #1.

Importance of Controlling Injection Flow

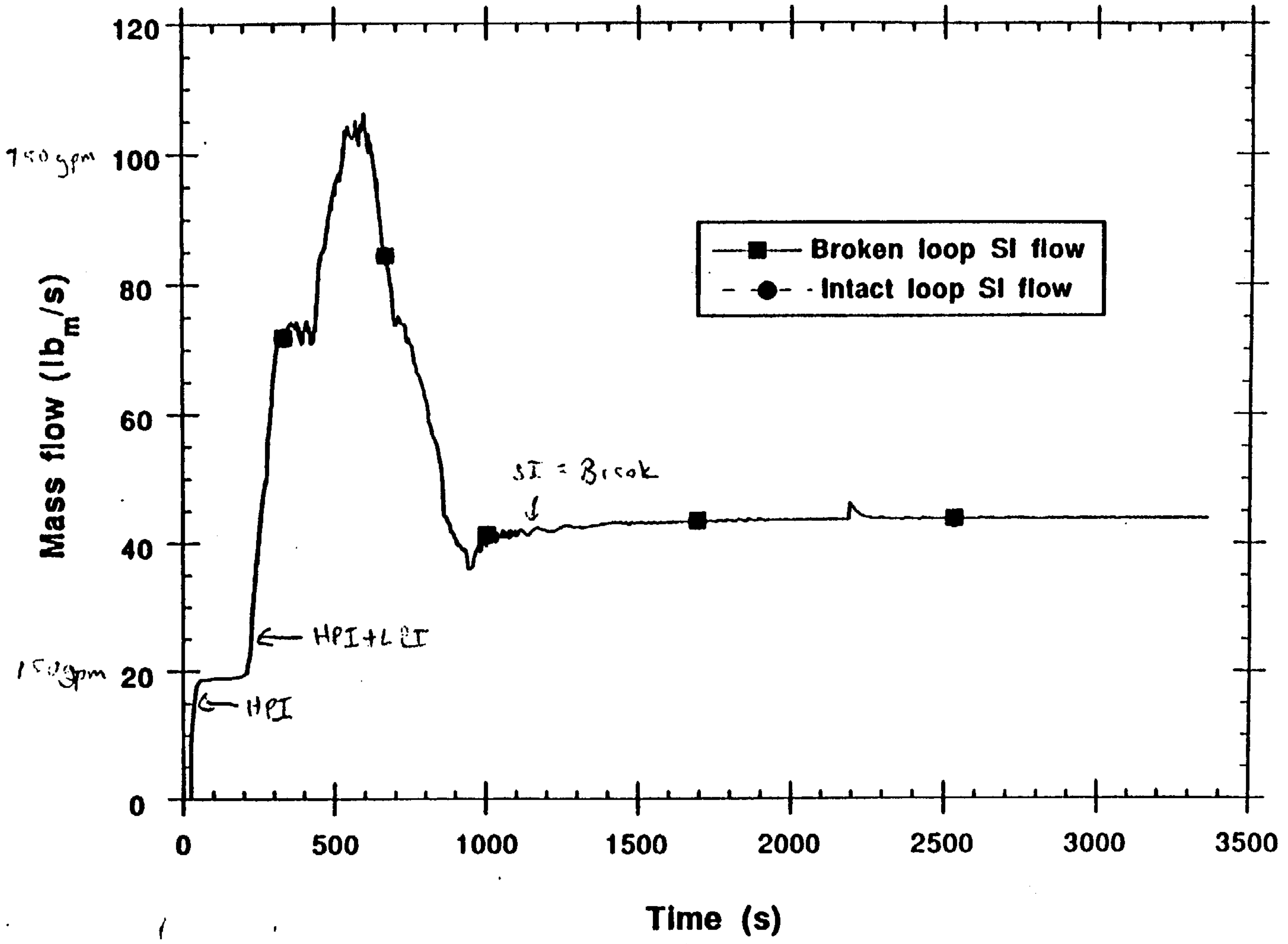


Figure 6 SI injection mass flow rates for Yankee Rowe SBLOCA run #1.

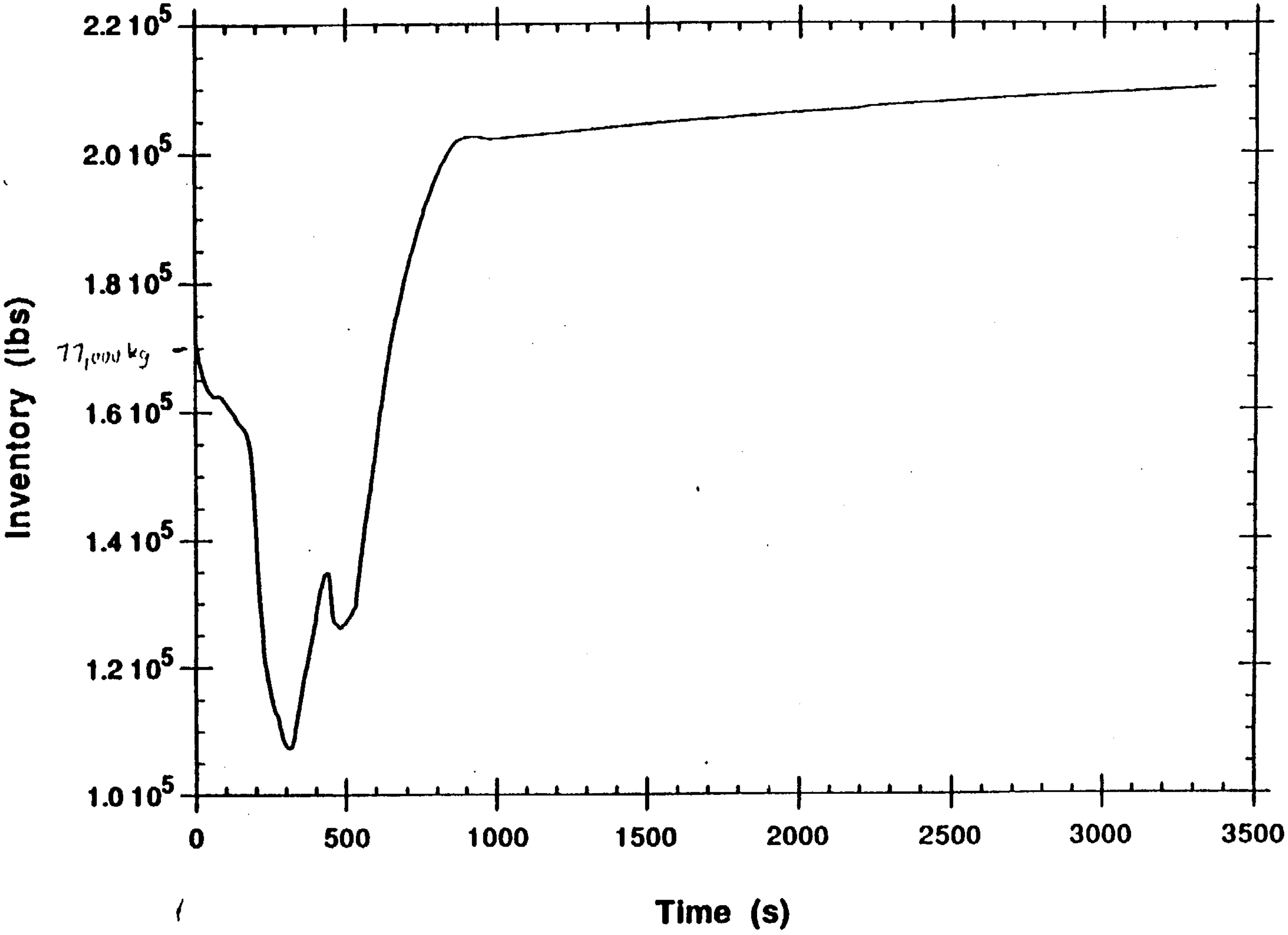


Figure 7 Primary mass inventoy for Yankee Rowe SBLOCA run #1.

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

- <u>Systems Codes</u>

  TRAC
  RELAP5

- <u>Special Purpose Code</u>

  REMIX

- <u>CFD Codes</u>

  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[1])

- 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.

---

[1] 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 much 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 loose natural circulation or those so large that the primary system depressurizes to a low pressure.

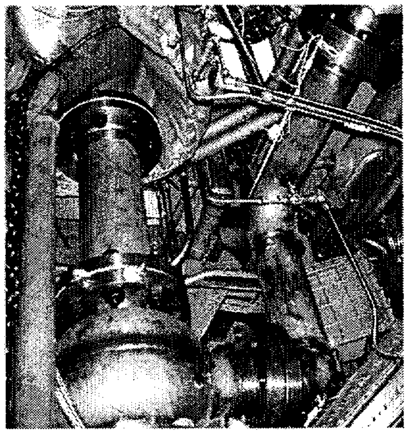
7. Screen remaining transients on the basis of P-T-h input to FAVOR.

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

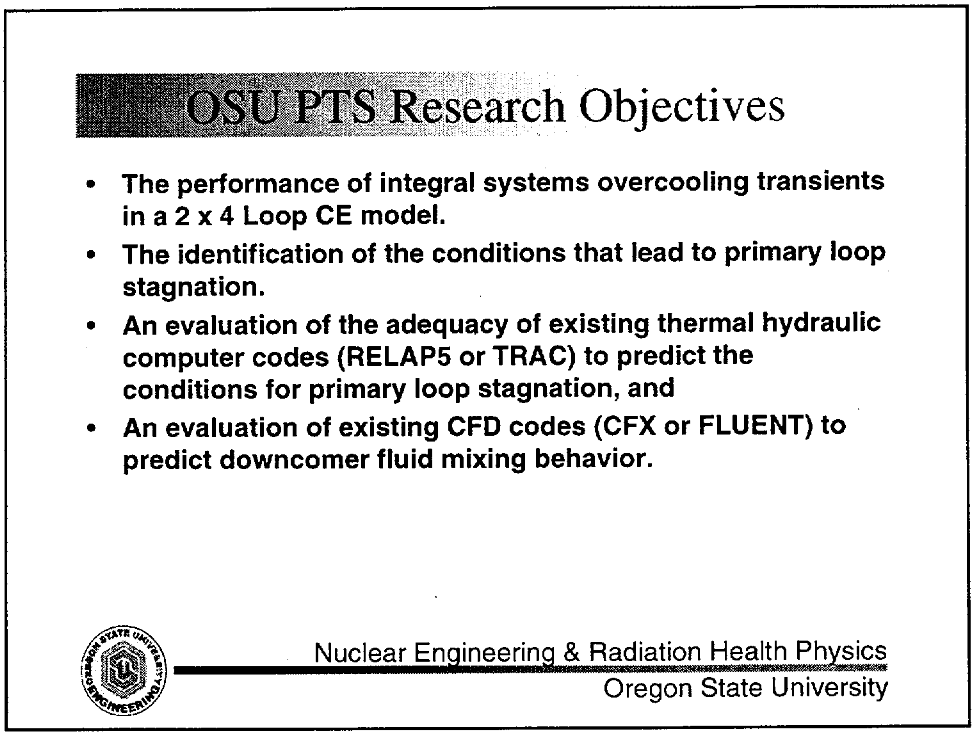


Nuclear Engineering & Radiation Health Physics
Oregon State University

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**

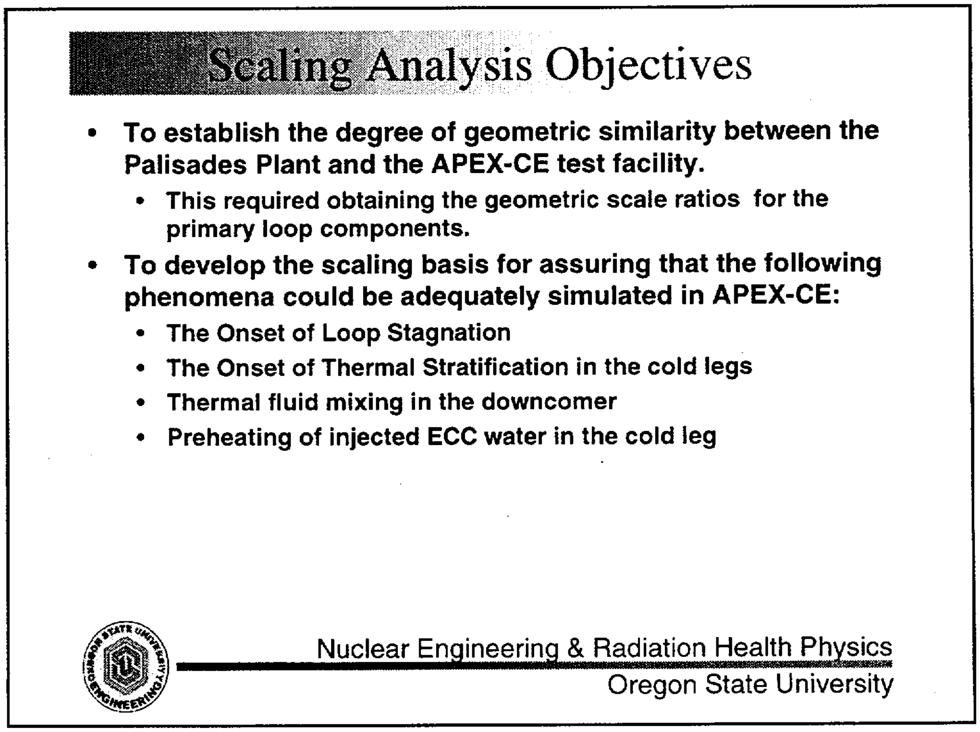
Nuclear Engineering & Radiation Health Physics
Oregon State University



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.**

General Scaling Methodology

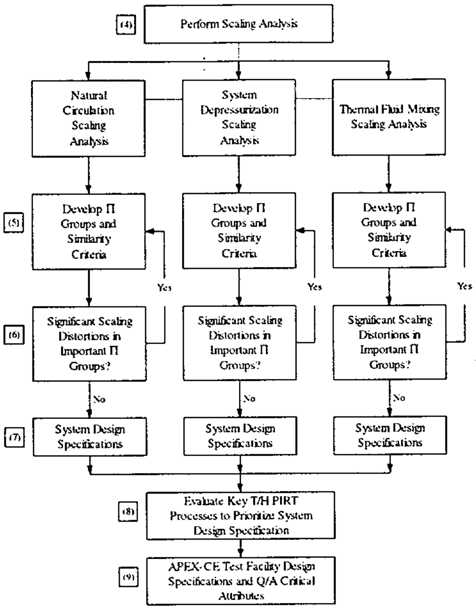
(1) Assessment of Integral System Geometric Similarity

(2) Specify Experimental Objectives

(3) PTS PIRT

(4) Perform Scaling Analysis

General Scaling Methodology (*continued*)



(4) Perform Scaling Analysis

Natural Circulation Scaling Analysis

System Depressurization Scaling Analysis

Thermal Fluid Mixing Scaling Analysis

(5) Develop Π Groups and Similarity Criteria

(6) Significant Scaling Distortions in Important Π Groups?

Yes

No

(7) System Design Specifications

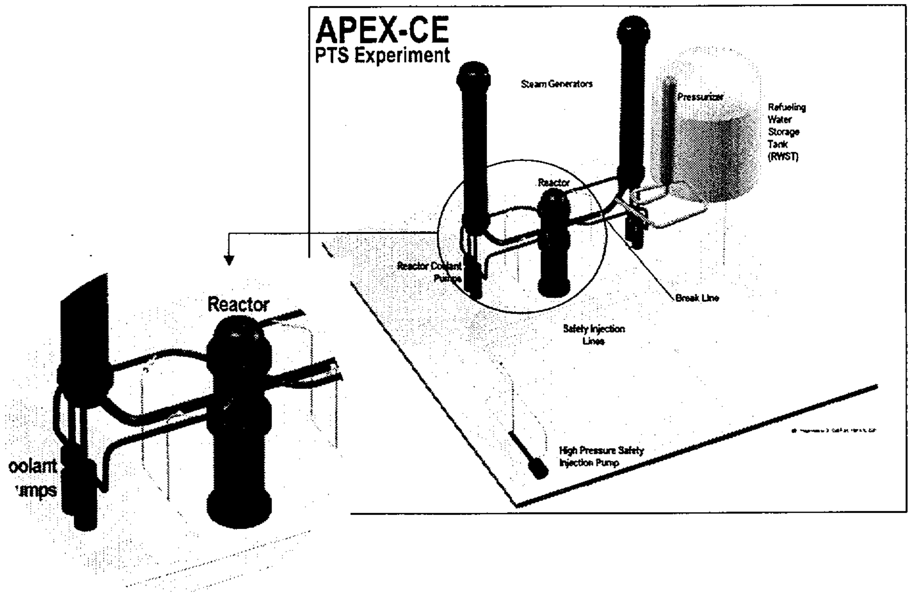
(8) Evaluate Key T/H PIRT Processes to Prioritize System Design Specification

(9) APEX-CE Test Facility Design Specifications and Q/A Critical Attributes

---

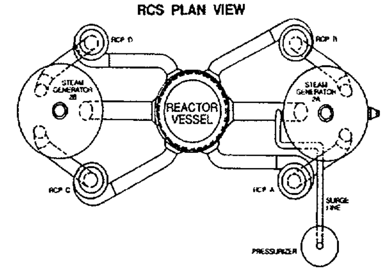
APEX Facility Modifications

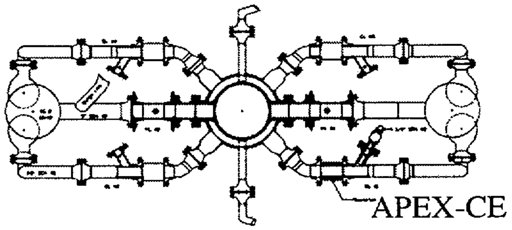
- **OSU has modified APEX to simulate the Palisade's 2x4 PWR. The following has been added:**
  - **Four HPI lines**
  - **Four cold leg loop seals**
  - **Additional cold leg T/C rakes and flow meters**
  - **50 additional downcomer thermocouples**



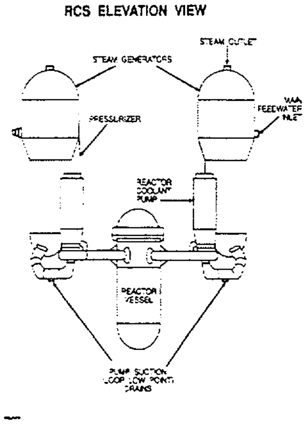
APEX-CE is Geometrically Similar to a Typical CE 2x4 Plant

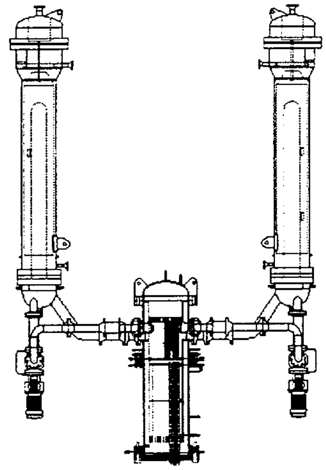
Palisades





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
Operating Parameters	
Power	1/276
Natural Circulation Mass Flow Rates	~1/276
Fluid Velocities	~1/3.7
Total RCS Power/Volume	1/1

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.**

Experiment Objectives

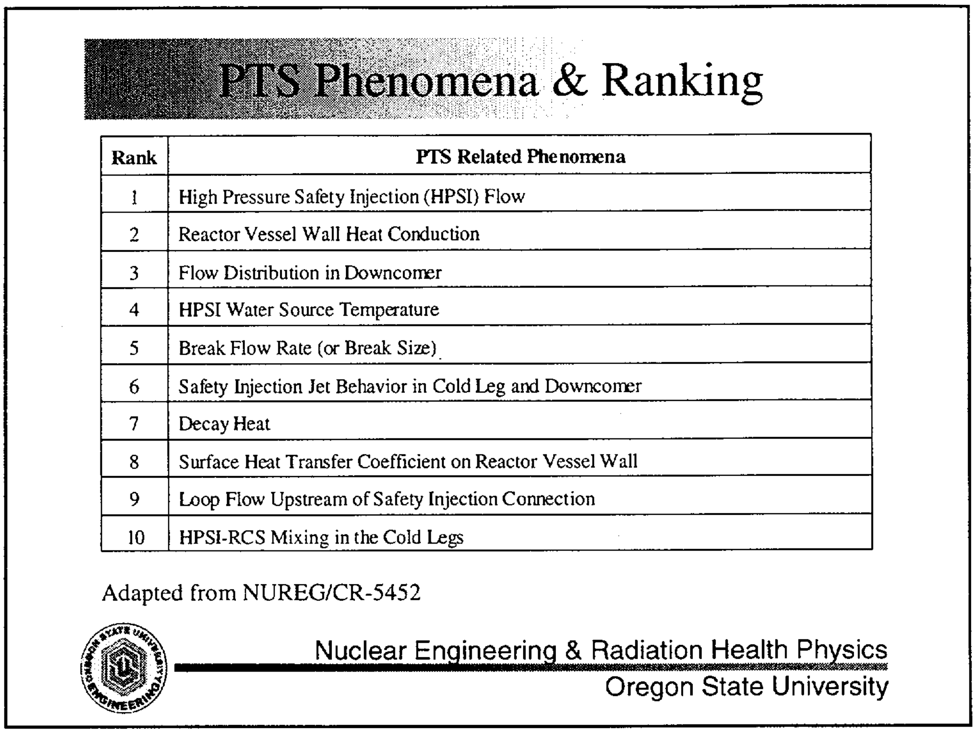
- Integral System Tests:
  - *Hot Leg Breaks.* Using cold leg injection, a spectrum of hot leg breaks (i.e., break energy equal to decay power) will be performed. The conditions leading to primary loop stagnation and the detailed temperature measurements and cooldown rates in the downcomer will be obtained.
  - *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

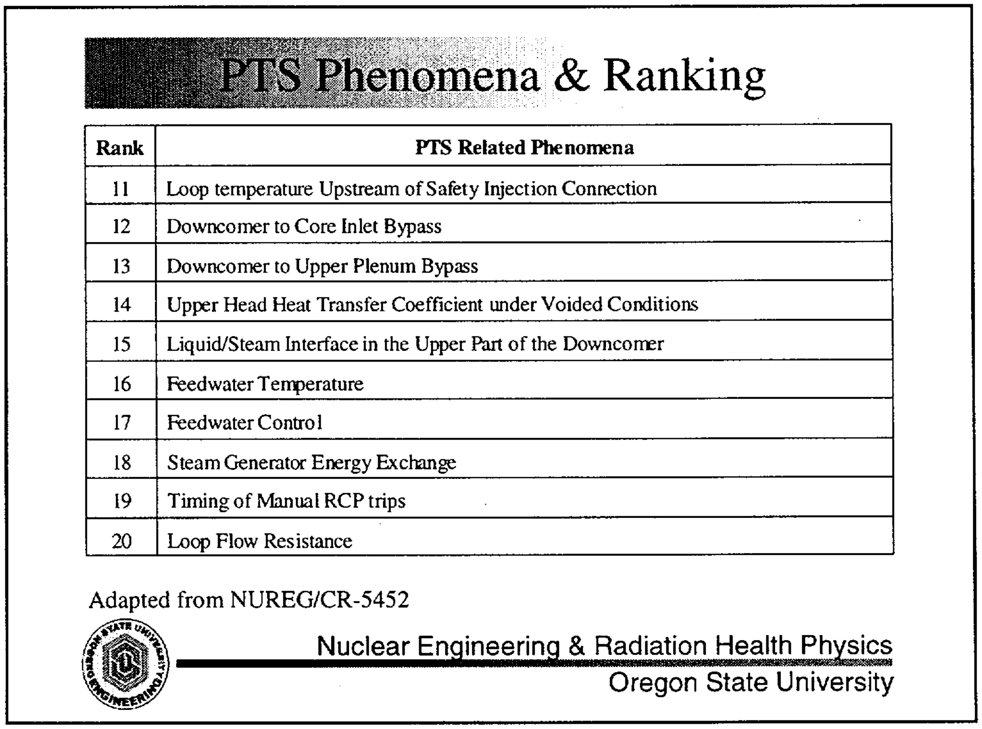


PTS Phenomena & Ranking

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



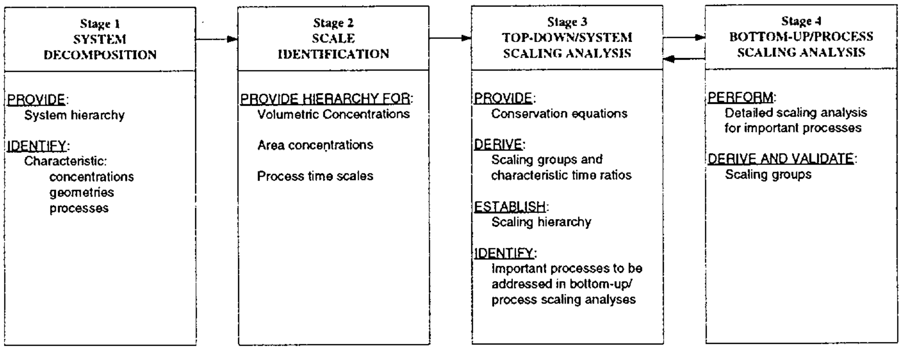
PTS Phenomena & Ranking

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



Stage 1
SYSTEM DECOMPOSITION

PROVIDE:
System hierarchy

IDENTIFY:
Characteristic:
concentrations
geometries
processes

Stage 2
SCALE IDENTIFICATION

PROVIDE HIERARCHY FOR:
Volumetric Concentrations

Area concentrations

Process time scales

Stage 3
TOP-DOWN/SYSTEM SCALING ANALYSIS

PROVIDE:
Conservation equations

DERIVE:
Scaling groups and characteristic time ratios

ESTABLISH:
Scaling hierarchy

IDENTIFY:
Important processes to be addressed in bottom-up/ process scaling analyses

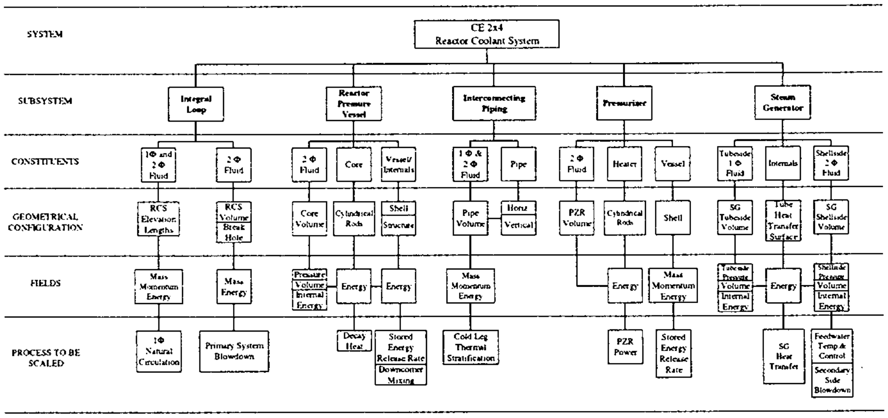
Stage 4
BOTTOM-UP/PROCESS SCALING ANALYSIS

PERFORM:
Detailed scaling analysis for important processes

DERIVE AND VALIDATE:
Scaling groups

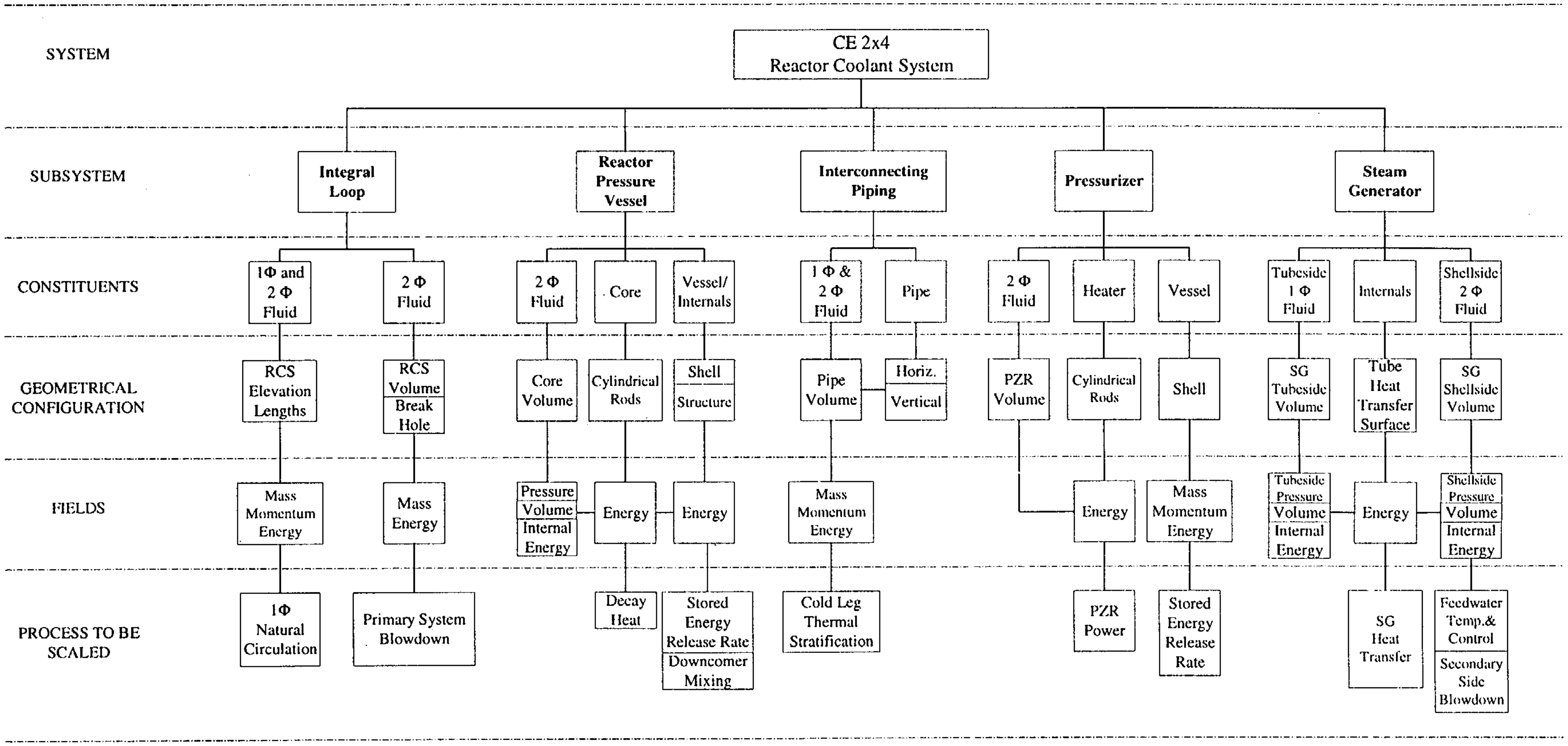
Nuclear Engineering & Radiation Health Physics
Oregon State University

System Breakdown & Process Hierarchy



Nuclear Engineering & Radiation Health Physics
Oregon State University

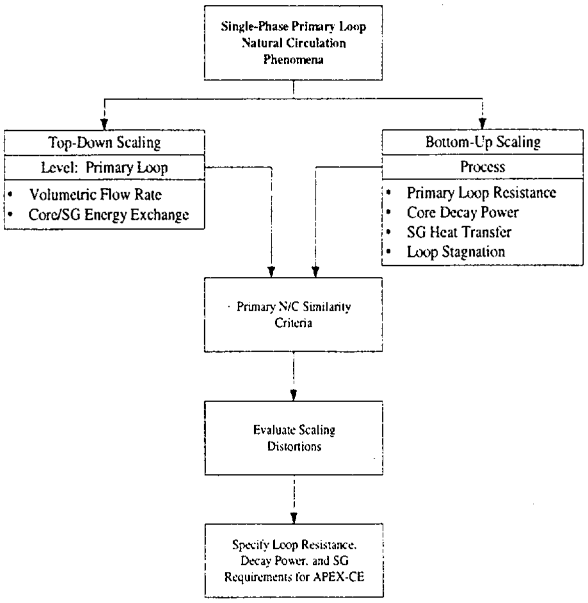
System Breakdown & Process Hierarchy



SYSTEM
SUBSYSTEM
CONSTITUENTS
GEOMETRICAL CONFIGURATION
FIELDS
PROCESS TO BE SCALED

- CE 2x4 Reactor Coolant System
  - **Integral Loop**
    - 1Φ and 2Φ Fluid
      - RCS Elevation Lengths
        - Mass Momentum Energy
          - 1Φ Natural Circulation
    - 2Φ Fluid
      - RCS Volume
Break Hole
        - Mass Energy
          - Primary System Blowdown
  - **Reactor Pressure Vessel**
    - 2Φ Fluid
      - Core Volume
        - Pressure / Volume / Internal Energy
    - Core
      - Cylindrical Rods
        - Energy
          - Decay Heat
    - Vessel/Internals
      - Shell / Structure
        - Energy
          - Stored Energy Release Rate / Downcomer Mixing
  - **Interconnecting Piping**
    - 1Φ & 2Φ Fluid
      - Pipe Volume
        - Mass Momentum Energy
          - Cold Leg Thermal Stratification
    - Pipe
      - Horiz. / Vertical
  - **Pressurizer**
    - 2Φ Fluid
      - PZR Volume
    - Heater
      - Cylindrical Rods
        - Energy
          - PZR Power
    - Vessel
      - Shell
        - Mass Momentum Energy
          - Stored Energy Release Rate
  - **Steam Generator**
    - Tubeside 1Φ Fluid
      - SG Tubeside Volume
        - Tubeside Pressure / Volume / Internal Energy
    - Internals
      - Tube Heat Transfer Surface
        - Energy
          - SG Heat Transfer
    - Shellside 2Φ Fluid
      - SG Shellside Volume
        - Shellside Pressure / Volume / Internal Energy
          - Feedwater Temp.& Control / Secondary Side Blowdown

Natural Circulation Scaling Analysis Flow Chart



Single-Phase Primary Loop Natural Circulation Phenomena

Top-Down Scaling

Level: Primary Loop

- Volumetric Flow Rate
- Core/SG Energy Exchange

Bottom-Up Scaling

Process

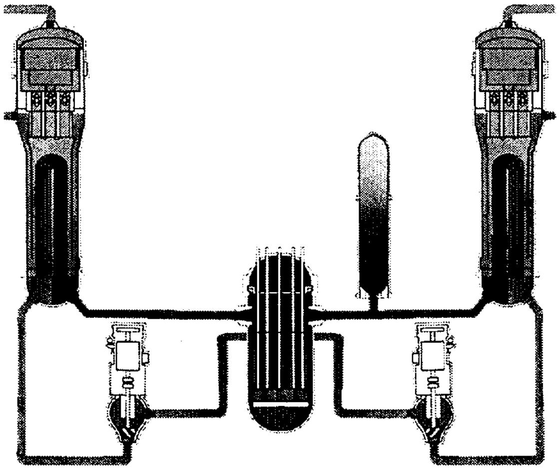
- Primary Loop Resistance
- Core Decay Power
- SG Heat Transfer
- Loop Stagnation

Primary N/C Similarity Criteria

Evaluate Scaling Distortions

Specify Loop Resistance, Decay Power, and SG Requirements for APEX-CE

Natural Circulation Control Volume



Balance Equations for Loop Analysis

- **Loop Mass Balance (at every cross-section):**

$$\dot{m} = n_i \rho_i u_i a_i = \rho_\ell u_\ell a_c = \text{constant} \qquad (5.4)$$

- **Momentum Balance for Parallel Loops:**

$$\left[\sum_{i=1}^{N} \ell_i \left(\frac{a_c}{n_i a_i}\right)\right] \rho_\ell \frac{du_c}{dt} = \beta g \rho_\ell (T_H - T_C) L_{th} - \frac{\rho_\ell u_c^2}{2} \sum_{i=1}^{N} \left(f\frac{\ell}{d_h} + K\right)_i \left(\frac{a_c}{n_i a_i}\right)^2 \qquad (5.5)$$

- **Energy Balance:**

$$C_{v\ell} M_{sys} \frac{d\langle T_\ell \rangle}{dt} = \dot{m} C_p (T_H - T_C) - (UA\Delta T)_{SG} - q_{loss} \qquad (5.6)$$

Dimensionless Balance Equations

- **Momentum Balance:**

$$\tau \frac{du_c^+}{dt} = \varepsilon_{nd} \left[\frac{(T_H - T_C)^+}{\Pi_{Fr}} - \frac{(u_c)^+}{2} \Pi_F\right] \qquad (5.15)$$

- **Energy Balance:**

$$\tau \frac{d\langle T_\ell \rangle^+}{dt} = \Pi_q \dot{m}^+ (T_H - T_C)^+ - \Pi_{SG} U_{SG}^+ \Delta T_{SG}^+ - \Pi_{loss} q_{loss}^+ \qquad (5.20)$$

Characteristic Time Scale & Π Groups

- **Loop Time Constant:**

$$\tau = \sum_{i=1}^{N} \frac{\ell_i}{u_i} = \sum_{i=1}^{N} \tau_i = \frac{M_{sys}}{\dot{m}} \qquad (5.16)$$

- **Loop Resistance:**

$$\Pi_F = \sum_{i=1}^{N} \left(\frac{f\ell}{d_h} + K \right) \left(\frac{a_c}{n_i a_i} \right)^2 \qquad (5.18)$$

Nuclear Engineering & Radiation Health Physics
Oregon State University

Characteristic Time Scale & Π Groups

- **Loop Richardson Number:**

$$\Pi_{\boxed{Ri}} = \frac{u_{co}^{\ 2}}{\beta_T g (T_H - T_C)_o L_{th}} \qquad (5.19)$$

- **Core Heat Transfer:**

$$\Pi_q = \frac{C_p (T_H - T_C)_o}{C_v \langle T_{\ell,o} \rangle} = \frac{q_{Core,o}}{\dot{m} C_v \langle T_{\ell,o} \rangle} \qquad (5.21)$$

Nuclear Engineering & Radiation Health Physics
Oregon State University

Characteristic Time Scale & Π Groups

- **Steam Generator Heat Transfer:**

$$\Pi_{SG} = \frac{U_{SG,o} A_{SG} \Delta T_{SG,o}}{C_v \langle T_{\ell,o} \rangle} \qquad (5.22)$$

- **Heat Loss:**

$$\Pi_{Loss} = \frac{q_{loss,o}}{C_v \langle T_{\ell,o} \rangle} \qquad (5.23)$$

Bottom-Up Scaling

- **Primary Loop Resistance:**

Component	**Palisades**	**APEX** **(½ Time Scale)**	**APEX-CE** **(1/1 Time Scale)**
	Π_F	Π_F	Π_F
Steam Generator	36.8	34.7	73.6
Reactor Vessel and Loops	33.7	33.0	67.4
All Loop Components	70.5	67.7	141.0