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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

THERMAL-HYDRAULIC PHENOMENA SUBCOMMITTEE

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TUESDAY

FEBRUARY 20, 2001

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., Dr. Graham B. Wallis, Chairman, presiding.

COMMITTEE MEMBERS:

GRAHAM B. WALLIS	Chairman
THOMAS S. KRESS	Member
DANA A. POWERS	Member
WILLIAM J. SHACK	Member

CONSULTANTS:

Virgil Schrock

Novak Zuber

ACRS STAFF PRESENT:

Paul Boehnert

Ralph Caruso

Ralph Landry

Joe Staudemeyer

ALSO PRESENT:

Jack Haugh

Mark Paulsen

G. Swindelhurst

I-N-D-E-X

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

(8:30 a.m.)

CHAIRMAN WALLIS: The meeting will now come to order. This is a meeting of the ACRS Subcommittee on Thermal-Hydraulic Phenomena. I am Graham Wallis, the Chairman of the Subcommittee.

ACRS members in attendance are Doctors Thomas Kress, Dana Powers and William Shack. ACRS consultants in attendance are Messers Virgil Schrock and Novak Zuber, who also have PhDs.

The purpose of this meeting is for the Subcommittee to continue its review of the Electric Power Research Institute RETRAN-3D thermal-hydraulic transient analysis code and discuss the status of the NRC staff's pending reviews of industry thermal-hydraulic codes.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee.

Mr. 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 January 30, 2001.

Portions of the meeting may be closed to the public, as necessary, to discuss information considered proprietary to Electric Power Research Institute. I would ask EPRI to point out if that is the case at anytime.

A transcript of this meeting is being kept, and the open portions of this transcript 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.

Now I am going to do what I almost never do at these meetings, and that's make some preliminary remarks.

There is a history to this story. About two years ago we received some documents from EPRI describing their code RETRAN-3D and, having read these documents, I made a presentation to the ACRS which was concerned with some problems with the momentum equations and their formulation and use.

EPRI met with us after that, still almost

two years ago, but we never had any technical discussion or resolution of the issues at that time. Since then, there's been an exchange of RAIs and responses between the staff and EPRI, and the staff has prepared an SER. I'm not quite sure if it is drafted at this time or final, but the ACRS itself hasn't been directly involved in this issue since 1999. So this is our chance to really get to grips with it.

I suggest there are three questions or maybe six. There are three questions, and each one of them raises another one that goes with it.

The first one is: What are the formulations of these equations? Let's clarify. Let's get the information straight so we know exactly what is going on. It's a fact finding question.

Related to that is the question that goes along with it, which is: Are they valid, and under what circumstances and with what kind of approximations or whatever?

The next question is: How are these formulations used? How do they actually apply to the real life nodes, control volumes and whatever in reactor systems? The question that goes along with that is: Are these methods of use valid? What's the

basis for validity, and what's perhaps the limitations and so on?

The third question is: How does the overall code work using these particular methods? Going along with that is the question: What's the basis for validation of this code?

I separate these questions, because it's conceivable that the formulations contain approximations, even errors, maybe used in a way which is difficult or can be qualified in some way, but there is a claim still made that, nonetheless, the code works, because there's some measure of working which is applied to the code.

The other thing I wish to say is I can't imagine how we would spend all day on these issues, and I actually have a plan to leave at three o'clock. Originally, we were going to have about an hour presentation, and I didn't expect that we would spend all day on these matters. Let's see how it goes.

I'm not sure just how EPRI is going to prepare, but if you prepared -- if you can address the three questions that I posed in the order that they were posed, that would help me anyway.

So I'm sorry to take the time of the Subcommittee, and now I will call upon Dr. Ralph

Landry who is bursting with enthusiasm to give his view on this matter.

DR. LANDRY: Thank you, Mr. Chairman. I don't know if I should say bursting with enthusiasm to get the view known, but I'll try to get it known. I think in our presentation and in our SER we do, in a sense, address some of the questions and our views of the answers to some of your questions.

First, what I'd like to do is very quickly go over the topics that we are going to cover and a quick rundown of some of the milestones, just to refresh the new members of the subcommittee on what we have done with this code, because it has been for quite a period of time.

So I'd like to get a highlight of the milestones, talk a little bit about the staff approach to the review, the evaluation of some of the aspects of RETRAN-3D which we did in the evaluation, which includes momentum equation, 5-equation model, critical flow model, and down the list talk a little bit about using RETRAN-3D in a RETRAN-02 mode.

One of the concerns that was raised by the applicant was that they would like to have permission to use RETRAN-3D in substitute for RETRAN-02, and I'll have some remarks on that, because you can't exactly

substitute the code. There are changes that cannot go back in time to the old code.

I would like to touch briefly on the conditions on use. The former versions of the code had an extensive number of revision conditions on use. We have reviewed some of those, and we have added more. Then the conclusions of the staff.

(Slide change)

DR. LANDRY: Very quickly, as the Chairman said, about two years ago, approaching three years ago, we received the request to review RETRAN-3D. We received the code itself and documentation in September of 1998. In December of that year we issued our acceptance for review of the material.

We met with the Subcommittee in December of '98, March, May, July of '99, March 2000 and again now in 2001, a lot of meetings that we've held with the Subcommittee. There was a meeting with the full Committee, as the Chairman pointed out, at which time he expressed his concerns with some of the material in the documentation.

The staff has met with EPRI on a lot of times, and we prepared our SER in December of 2000.

(Slide change)

DR. LANDRY: The approach that we took to

this review is, as we have said several times, in the past we used a lot of contractor support in reviewing codes. This was one of the first codes in a long time in which we assembled a staff group to do the review without relying on contractors.

We assembled a group of four, which a former member of the Subcommittee referred to as "the Gang of Four," to perform the review, people with expertise in thermal-hydraulics, kinetics, numerics, that could look at the code and do a review.

Originally, we had planned on concentrating on only the differences between RETRAN-3D and RETRAN-02. However, fundamental problems that were pointed out caused us to go back and start looking at the basis in the code itself, some of the fundamentals which we had not planned on reviewing.

We exercised the code extensively. We made many, many, many computer runs using models which we obtained from the applicant, models which we put together, attempts to break the code, to find where the code could fail and where it had shortcomings.

We looked at the conditions and limitations on the previously approved versions of the code. We identified additional conditions and limitations, and we put together a long list of

conditions on use of RETRAN-3D as RETRAN-02 substitute. I'll go into some of those a little later in this presentation.

(Slide change)

DR. LANDRY: Okay. One of the first problems we ran into in looking at extensive concerns with the code was with the momentum equation. Some of these problems, as Dr. Zuber has pointed out, go all the way back to 1974, and with the RELAP3 and RELAP4 codes from which RETRAN derived. In fact, I believe some of them even go back all the way to the FLASH code.

Some of the points of concern that the staff raised, and these are all delineated and discussed further in the SER: We were concerned with the attempt at rigor in the derivation of the momentum equation. A lot of effort is spent on a derivation, forms, terms that are not really in RETRAN-3D itself.

We have problems with the notation that was used in the derivation in the text. The documentation goes through an indicial notation, then goes into a non-standard notation. So that when we thought we understood an equation on one page, we encounter the equation on another page and, because of the change in notation, it's a totally different

equation. We have to sit down and try to figure out what in the world we are looking at on the next page.

There are typographical errors. Sometimes we weren't sure if we were seeing typographical errors or changes in notation.

Distributed descriptions occurred in the text. Descriptions of the equations spanned sections and chapters in the documentation. There wasn't one concise description and derivation.

Nomenclature is missing. Sometimes terms are defined within the text. When we have found a term in an equation we didn't understand, we didn't know if it was a change in notation, a typographical error, or if we had to go back and start reading text to find what the term meant, because it wasn't in the nomenclature list.

DR. SCHROCK: Excuse me, Ralph. On slide 3 you had an item "acceptance of RETRAN-3D for review." It seems to me that so much of the effort -- it's just wheel spinning here -- could have been avoided if you had stepped up to the plate and said at that time, this list of things renders this submittal inadequate for NRC review at this time.

I think that's what you were driving for in your revision of the standard review plan and in

the reg guide supporting it. So I think you've got to address that issue at some time. When are you going to do that?

DR. LANDRY: Well, some of these problems -- Let me back up. We have to understand what the acceptance for review process is, in the first place. If it's a mini-review to see that there is enough material there to begin a review, then you won't find these kind of problems until you go into the text in depth and start finding the problems.

If you want to say an acceptance review means that everything is absolutely correct in the text, then you have done the review at the same time. The acceptance review process which we envisioned was one in which we would look at the documentation and say, yes, this documentation has enough material, covers all the topics that it should cover, and we can begin the in depth review of the material.

That was our initial goal in doing an acceptance review.

DR. SCHROCK: Well, when I reviewed it, I could have said after the first two hours that this is not a document that describes a code that can be defended.

DR. ZUBER: Zuber. Let me add, I

completely agree with Virgil. If a code has errors, which should be really at the junior level, that code should not ever be reviewed for the reason that this is not acceptable, period, and not really go for two years, which we have been now and God knows how long.

I think that doesn't do credit to NRC. It doesn't do credit to the technology. Basic errors in the code which on the junior level can be detected should not be even accepted.

DR. LANDRY: In our writing of the SRP, which has a lot of information and based on our experience in this review, I think that in the future we are going to do a greater review of material before we accept it; whereas, at this point we just looked through, said okay, there's enough material here we can start a review.

We were coming off of an experience with a previous design submittal in which we were reviewing an SB LOCA code, which is -- the documentation was less than a quarter of an inch thick. We said, obviously, this isn't adequate to do a review of the code.

So we needed to do a review of the material first to see if there's enough material to review before we could accept it, and that was the

mindset that got us into this position; and as we then got into the review in depth, we've started learning more and more of errors in it and that perhaps this should have been done in a different way.

CHAIRMAN WALLIS: Maybe it would help if you had someone like Professor Schrock review the code and say just what he said, that after sort of an hour reading he could tell you that, you know, this ship is headed for an iceberg, let's not let it happen.

DR. LANDRY: I think we have learned a lot from this experience and learned how we have to do things.

DR. ZUBER: Just one more comment. You see, you get into a position. If you accept it for review and after sometime you cannot really approve it, you are being accused or put in a position it costs so much money to go to NRC, and then you get the lawyers on your back.

What you should really do, stop in the beginning and say this is not acceptable, go back. You save them money, but if they want to waste their money, that's their own prerogative. But they should not waste your time.

DR. LANDRY: We agree with you, Novak. We have learned a lot from this.

Okay, I think I was down to the last step. In looking through the derivations of the momentum equation, we also found that there were missing steps. Where there had been a great deal of detail lavished on the initial phases of the derivation, the derivation became very sparse, and very great leaps were taken at the end.

(Slide change)

DR. LANDRY: In our review we determined that the so called "vector momentum equation" really isn't. The equation that is in the material is a scalar equation of motion. It is projected on a vector momentum along a control volume dependent direction. It's really not a vector momentum equation.

We found a number of errors, some of which you corrected.

CHAIRMAN WALLIS: You concluded that it was a projection of a vector momentum equation?

DR. LANDRY: We viewed it as that it's a projection of vector momentum along a --

CHAIRMAN WALLIS: Because it appears to be a strange hybrid, which isn't really projection of a vector momentum equation. It isn't energy conservation, and it isn't recognizable based.

DR. LANDRY: That's what we are trying to say. It's not --

CHAIRMAN WALLIS: But you said something there which I don't think is --

DR. LANDRY: Well, I was trying to shorten up a statement.

CHAIRMAN WALLIS: -- is true.

DR. STAUDEMEYER: Joe Staudemeyer, NRC staff. If you look at the derivation, it really is a projection of a vector momentum equation along a direction that depends on what the volume is on the direction of volume that it's in. So --

CHAIRMAN WALLIS: Well, that's what it claims to be.

DR. STAUDEMEYER: And you can work out all the terms, and it does work out that it's that. But then you end up with 20 terms left over that don't --

CHAIRMAN WALLIS: Okay. Well, we are going to get into that with EPRI, I guess. I think that all of us have great difficulty projecting several of these terms in a direction which makes any direct link between a vector momentum equation and the equation that actually appears.

DR. STAUDEMEYER: Yes. Well, there are some other assumptions I have to go into to get it,

too.

DR. LANDRY: Okay. In the review we pointed out a number of errors. I know the Chairman had pointed out a number of errors and a lot of information on the momentum equation also. Some of these overlap. We haven't gone back to see if we have a one to one correspondence, but I'm sure some of this overlaps with what the Chairman has pointed out also.

We found that there is a cosine term missing from a vector dot product in going from equation 236 to equation 237. We pointed out where this would be easily seen if one tries to solve this equation for a bend in a pipe.

We said that it was mathematically possible to eliminate the cosine term from the pressure difference term if a constant pressure is assumed in the cell, but then the cosine term has to appear somewhere else. It has to be moved to the F_{loc} term, projection of nonuniform normal wall forces.

The EPRI staff told us that this was going to be evaluated based on empirical information and empirical data. The staff is anxiously awaiting to see the source of that information. We are not aware of any such information. We would very much like to

see it.

We have said that the equation for mechanical energy conservation cannot be derived from the equation of motion. Therefore, you cannot show that your mechanical energy is being conserved.

We said that pipe configuration with a TEE split or two parts coming together, such as a jet pump, results in a non-zero pressure difference that is dependent on the area of the exit path or paths. The EPRI staff agreed with this, and has gone back and fixed the information.

We have looked at an attempt at a derivation called the "Porsching Paper." According to the staff's view is that the paper is irrelevant. We said it's irrelevant, because the paper does not appear to have any mathematical errors, but the definitions and restrictions on control volumes that are required to be consistent with the mean value theorem makes the paper irrelevant.

Pressures and flows in RETRAN are defined in a control volume with specified functional dependencies. The integrals in the paper should be evaluated with the RETRAN-3D assumed function dependence for pressure and flow. In our view, the paper doesn't pertain to the derivation.

I'm sure EPRI is going to want to respond to that a little later also.

(Slide change)

DR. LANDRY: We looked at the 5-equation non-equilibrium model. This is a topic that caused us quite a bit of concern during the review.

Part-way -- A year into the review, part-way into the review, we found out that there was a fundamental change in the code which we weren't aware of. That was being in the works at the time the code was submitted.

This caused us a great deal of consternation. Finally, the material was submitted. We came back in our review and said that this model has not been assessed properly and, therefore, is not acceptable for use.

Licensees who wish to use the 5-equation non-equilibrium model have to provide separate effects, integral systems effects assessment over the full range of conditions that are to be encountered for which the model is applied.

Assessment of uncertainties --

DR. ZUBER: Every time you get an applicant, you will have to do another review.

DR. LANDRY: That is correct.

DR. ZUBER: Well, that's a waste of money and waste of time. In a sense, you have to review, but not at this level. This should be the level of code acceptance, and then you apply to a given plant. That's another story, but this is really the basic equation, the basic model. If you have to do this for every applicant, it takes your time. It costs money, and it costs them money, and I'm really surprised that they didn't address this problem.

DR. LANDRY: This was -- In the original phase of the review, our understanding was that the code was being submitted so that we could review the code, as we have with a number of other industry codes, and say that the code is approved for use and, as long as it's used within the constraints, we don't have to review the submittal. But -- Let me finish, Novak.

Back in the RETRAN-02 days, RETRAN-02 was approved, but there were 39 conditions and limitations on use, which meant virtually everybody who used the code had to come in with a justification assessment and support why that code is applicable for their application.

We thought we were getting out of that mode. However, we can't. We are still in that mode

with RETRAN-3D, because of our view of the assessment. When the code is used, it still must be heavily supported for every application, and yes, we agree with you.

DR. ZUBER: That really surprises me, that the industry complains for money, and yet really that puts NRC in the position that they have to do it.

DR. LANDRY: The code has to be assessed properly for the application. If it's not done generically, then it has to be done for each specific application.

DR. ZUBER: Well, this approach really makes -- four separate effects. You can really put the burden not on the co-developer but on the applicant. I mean, that's the philosophy, I mean, if you follow logically this approach.

DR. LANDRY: You are going to hear me say that throughout this presentation.

DR. ZUBER: Good.

CHAIRMAN WALLIS: Well, what happens when the applicant, say Maine Yankee which doesn't exist anymore -- we'll pick someone -- comes up, wants to use RETRAN, and their engineers look at it and say, gee whiz, we can't figure out this momentum equation? Is it their responsibility to defend it?

DR. LANDRY: The defense of a methodology used in a licensing application is put on the applicant, the licensee. The licensee --

CHAIRMAN WALLIS: But do they have to defend something in the code which they didn't originate?

DR. LANDRY: The licensee is responsible for everything that is submitted on their application.

CHAIRMAN WALLIS: So they have to go over the same terrain again maybe.

DR. LANDRY: If material is not correct.

CHAIRMAN WALLIS: It's an awfully wasteful and inefficient process.

DR. LANDRY: If the material is not correct or not done adequately, then the burden is placed on the licensee.

CHAIRMAN WALLIS: I guess that's the theme that the ACRS keeps trying to sing that no one has listened to. If you do the job right the first time, it saves one hell of a lot of wasted energy and money.

DR. LANDRY: We're not going to disagree with you.

CHAIRMAN WALLIS: What's wrong with that statement? We've said that before, and we get all this gripe about, well, it's too much effort to do it

right and, no, no.

DR. ZUBER: Limited resources, too much money, and it ends up they to minimize any effort. I'm sorry.

DR. LANDRY: We don't disagree with you.

CHAIRMAN WALLIS: Let's move on.

DR. LANDRY: This is why we like to do -- let's call them topical type reviews, because we can review a material one time and then, when it's applied, all we have to do is see that it's applied properly. It saves everybody.

CHAIRMAN WALLIS: Well, it's like the homework. If everything is right, you just check it out and give them an A, and that's the end of it, and it's five minutes work.

DR. LANDRY: I wish I had people like you in school. Do you give multiple choice quizzes?

CHAIRMAN WALLIS: The interesting part is, if it's a better derivation than the professor's, then you have to think about it.

DR. SCHROCK: Doesn't it seem reasonable that, if you are unable to approve something as a generic tool for general applications, maybe a minor exception here and there, but for general applications, if you are not able to do that, then why

don't you ask what is the function of such an approval? What does it accomplish for anybody?

DR. LANDRY: When we look at a new methodology, new model, that's one of the things we look at. Back on another code that we reviewed recently when we talked about replacing one of the transfer correlations, we were looking at what is the benefit. It's a newer equation --

DR. SCHROCK: I'm not talking about details at that level, but the conclusion is that the code is basically unacceptable for -- I guess you've identified something like 40 different situations, and if it's going to be used for those situations, then additional -- significant additional work will have to be done.

So you really haven't produced anything that's useful either to the industry or to the regulators, it seems to me. You've --

DR. LANDRY; Well, one of the bottom lines we are going to get to in this is that, while there are a great many conditions and limitations on use and a great many things that the applicant must do when using this code, the code is an improvement over RETRAN-02.

It is numerically improved. It is more

robust. But -- and then we get into the "buts," all the things that must be done. So, yes, it is an improvement, but it's not perfect especially in that it's not totally supported in its assessment validation.

This has been an ongoing discussion.

DR. ZUBER: But that is where I see the kind of trouble recently is you try always to put everything in that one basket. One is the formulation, the basic equations, and this is, I think, question one that Graham had.

The second one is what kind of validations. I think you should separate those, and on the first level the equations, the formulations, then the constitutive equations. Then you will go back into validations. Don't try to kind of jump from one to the other, I think. Focus on one. If it's acceptable, then look at the validation, but putting them together -- and this is what industry does -- is at least confusing.

CHAIRMAN WALLIS: I think you also have to decide when you review is this sort of a series of filters, and if you filter the fundamental formulation and, if it doesn't pass that filter, do you go any further or do you sort of go on to start looking at

assessment and stuff with loft, no matter what happened in the previous filters.

I think that's something you guys have to think about in the process. That is a sort of series of steps with yes/no and, if there's a no, you don't go any further or do you have some yes/maybes. How are you going to do that?

DR. LANDRY; That's a difficulty. As you come down through a particular model, is this -- does it look valid, what they have done? Is it assessed? If you come out no, do we stop altogether or do we go to the next stage and say, okay, the next model. Okay, we've a yes here. This one we have a yes. This one, you have to go back and support or you put a limitation. We keep doing down the list --

CHAIRMAN WALLIS: How many of those are necessary, and to what degree is the thing. You have to ask yourselves pretty carefully.

DR. LANDRY: That is a very difficult question, because that really doesn't show up until you start assessing against things like an integral system or full size data where you can say the overall package does a bad job or the overall package does a good job, but it could do a better job if this was fixed.

DR. ZUBER: Let me say, I think, if I may be direct, there you are really going on a kind of a tangent. You used the word model. What does it mean? Does it mean the formulation, which is also model, or does it mean the constitutive relations, and that's all similar. And don't put those things together.

The first thing is, is the formulation correct? Are the equations correct? If they are, then you proceed to the next one. Then you look at the model. If you question the model, you go to the validation. There is a kind of a hierarchal approach, how you look at these problems. But don't take immediately model, because you don't know -- at least, I don't know what you are really addressing.

So look at the formulation equations. If they pass, fine. If not, send it back to the student. Go back then to the constitutive equations. If they are acceptable, fine. If not, what is the validation.

CHAIRMAN WALLIS: Well, there is also the question of what you mean by correct. I mean, there are errors that reveal a fundamental misunderstanding, and there are errors which are more in the form of you can't solve this thing exactly, so you make some assumptions, but you've got to be clear what they are, and those aren't exactly errors. Correctness, I

think, has to be qualified.

You are not looking for something which is exact. We are looking for something which is plausible and doesn't contain real errors, which sort of exaggerate some fundamental misunderstanding and produce a ludicrous answer under some circumstances, that sort of thing.

DR. LANDRY: I think to follow that up and back up just a second to the momentum equation as an example, in the derivation -- Now we've argued about it. We've heard the Chairman's views on it, the views of the Committee, the views of the consultants, our views. We've been in a long debate with the applicant.

I think the bottom line to this as an example is that this was an attempt at a rigorous derivation of a momentum equation for use in a computer code. Fundamentally, you can't get to that point the way it's been done.

A far more productive method, and one which we pointed out to the applicant at one point, would be to tell us what is in the code. What are the terms? What do the terms mean? Why is it acceptable? Why is it valid?

Rather than trying to do a rigorous

derivation from basic principles, which you can't get to because of all the assumptions you have to make, tell us what's in the code, and tell us why it's valid.

This would have been a far more productive --

CHAIRMAN WALLIS: Well, I assume what's in the code is what's written down in the equation. Is there something different between the equations and the code?

DR. LANDRY: What's in the documentation can't be in the code, and that's not the way it has been derived.

CHAIRMAN WALLIS: Well, see, that's yet another mystery that I didn't raise in my questions, is what's actually in the code.

DR. LANDRY: And that's what I'm getting to, that tell us exactly what's in the code. Tell us what the terms are. Tell us what the terms mean, and tell us why it is valid.

CHAIRMAN WALLIS: Doesn't the code come with some kind of code documentation which says that these lines in the code formulate the momentum equation, and these lines have the momentum fluxes, these are how the terms are evaluated? I would think

that has to be, as just quality assurance in code documentation.

DR. LANDRY: Well, some codes are better than others at that. Some codes have a great deal of comment in them. Some do not.

CHAIRMAN WALLIS: Well, I think you should require enough comment so that you can read the code.

DR. KRESS: Do you do that with codes, go through line by line?

DR. LANDRY: No.

DR. KRESS: You normally don't do that, do you?

DR. LANDRY: No.

CHAIRMAN WALLIS: I do, when a student writes me something that purports to be the right way to do something. I mean, that's how I learned how to program a computer, was by figuring out what the students were doing.

DR. KRESS: What you generally have is this is the finite difference form of the equation that we coded in the codes. You usually have that documented.

DR. LANDRY: Right. That is in the manuals. We can say, okay, that's done right. We assume that they've gone from this to the code itself.

CHAIRMAN WALLIS: Because, well, if there are typos of the type we've seen in some of the documentation, there should be -- you would expect typos in the code, too.

DR. LANDRY: We've had this discussion before for years, and no, we don't go line by line in the code.

CHAIRMAN WALLIS: I think you should. At least, if you don't, you should threaten to, and you should perhaps do it from time to time in a small bit, bite sizes.

DR. LANDRY: I think our management would like to discuss resources.

CHAIRMAN WALLIS: Oh, don't give me that nonsense. If it's the right thing to do, it has to be done.

DR. LANDRY: Anyway, this is an example of how we've tried to interact and say what you should be doing to make this job right, and we just disagree with the approach that's been taken.

DR. SCHROCK; Code people have developed standard procedures for validating codes. They use different words to describe the different parts of the process. There are, in fact, codes available that will check that programming.

I never hear about those things having been applied in this arena, and I wonder why not. And it's not that it isn't known to industry.

I served on a review committee concerning the NPRs that went into this in great detail at General Atomic, and it was very clear that industrial representatives were on top of this. But it doesn't come here. Why is that?

DR. LANDRY: Well, there is almost a loss of corporate memory going on. This began -- and you were involved in it, if I remember right, Virgil -- back '78-'79, even before Paul was with the Subcommittee. I think Andy Bates was with the Subcommittee, and Milt Plessett was the Chairman then.

We've got into a long debate, and this began out in Idaho Falls at a meeting, a long debate over what do the terms validation, verification assessment mean, and after about six months finally arrived at definitions, which we started using as we went through the code development work for a number of years.

Now we are going back, and we have a new crop coming in, and we seem to have lost our understanding of what those terms meant.

CHAIRMAN WALLIS: One of those words means

that the code as written reflects equations as formulated. That's one of those words, verification.

DR. SCHROCK: That says that the equations you meant to program are, in fact, in the program.

DR. LANDRY: Validation says that, yes, it's performing the function it was intended to perform. An assessment is that the code is performing at this level overall.

DR. SCHROCK; But there are available recognized methods, computerized, to check that verification step. Have those ever been applied to a code like RETRAN?

DR. LANDRY: Not that I'm aware of.

MR. CARUSO: Dr. Schrock, this is Ralph Caruso from the staff. I think that's actually quite a good idea. I'm just going to give an observation.

It's my observation that -- I'm thinking back to some people that I know in Europe who used to work with RELAP, and I do believe that they tried to use one of these tools about ten years ago, and they were not successful.

I believe it had to do with the same reason -- same reasons that we have problems with compilers trying to optimize codes; and when you try to optimize some of these codes with those optimizers,

they don't work very well because of the way the codes are structured, because they were designed to run originally on very small memory machines, and people were very creative in how they did the coding. So that the logic checkers get confused. They don't understand what's going on.

DR. SCHROCK; I think what you are saying is it's a matter of getting caught up in obsolescence. The actual programming is so old that the modern techniques can't recognize what it's all about.

MR. CARUSO: I do believe I heard an argument about this similar to this about ten years ago, but one of the reasons I believe -- A lot of the people who are doing code development now are updating the codes. They are restructuring them. Research here is doing that with TRAC-G, so that it will be able to be maintained better and also to be optimized better and maybe even make it amenable to these logic checker programs.

I don't know if RETRAN-3D was restructured with that in mind, but that's certainly something that we would like to keep in mind in the future.

DR. ZUBER: Well, I think this will be a good field for Research to contribute. If the method is not available, a contribution to NRR would be to

develop such a method instead of doing some other things which are really irrelevant.

CHAIRMAN WALLIS: Let's move on.

(Slide change)

DR. LANDRY: Okay. Another area of our review, another topic we would like to bring up, was the critical flow model. Three critical flow models are included in RETRAN-3D: Extended Henry/Fauske; Moody; and Isoenthalpic Expansion/Homogeneous Equilibrium.

DR. SCHROCK: That one I pointed out in my report, that isoenthalpic expansion is a misnomer for what it actually does.

CHAIRMAN WALLIS: Let's just point out, Ralph, you had this set of slides before this Subcommittee before.

DR. LANDRY: Some of this, I may have.

CHAIRMAN WALLIS: So I don't want to go through it all again.

DR. LANDRY: Okay. These are points we brought out --

CHAIRMAN WALLIS: We would like to focus on --

DR. LANDRY: -- in the SER.

CHAIRMAN WALLIS: We would really like to

focus on what EPRI has as a response to our concerns, and we have had a discussion with you about this before.

DR. LANDRY: Did you want to cover at all the drift flux, Chexal-Lellouche?

(Slide change)

DR. LANDRY: Chexal-Lellouche is --

CHAIRMAN WALLIS: We didn't really get so far. You see, we got hung up by asking questions of EPRI to which they did not respond in our first encounter with them, and then I thought what we were trying to do today was to reach, if possible, some consensus on those matters.

DR. LANDRY: Okay. I was trying to just--

CHAIRMAN WALLIS: And you are helpful, but we have been through all this before with the Subcommittee, not quite the same membership, but you had a meeting with us a month ago or something where you went through this.

DR. LANDRY: Okay. I'll let the members just read through then. Basically, our conclusion is that overall Chexal-Lellouche is accurate, but the user must be careful and use it within the range of validity and for the proper fluid. You cannot use Chexal-Lellouche for air-water parameters for steam

water calculations.

DR. SCHROCK: What are they left to do if, in fact, they find that they are operating outside the database?

DR. LANDRY: Then they have to come up with a database or a different methodology.

CHAIRMAN WALLIS: That's one of your restrictions that you have.

DR. LANDRY: Right.

DR. ZUBER: I think, if this is correct, I think those equations are not applicable to this, and you should stick to it.

DR. LANDRY: Yes, that's what we've said, unless they can prove it.

(Slide change)

DR. LANDRY: Boron transport, I think we have already discussed, the technology --

CHAIRMAN WALLIS: The interesting thing with boron transport -- excuse me -- is that if you have a code that's validated in terms of peak clad temperature for LOCAs, then --

DR. LANDRY: This code can't be used for LOCA.

CHAIRMAN WALLIS: -- it can't be used just without any testing or validation or assessment for

boron transport. It's a different problem.

DR. LANDRY: And this code is not used for LOCA.

CHAIRMAN WALLIS: Right. Thank you.

(Slide change)

DR. LANDRY: Let's see. Neutron kinetics, we've gone through in great detail with you. We showed you our calculations. The only problem there is we felt a little rub would --

CHAIRMAN WALLIS: Did you want the ACRS to give as much attention to the neutron kinetics as it did to the momentum equation?

DR. LANDRY: No.

(Slide change)

DR. LANDRY: Code assessment: We had a lot of problems. We've pointed this out throughout the review, that the bulk of the assessment -- This gets back to what we were just talking about a few minutes ago. The bulk of the assessment is based on plant calculations performed by utilities. A lot of the figures don't include who did them, what code version they even used.

CHAIRMAN WALLIS: There are options in the code, aren't there?

DR. LANDRY: What options were used. So

that the assessment models do not explicitly -- approved in the SER will be either the responsibility of the licensee or the applicant.

The bottom line is each applicant of RETRAN-3D will have to submit a valid approach to assessment which we think should include a PIRT.

(Slide change)

DR. LANDRY: Code use: Code, as we've discussed a number of times, is highly dependent upon the user. We've pointed out throughout the discussion problems in use of the code.

DR. ZUBER: That really concerns me, because as time goes by people who have some experience and knowledge who are away, the memory is gone, and you have people who are not experienced working under pressure of being efficient and pushing the limits.

I think this is really a topic which NRC should really consider.

DR. LANDRY: That's why in our SER we've said that there has to be a statement, a certification of the ability, the training, the background, the experience of the analyst who has used the code, one that a submittal is sent in.

DR. ZUBER: That applies to NRC also.

DR. LANDRY: It's harder to regulate ourselves.

(Slide change)

DR. LANDRY: RETRAN-3D in a RETRAN-02 mode: I'd like to spend just a minute on this one. This was a topic that came up. I don't know if we've discussed this at length with the Subcommittee. But the request was made to approve use of RETRAN-3D as a RETRAN-02 substitute by utilities that have RETRAN-02.

We looked at this and said there are a number of areas where RETRAN-3D is an improvement over 02, improvements that cannot be backed out. Implicit numerical solution, time step lock improvements, improved water property tables are good, and these are improvements in the code to make the code more robust. We would not want to back off from those.

There are a number of items that we point out in the SER that can be used in using RETRAN-3D in an 02 mode, and there are a number of models which we point out, a number of options which the analyst cannot use, that they are not permitted to be used for RETRAN-3D as a RETRAN-02 substitute.

One of the big ones, again, is Chexal-Lellouche that we were just talking about a minute ago.

DR. SCHROCK: What is the 3-D neutronics? What's the reason for that one being excluded?

DR. LANDRY: Because 02 does not have 3-D neutronics. RETRAN-02 is point kinetics, and -- or 1-D, 1-D kinetics. There are significant differences between 3-D and 1-D kinetics, and we've said that you cannot use the 3-D kinetics.

DR. SCHROCK: Yes, I get it.

DR. LANDRY: The bottom line is that organizations that have been approved for using RETRAN-02 can use 3-D in an 02 mode without additional NRC approval, as long as they stay within the constraints of the SER. However, if they go outside of those constraints, they then have to have individual approval for use of 3-D.

This is quite a restriction, because this says that a utility, an entity who has not been approved for use of RETRAN-02 cannot come and say, okay, now we're using RETRAN-3D, but we're using it as RETRAN-02, is that okay. We are saying, no, it's not okay. You're not approved for use of RETRAN-02. How can you use 3-D in a substitute mode?

This case has come up, by the way, and we asked that utility an identical RAI: Enclosed are the 45 conditions on use on RETRAN-3d; show you compliance

with each and every one of them. When they get to this one, they can't.

(Slide change)

DR. LANDRY: Conditions on use: RETRAN-02 had 39 conditions on use. Ten of those still apply to RETRAN-3D. In addition, we have added six more which are rather restrictive.

DR. ZUBER: I thought you just mentioned 45 conditions.

DR. LANDRY: There are 45 total for conditions on use which we address in the SER.

DR. ZUBER: And on RETRAN-02 there were 39.

DR. LANDRY: Right.

DR. ZUBER: So this is not a progression. This is retrograding.

DR. LANDRY: Well, some of those 39 no longer apply.

CHAIRMAN WALLIS: Now when you've got these conditions on use, it seems to me that they have something to do with the importance of doing it right, to getting a valid answer for nuclear safety purposes; and if the problem with the momentum equation has an effect on nuclear safety, then one has a real justification for saying you've got to do something

about that.

I don't see how these conditions are tired in with some sort of leverage on the important question of nuclear safety, and you can put on conditions, but really you have to focus on those parts of the things you are nervous about or uncertain about or are not quite right somewhere and what effect they have on regulation and so on.

I get the impression that people have sort neglected the momentum equations in the past, because there's been some kind of corporate belief that it didn't matter anyway. That, seems to me, a very dangerous line to take.

So then it becomes -- You don't question it; you don't make a condition on it. You don't think about it. You've got to tie in -- If you're nervous about some term in the momentum equation, it would seem that when you are thinking ahead to realistic codes that someone then has to say, okay, suppose it's twice as big or something and suppose you're uncertain about how big this term is, what effect does it have? What leverage does it have on the kinds of answers we're likely to get in our code prediction?

That, I think, is going to happen in the future, isn't it? So the conditions -- I'm making a

speech, I suppose, but these conditions have to be related to the actual use to answer safety questions.

DR. LANDRY: Right. When individual applications come in, that needs to be addressed.

CHAIRMAN WALLIS: And those will be different, depending on the question. And if you come up with a new reactor design or some new concern like boron dilution or something --

DR. LANDRY: That's correct. It will be different for each application, each use of the code.

CHAIRMAN WALLIS: And you may actually find when you look at some of these applications that you need other kinds of conditions. That's the sensitivity of the answer to something you hadn't realized before.

DR. LANDRY: That's correct. Just because something has not been pointed out in this review does not mean in an individual application review an additional condition cannot surface.

CHAIRMAN WALLIS: Well, BWR, of course, is an interesting one, because as you upgrade the power, you may be pushing some of those envelopes.

DR. LANDRY: Right.

CHAIRMAN WALLIS: We haven't really studied that yet enough to know how important the

resurgence might be.

DR. LANDRY: That's right.

DR. ZUBER: Let me just make -- follow on what Graham said. What is missing from this approach, the NRC and the industry after 20 years or 25 years, really, they didn't establish really the importance of some factors or elements, when you can really neglect something and when you must take it into account and, if you don't have to take into account, you are justified to not use it, then you had a good -- to defend it. But then you have to address what is important, and this was really never done.

I think this could really improve the efficiency of a regulatory agency, and I think this is what research should do. This will also cut the cost of approval by the industry. I think this is a field which really -- and therefore, it should be done in this -- you know, that regulation.

DR. LANDRY: I think the attempt at a PIRT is an initial step at that, and I realize -- another concern that you've expressed before -- that we have to understand for individual events what are the overriding effects, what are the critical effects for a particular event, and which are unimportant, and are there certain effects taking place that mask

everything else happening. That hasn't been done.

CHAIRMAN WALLIS: That's what we call sort of concluding the loop. You put experts in the room. They give you the PIRT. That's just the first step, and you have to go through the whole questions of making sure that, if something is of high importance, that it's actually evaluated and someone checks. But, yes, indeed, you have a good enough evaluation to meet some criteria.

DR. LANDRY: Okay. We have pointed in the conditions on use also that anytime that an auxiliary calculation is performed, an auxiliary code, that there has to be an assessment showing that there is a consistency in going from RETRAN-3D to that auxiliary calculation, such as DNB.

As I said earlier, we have to have a statement on the user's experience and qualification with the code, and assessment of the code for models and correlations not specifically approved must be submitted by the licensee or the applicant.

(Slide change)

DR. LANDRY: Our conclusions in the SER are that RETRAN-3D is a significant advancement in the analysis tools base for licensees.

CHAIRMAN WALLIS: Did it significantly

advance the momentum equation? Well, we are here today because of the momentum equation.

DR. LANDRY: I know. No, I would go back to what I said earlier. The formulation that is given, the derivation that is given, in our view, should not be in there. It's much more productive to say --

DR. ZUBER: Let me say -- I mean, this is passing the word. What does it mean, it should not be there? If the derivation is incorrect, call it incorrect and call a spade a spade. It's irrelevant -- Well, you may take the -- but these equations are in the code. No, you cannot have it both ways.

DR. LANDRY: This is what I meant earlier. The code equations, the formulation that is in the code should be explained and why that formulation is correct, not the derivation that is given.

The code lacks sufficient assessment in places and places a burden on the applicants to justify the code use. Code used in the RETRAN-02 mode can be used in the RETRAN-02 mode, provided it's justified, and we have outlined what that takes.

One thing that the RETRAN Maintenance Group has done that we are very encouraged by and that we agree with very strongly is that a peer review

process has been put in place. We were told back in November that the RETRAN Maintenance Group has taken the step of -- It's not legislated to anybody using the code, but the members are encouraged to submit their material to their peer review process before it's submitted to the NRC.

This would alleviate a number of the staff concerns over user experience, over nodalization selection, over option selection, because the RETRAN Maintenance Group would look at this, the experienced people, and say, yes, this has been a valid approach that has been taken to the analysis. We feel that that is a very encouraging step.

We have said that Chexal-Lellouche drift flux model is an improvement, but it has to be used cautiously. You can't use it outside --

DR. SCHROCK: Why do you think it's an improvement?

DR. LANDRY: It seems to give good results for certain ranges of a void fraction. There are some ranges of void fraction where it does not.

DR. SCHROCK: And do you think it's not possible to do that with phenomenologically based correlations?

DR. LANDRY: Yes, it should be. But this

is a heavily supported correlation. It has a great deal of --

DR. SCHROCK: Well, it has a lot of politics behind it, but for you to make the statement that it's an improvement, an improvement compared to what and on what --

CHAIRMAN WALLIS: This is the model that uses a bubbly flow model to model annular flow?

DR. LANDRY: That's correct. But that -- And we point that that's not good.

DR. ZUBER: A droplet, a mist flow.

DR. LANDRY: Yes. We've pointed out in annular, an annular mist flow -- we pointed out in the SER that the correlation underpredicts.

DR. ZUBER: Okay. Now let me ask you. What about the type where you have the perforations? Is it there you have a void fraction maybe of .3 or .4, but do you consider this applicable or not? Let me help you. It would not be applicable.

The reason is -- I wrote a memo to -- my last memo to you to tell you why the thing is not applicable, not only for this equation but the other equations.

There are data in the literature which you could use and test your models, and the applicants,

especially Lellouche, never used it to my knowledge, and that equation has absolutely no physical meaning. It's a hodge podge of everything, and it cannot be applied -- -- cannot be applied to mist flow, to droplet flow.

CHAIRMAN WALLIS: It's a big recipe with quite a big database.

MR. STAUDEMEYER: This is Joe Staudemeyer, Reactor Systems Branch. The statement that it's an improvement is based on void fraction predictions in BWR channels, which is its biggest place of applicability.

If you look at the Chexal-Lellouche results compared to previous RETRAN correlations, it's much better at predicting void fraction in BWR channels.

DR. SCHROCK: So it is compared against the previous correlation in RETRAN. But other things are available that were not compared. So I think your statement is misleading.

DR. LANDRY: I think you have to read the whole text in the SER. I tried to condense the SER in these slides.

DR. SCHROCK: Well, I've read the SER, and I find it, frankly, to be very much more flattering to

the code than it deserves, despite the criticisms.

DR. ZUBER: And I agree with Virgil.

CHAIRMAN WALLIS: There seems to be two discussions going on today. One is with you, and one which we are going to get to with EPRI, which I think is going to be on a different plane altogether.

DR. SCHROCK; But this may be our only chance.

DR. LANDRY: We have also said that final acceptance of RETRAN-3D for licensing basis calculations depends on successful adherence to conditions and limitations on use discussed in the SER.

CHAIRMAN WALLIS: Now is this SER a final document?

DR. LANDRY: No SER can be final-final. At this point --

CHAIRMAN WALLIS: It's not labeled Draft.

DR. LANDRY: It's not labeled Draft. At this point we've given it --

CHAIRMAN WALLIS: So EPRI has it?

DR. LANDRY: EPRI has it.

CHAIRMAN WALLIS: And if the ACRS had some concerns about, let us say, the momentum equation, that might irrelevant of the regulatory process?

DR. LANDRY: No, it might be relevant, and if material comes out that necessitates a supplement or addendum to our SER, then we can write one. We're not restricted to this is the last word.

CHAIRMAN WALLIS: Well, I guess what concerns me is that I think we are going to find that our discussion with EPRI is somehow of a different nature than yours. We are going to go after where this equation comes from, what does this term mean, not common sense because all you have to do is bend the pipe this way and you get an absurd answer or something like that. That's the kind of thing we are going to do.

The process you've been through, it's not clear to me brings that sort of thing out. We seem to be doing something different here, and I'm not sure how the sort of thing we are going to be doing relates to the formal regulatory process of coming up with an SER.

Maybe we'll come back to you with that at the end of the day. Unless we've gained some time, I think you're through, Ralph. Thank you very much.

Should we move on? Can we move on with EPRI? I would like to say that we are here today because of concerns about formulation of momentum

equations, and really the sooner we can get to that, the better.

I'm not sure what EPRI has in mind, but last time we never got to it, and our advice, as much as we could get through in a short time with e-mails and so on, to EPRI was explain the responses to RAIs which resolve the questions which ACRS had and not go through a lot of stuff which we've already been through before about the code and industry and uses and things, which are not part of our discussion.

I'm not quite sure what you have in mind for this presentation.

MR. SWINDELHURST: My name is Greg Swindelhurst. I'm the Chairman of the RETRAN Maintenance Group, which is the group which are the main users of RETRAN, both domestically and internationally.

I'm going to give a very short presentation which does respond to some of the questions which came up during Ralph Landry's discussion, but we realize what you really want to get to, and we will get to that quickly.

(Slide change)

MR. SWINDELHURST: I will not repeat the items which the NRC has adequately covered, but there

are a few things which need some emphasis, and that is that we have worked for over two years with the NRC staff to go through their issues, their concerns, and those have been resolved.

I'm not saying that they have been resolved in a positive, successful way that everybody is happy with, but they have been resolved to the extent that perhaps things have happened like certain models have been withdrawn from review, because we realized they did not have an adequate validation basis.

We've resolved some things in the form of errors which have been identified, which have been corrected.

CHAIRMAN WALLIS: Now there are two code errors. That says code. That's not documentation. It's actually something in the code itself?

MR. SWINDELHURST: Right. I'm referring to two code errors.

Now there's also been numerous documentation problems which we are cleaning up and correcting. We've issued change pages to the NRC staff along the way, and that will all take place, and when we --

DR. SCHROCK: Can you tell me where I

could read about these two code errors?

MR. SWINDELHURST: I think Ralph already had them on his previous slide.

CHAIRMAN WALLIS: They are not responsive to the ACRS concerns.

MR. SWINDELHURST: Yes, they are.

CHAIRMAN WALLIS: Well, I don't think so, because as far as I can see, the new documentation is the same as the old. There is one thing which has to do with resolving something through an angle. Is that one of the ones you meant?

MR. SWINDELHURST: We will cover these in detail in a minute, but --

CHAIRMAN WALLIS: Okay, we'll get to those.

MR. SWINDELHURST: -- I think the staff and ourselves agree there have been two code errors that -- They are Fortran errors which have been corrected. There's been a lot of equation and --

CHAIRMAN WALLIS: If they were Fortran errors, that's fine.

(Slide change)

MR. SWINDELHURST: Okay. I would also like to point out, as Ralph mentioned, a lot of the issues remain to be addressed by the applicant

submitting in the future an application of this code.

DR. ZUBER: You are really confusing me. You said everything was resolved between EPRI and NRR. The problem is that we just heard that NRR said that RETRAN -- I mean the formulation is irrelevant, because it was incorrect. How did you want to answer that?

MR. SWINDELHURST: I think --

DR. ZUBER: That's not an error. This is the basic questions. Do you agree with that statement they make? If yes, why? If no, again why?

MR. SWINDELHURST: Okay. The review process results in the NRC asking us questions which we respond to, and then the SER is written with certain conditions and limitations on the use of the code. When I say that we've resolved it, what I mean is we've gone through that process, and we reached this point in the review where an SER has been issued, and we understand how we are permitted to use this code in the future.

Now a lot of the issues are carrying over to the applicant in the area of validation, licensing of new RETRAN-3D models, things of that sort.

DR. ZUBER: But wait. You are really dancing around the point, using this expression. if

the code -- If I understood Ralph, they detected some incorrect -- or errors in the formulation, and for this reason they said it's not applicable or irrelevant. Do you agree with that statement, yes or no?

MR. SWINDELHURST: We do not.

DR. ZUBER: Are you going to address it?

MR. SWINDELHURST: Yes.

DR. ZUBER: Today?

MR. SWINDELHURST: Yes.

DR. ZUBER: Okay.

MR. SWINDELHURST: We may not address it to your satisfaction, but we will address it. We think that these code equations are suitable for the intended use of this code.

DR. ZUBER: Again, suitable -- It's a very elastic word. It may be suitable for something and not suitable for others.

CHAIRMAN WALLIS: Can we get to it when we actually look at an equation and find out if it's suitable? I might point out that the ACRS has deliberately been a spectator. We are not involved in producing SERs. The staff does that.

We don't do the RAI process. So we've been spectators up to now, and now we're coming in

again and saying do we like what we see.

MR. STAUDEMEYER: We understand that, but we are also of the opinion that your comments have been heard by the NRC staff, and they have been forwarded to us through the RAI process, and that's the way that we respond to things. That's just -- That's nor NRR works.

CHAIRMAN WALLIS: Yes, that is the process. Right. I agree.

(Slide change)

MR. SWINDELHURST: I'm skipping one slide, because we've covered it adequately. On this slide I would like to just emphasize a couple of things, although Ralph has gone through this adequately.

We do have this RETRAN-02 mode. We do have any of the new models, not the RETRAN-02 mode. Maybe the validation hasn't been adequate. The future applicants are going to have to come in and justify that to the staff's satisfaction. We fully agree with that.

It's a fully acceptable way to move forward with the use of this code for licensing applications. This is nothing new, this third bullet here. Any organization using a code like a thermal-hydraulic is obligated to come explain to the NRC and

document and show that they are skilled and capable of using this code, and we fully agree that that process ought to continue in the future.

CHAIRMAN WALLIS: But it says here, "Organizations without NRC-approved models." So the implication you have is that the models in RETRAN have been approved and do not need to be reviewed again?

MR. SWINDELHURST: Some of the models have, and some of them have not. The ones which have not are called out in the conditions of the SER.

CHAIRMAN WALLIS: So if we look at -- So something like equation 2.3-4 -- this is a momentum equation or subsequent things -- Your impression is that NRC has given these derivations its blessing?

MR. SWINDELHURST: I would say NRC has given the use of this code, including those equations as they end up in the coding -- Yes.

CHAIRMAN WALLIS: And so, if an undergraduate student read this equation and submitted it to me in homework and I gave him a D, and he said, no, it's got NRC blessing, would that be a true statement by the student?

MR. SWINDELHURST: I guess that would depend on what his intended application of that equation was.

DR. ZUBER: Now let me say, you just remind me of something, the difference between science and technology and politics and law. In science and technology, the word is mean is technology is either correct or is incorrect, and what you are saying there, it depends how you end up with the thing.

MR. SWINDELHURST: Certainly.

DR. ZUBER: The question is not if it's wrong. Even for a junior, it cannot be fashionable.

MR. SWINDELHURST: Just as a simple example, you know, we are clearly stating that this code should not be used for doing large brick LOCA calculations. We agree to that, because these equations are not suitable for that application.

They may very well, and we maintain they are suitable for a lot of other applications where the phenomena are less complex and the event that you are simulating is less dynamic.

DR. ZUBER: The simplest example is the flow to a straight pipe, and what I keep seeing here in the memo which was sent by Lance Agee, I think, the error there is -- I mean, on the junior level.

MR. SWINDELHURST: Well, we'll cover that in the next --

CHAIRMAN WALLIS: I think your claim is

that, even if there should be errors, it doesn't matter for the applications you have in mind.

MR. SWINDELHURST: I don't think we would call them errors. I think they are approximations that are used to put the equations in a form they can be solved in a computer for this type of an application.

CHAIRMAN WALLIS: Well, that's interesting, because if you look at what happens in politics, our late President was accused of lying about something which many people may have considered to be minor, and then he did a lot of things which were valid policies. But half the political body in Washington seems to condemn him for this incorrect, invalid statement he made right up front. That somehow for them cast a shadow over everything else.

I think what you are saying is it doesn't matter, because for the purposes we have in mind, everything is okay. Is that your viewpoint?

MR. SWINDELHURST: We would claim it's not an error. It's the way the equation is being formulated for this application.

CHAIRMAN WALLIS: But if it were that these equations had errors in them which were of a really fundamental nature --

DR. SCHROCK: The problem I have is the presentation has this pretense of rigor. The errors are there, and then you emerge from that with a claim that these are approximations. They are never introduced as approximations. They are simply errors, sometimes even defended as not being errors.

Then the bottom line is that you say, well, the equations are okay, because they are, in fact, engineering approximations. But this has never been shown that they are satisfactory approximations, what is being approximated, that indeed the approximation is satisfactory for all applications that have been approved.

MR. SWINDELHURST: I think we understand the comment that the documentation hasn't met your needs, and we understand --

DR. ZUBER: The basic need of -- you expect from a junior.

CHAIRMAN WALLIS: Now you cannot write statements which just are not correct and get validity, really, it seems to me. It's very dangerous to make statements about momentum balances which just are not true and then to expect credibility in the rest of the document. That's where we are.

Now the NRC, it may be, operates in a

different way, but that's the puzzle we have anyway. So we're going to get to that.

MR. SWINDELHURST: We're going to get to that.

DR. ZUBER: Just one -- Think about intervenor going in front of television and showing your equations, and he is a professor somewhere. He says, look, I would have flunked a junior if he gave me this solution. Then you say NRC and industry license safety calculations based on these errors. What would this do to the industry?

MR. SWINDELHURST: We don't think we are in that situation.

DR. ZUBER: You may well be.

MR. SWINDELHURST: I understand, but --

DR. ZUBER: You may well be, and let me say you will be there.

CHAIRMAN WALLIS: But if you were there, it would be a serious matter, would it not be? That's what's baffled me about this whole thing, is that, you know, you've had two years to respond to what seem to me just very trivial things, and you come back with not really seeming to understand the issue.

We'll get to that, I'm sure, but I think you as a sort of manager, a responsible person, ought

to wonder about whether this matters and whether you can really go forward with the statements you are making when somebody, as Dr. Zuber said, could make those kind of claims against you. It is a sort of Achilles heel which I wouldn't want to have.

DR. ZUBER: This is going to kill this industry.

CHAIRMAN WALLIS: No, it isn't going to kill the industry. I mean, the last thing we want to do is kill the industry because of something so foolish.

DR. ZUBER: Foolish things kill big things.

CHAIRMAN WALLIS: Okay. Well, I guess we have to move on. I think we have to say something to you, because you are a responsible person, really. I don't know if the buck stops with you, but it stops with somebody.

MR. SWINDELHURST: I think you're right.

CHAIRMAN WALLIS: Does it stop with you?

MR. SWINDELHURST: It certainly does in terms of what we do --

CHAIRMAN WALLIS: The buck stops with you?

MR. SWINDELHURST: -- and my company doing this type of work. We have to be sure it's correct

and accurate for the intended purposes. There's no doubt. We're the licensee. The licensee is responsible.

DR. ZUBER: I also think it's the responsibility of NRR to accept or discard such an approach.

DR. KRESS: On your fourth point, before we take that, if there are things in RETRAN-3D that are -- we say are fundamentally wrong with the momentum equation, it's very likely that those are in RETRAN-02 also. Does that put into question the use of RETRAN-02?

If it puts in question the use of RETRAN-3D, would it also put into question use of RETRAN-02?

MR. SWINDELHURST: Most of what we are talking about is also applicable to RETRAN-02 and, when we find an error in the RETRAN-3D, we go backwards and see if the same error s in RETRAN-02. If it is, we get that fixed also.

DR. KRESS: And do you have to reapply for approval of that part -- those changes? Is there a change?

MR. SWINDELHURST: No. No, if there's an error correction, the NRC staff allows us to correct errors without re-review.

DR. KRESS: Okay. That probably answers my question.

(Slide change)

MR. SWINDELHURST: I would like to just bring in a topic which may not seem like it's directly applicable, but we believe it is.

As you are aware, the staff has issued this draft guide 1096 for comment within the industry. We are expecting that this will run through -- The comment process will be issued, and it will require more technical justification for future submittals of, you know, realistic or best estimate, whatever terminology you prefer, codes and applications in this thermal-hydraulics area. That's a fact, and that's perfectly okay.

As Ralph also mentioned, we think these requirements ought to be commensurate with the significance of the application. If the application is a relatively simple transient where the phenomena are mild and all of us would agree to that, then they should not be a lot of required validation testing, because there shouldn't be any concern of the need for that.

CHAIRMAN WALLIS: That is an awkward -- I essentially agree with that, but this is all done, I

think, in the public view, and you have to be sensitive to the view of the community, and that includes people like undergraduate students. If they read something in the document which their professor has just corrected as wrong in their homework, then that's going to demolish a lot of their faith in what's going on in this industry, isn't it?

I mean, it's not just a question of the requirements being commensurate with this, a game played between you and the NRC. At some level I think you have to be concerned with a wider audience. That's where, I think, you fall down here.

I agree that it may well be that, as I found with TMI, analyzing it myself, mass and energy balances is most of the story for most transients, and who cares about momentum equations. Well, if you can show that, that's great. But if you claim that you've got a derivation where the term so and so means something and the term something means something, and it doesn't mean something, then that cannot be excused, I think, just by making the statement in line 3 here.

I agree with line 3, but I think there is a wider audience out there. It includes your own engineers.

MR. SWINDELHURST: I realize that. I think we realize that there is a wider audience and that --

CHAIRMAN WALLIS: Industrial engineers and NRC staff and everybody.

MR. SWINDELHURST: I understand.

DR. ZUBER: See, underlining what Graham said is you are going for exactness. I mean responsibility. You have a good derivation, basic principles, etcetera, etcetera, and you come with something which is not so.

You could really simplify the problem which you can defend and be more efficient, and then if something cannot be applied, then you have to develop a rigor. What you have here is something, a mish-mash. I mean exactness or basic principles, which they are not and something, then which is very difficult to apply long running.

It's not really an efficient way to do this analysis.

CHAIRMAN WALLIS: But you could say that no one knows how to solve this problem. So we make the only thing we know how to do, which is to analyze it as a series of straight pipes, whatever it is, and then say, look, we've got some data that show that for

our purposes that's okay.

MR. SWINDELHURST: I think that's exactly what we're doing. Okay?

CHAIRMAN WALLIS: But it's this -- Well, we'll see when we get to it. Okay.

MR. SWINDELHURST: And we've never gotten into that in this discussion, is to what extent does it make a difference? To what extent do you get acceptable answers at the end of this? That's where we are, and we've been there for 20 years using this code in that way.

Okay. The last item here I just want to mention is, you know, we did talk a lot about best estimate/realistic, and that's kind of the looking forward way of doing licensing type analyses perhaps, but we've still got this traditional conservative way which is the way things are done now, and we need to -- the industry needs to make certain that that option is still recognized as being a valid and useful way to continue to do this work in the future.

DR. SCHROCK: That is a problem, I think. Seems to me that industry should want to get away from that crutch in the long term. I don't understand why you have this strong desire to preserve it.

In the shorter term you don't want to go

through required relicensing processes to continue to qualify operating plants. That's understandable. But you should expect a normal transition, and that normal transition might even be as long as 20 years. I don't know. But you should at some point in the future stand up and say, yeah, we're proud of the fact that we began an industry which was based on pretty shaky engineering calculations. We did it very conservatively. We went through a transition in which we believe we have better calculations, and we can, therefore, up-rate the power on our plants. But indefinitely into the future, we demand the right to license power plants according to 1971 technology. That's stupid.

MR. SWINDELHURST: I think that the evolution you are talking about probably is going to occur. You know, it may take 20 years. Who knows? But --

DR. SCHROCK: It won't occur in 20 years the way we are moving.

MR. SWINDELHURST: Well, this is rather new, though, this transition to realistic or best estimate.

DR. SCHROCK: No, it goes back 13 years. What do you mean, it's new?

MR. SWINDELHURST: For the non-LOCA stuff, it's relatively new, and the reason, in my opinion, that it hasn't been moving that way faster is because there hasn't been a need to do it.

As you mentioned, with up-ratings or other things that come along, there may, in fact, be a need to do it, and then it will be forced through another action.

DR. ZUBER: And if you wait for 20 years, you won't have this industry.

CHAIRMAN WALLIS: Well, it's coming back.

DR. ZUBER: Not following this work. This will kill it.

(Slide change)

MR. SWINDELHURST: Okay. Just a few more comments here.

The NRC has mentioned, as Ralph has, that there's a concern of an absence of user guidelines. We don't share that perspective. We think there's adequate documentation and understanding within organizations as to what it takes to use a code like this to build models, to submit topic reports to the NRC to get approval to do this type of licensing work, and we do not share their opinion that there's an absence of information available to do this.

CHAIRMAN WALLIS: Well, I'm not a user, but I must say, when I looked at your RAI reply, which we are going to get to about how you model, say, the lower plenum, I hadn't a clue what was going on and how anything you told me there related to what I would stick into your momentum equation in order to have a formulation.

So I struggled. I had sleepless nights, and I still couldn't figure out what was going on. So at least this user didn't understand how to use the code for a geometry other than the very simple ones showed in your examples.

MR. SWINDELHURST: We will have to work on that then, and we are prepared to talk about that as necessary.

There has also been expressed concern about inexperienced users or maybe even experienced users misusing this code. That's true of any code. You've got to have code experience. You've got to know what you're doing.

This is a highly technical code. Ralph has mentioned that there's a lot of options and a lot of different ways users can model a plant, model a particular analysis. That's one of the reasons why, just because we are not starting this, we're not

embarking on a new program here -- this is 20 years of organizations using codes like this -- it's very difficult to retool and standardize and do everything the same way.

There's lots of different plant designs out there, and different organizations do things different ways. And because of that and because the organizations are not choosing to retool and start all over with standard methods, it is necessary for us to get to this step, which may not be desirable and may not be efficient, of individual organizations needing to validate, assess their models independently.

There's really no other choice on this point. That's where we are, and that's what we are going to have to do, and we accept that.

Ralph mentioned peer review. This is a brand new thing. We've been waiting for the SER to come out so we could start communicating this. We think it's a good thing. We have unanimous support within the RETRAN user group that this is something people ought to consider doing.

Then again, it's still optional, and we will definitely encourage people, especially new users, to make use of this. It makes sense, and especially with the incentive from Reactor Systems

Branch that this is something they would think is worthwhile. It would be good for an applicant to do it in terms of their future deliberations with the NRC staff.

CHAIRMAN WALLIS: I would hope that some of those peers are like some of the people you see on this side of the table today who have come with a sort of basis of knowledge but not -- they're not so tied up with the code, they have anything at stake in it or anything, and they don't know the history. So they can ask the questions which maybe haven't been asked before and things like that.

MR. SWINDELHURST: Okay. We really have attempted to answer your questions, and the questions we've attempted to answer is what we see in the RAIs. We are certainly going to try to answer your questions today.

We also realize that it's very likely we will not be able to reach an agreement that we are all happy with in terms of your questions being --

CHAIRMAN WALLIS: I was going to ask you what you hoped would come out of this meeting today. What's your expected result?

MR. SWINDELHURST: I was hoping that we would be able to answer your questions maybe better

than we have in the past, and maybe to characterize our perspective that the equations are suitable for the intended purposes.

Yes, there's approximations that need to be made along the way. There's engineering judgments that need to be made along the way. But the end result of that in terms of using this code for the types of analyses we do with this code, non-LOCA analyses, that it's a suitable framework for doing these analyses.

CHAIRMAN WALLIS: If we were -- You know, we are all competent professional technical people, and these are relatively straightforward matters. It would seem that you ought to be open for a consensus.

MR. SWINDELHURST: I think that's a nice thing to hope for, but I would say, based on where we are, we're not really expecting that.

DR. ZUBER: You are here where you were two years ago, the same position. Reading this memo from Agee, I didn't see much difference of what we saw two years ago.

CHAIRMAN WALLIS: So what's happened? You have helped us -- You helped me. You've been more explicit about some of the things in your documentation. That helps me to know what it is you

are saying, but not perhaps to understand why you are saying it; because the basic problems seem to be still the same.

You've clarified. So I think there's better information. But that may just reinforce our areas of disagreement.

MR. SWINDELHURST: That may be true.

CHAIRMAN WALLIS: We'll see about that later.

MR. SWINDELHURST: But we'll give it a try, and we'll see how it works.

CHAIRMAN WALLIS: For all of our sakes, the best thing that could come out of here today would be all agreed that, yes, this written down is a good momentum equation. The way it's resolved is fine, and so on and so on and so on, check off these things, and say let's go home and open a bottle of champagne or something.

MR. SWINDELHURST: Just for example, let's say somebody is not happy unless it's a three-dimensional code, and I don't mean 3-D neutronics. I mean the whole code, the whole thing is three-dimensional.

If that's somebody's expectations of what's necessary here, then certainly we are not going

to get there.

CHAIRMAN WALLIS: No. My level of review is the same -- I got to put it bluntly -- is the same as the level of review I would give to an undergraduate homework in flow mechanics. And if we can't agree on that, I'm astonished and flabbergasted and bamboozled and vexed and -- you know, I could go on for a whole torrent. It's very strange.

DR. ZUBER: Okay. Graham, you gave us the most optimistic, desirable solution. The other one is for the industry to admit, yes, there is an error. We are aware. We didn't correct it for two years, but we shall now evaluate case by case the effect and do sensitivity analysis, and then give us how you are going to do it.

Then let me guess it's wrong. What you really want is to smother something which doesn't smell too good and use all these elastic words. I think this is not good for the industry at all, and for a regulatory agency.

CHAIRMAN WALLIS: Well, it may be or may not be. Got to be careful what words we use.

DR. ZUBER: For me or they?

CHAIRMAN WALLIS: Well, they have to be careful, too. Maybe you don't have to be careful.

DR. SCHROCK; In my mind, the operative word here is formally. You've formally addressed ACRS concerns, but you've not addressed ACRS concerns in spirit. You've dealt with the regulatory process in a way that you perceive as meeting the requirements of the regulatory process, but you've not had deep concern about the technical issues which have been raised here.

MR. SWINDELHURST: I think we've had deep reflection on all the technical issues raised here, and we've gone back and considered each one.

DR. SCHROCK: For one, I don't see that you have.

CHAIRMAN WALLIS: Well, this is going to be embarrassing, because I mean, if we get someone up there and we look at this equation and the claim that say the pressure drop is balanced by the frictional forces when all the other terms are out of this momentum equation, well, that isn't true.

We can pull the whole thing apart, and we can look at all these statements. That's going to be very embarrassing to go through. Are we going to go through that sort of thing?

MR. SWINDELHURST: To the extent you want to go through it, I believe we will go through it.

CHAIRMAN WALLIS: Well, if you don't resolve it, I guess we are going to be under some obligation to write our opinion.

MR. SWINDELHURST: That's right, and --

CHAIRMAN WALLIS: And if there's no response from you that helps to clarify things, it's going to be the opinion we get from reading the documentation, which is the same -- at least from my point of view, the same opinion I had before. And in a way, it's reinforced, because the strange features are now clearer.

MR. SWINDELHURST: Well, let's give it a chance, and maybe there will be some --

CHAIRMAN WALLIS: Well, I'm giving you a chance. You know, I'd love to feel that I was wrong and discover that I was wrong.

DR. ZUBER: I'd like to have a bottle of champagne.

MR. SWINDELHURST: We believe that your concerns are generally generic to other codes like this code, and I believe you've shared that opinion.

CHAIRMAN WALLIS: That is -- Yes, that is a niggling thing, isn't it? That's true.

DR. SCHROCK: It's true, but it doesn't help RETRAN-3D.

CHAIRMAN WALLIS: No, it doesn't help.

MR. SWINDELHURST: I'm not saying -- I'm just saying that this is the way the industry uses codes like this, and not all codes do things this way, but a lot do.

DR. ZUBER: You see, but the difference is you are addressing problems which we had 30 years ago, 25 years ago. Now you get into the edge of the regulations, and again has changed. The environment has changed, and you cannot use the same argument -- alibi, one used 20 years ago when you hear much of conservatism, which are now going to decrease and, therefore, all these codes which were applicable for a previous era are not good for a time and era which is coming now.

MR. SWINDELHURST: I agree with you. When you start decreasing the conservatisms, the importance of accurate modeling becomes even more--

DR. ZUBER: Even more so. Even more so.

CHAIRMAN WALLIS: Go ahead.

DR. ZUBER: One was able to live under those -- with these errors, because we had a large conservatism, which we didn't have to have, had we done it correctly. Now when we want to decrease it, we have to do it correctly. I think this is the

problem which neither the industry nor NRR, NRC, has addressed, as far as I have seen today.

MR. SWINDELHURST: Well, I think we're seeing that in the draft guide that came out. That's exactly what it's speaking to, and we recognize that.

DR. ZUBER: But I don't see this reflected in the code developments and code analysis. That's my problem.

CHAIRMAN WALLIS: I'd like to say something in praise of EPRI. You do realize that there are generically applicable difficulties, particularly with the momentum equations in codes. I think EPRI realizes that or your contractors do.

So an effort was made to provide different justifications, and I think that's praiseworthy. It's good. It's just that we have some difficulties with what you have now done. I think it's good that you've faced up to the fact there was a problem there.

MR. SWINDELHURST: Well, we certainly got concerns we have to respond to, and we're trying to do that, and I think a lot of it --

CHAIRMAN WALLIS: No. I mean you faced up to a problem that probably is generic in a whole batch of codes and tried to better than they have. I think that's a good thing to try to do.

(Slide change)

MR. SWINDELHURST: Okay. We have -- EPRI has had an independent derivation of the RETRAN momentum equation, as it's been labeled, by Dr. Thomas Porsching. He is with us here today.

CHAIRMAN WALLIS: If someone will explain that to me, because the equation I saw Dr. Porsching derive is not the same as the RETRAN momentum equation.

MR. SWINDELHURST: We'll be prepared to speak about that.

CHAIRMAN WALLIS: Okay.

DR. SCHROCK: But you also have the fact that NRR has said that it's irrelevant to the issues that it's examined. So what's the purpose of the bullet on this slide?

MR. SWINDELHURST: Well, obviously, we don't agree with that. So I guess we would like to take an opportunity today to have our side of that story.

We would like to clearly point out that we are calling it a momentum equation. It's sort of a perhaps mislabeling of this equation, and we just want to admit up front that we recognize that. It's more directly a flow equation.

CHAIRMAN WALLIS: But you call it a momentum equation, and all your derivations say it's based on some general microscopic momentum balance. And I agree. It does look more like a flow equation, but that's not the claim that's made in any of your documentation.

DR. ZUBER: Let me say, I have a problem. I mean, I know momentum mass energy. I never knew a flow equation. What is that?

MR. SWINDELHURST: We will cover that in the next --

DR. ZUBER: Well, no. What you are really doing -- Are you developing new physics or what?

MR. SWINDELHURST: I think the reason we are making this acknowledgment, which we've made in the past, is that momentum equation means a very specific thing.

DR. ZUBER: Momentum.

MR. SWINDELHURST: And the way it's used to term the equation in this code and the derivation of it is somewhat loose with that terminology.

CHAIRMAN WALLIS: So we are going to get into that after the break, I guess.

MR. SWINDELHURST: Correct.

(Slide change)

MR. SWINDELHURST: Just repeating one thing. You know, we believe that this equation is suitable for this application. The whole code, the use of the code, all the features is up to the user to defend it. He has to deal with the SER we have, the conditions and limitations we have.

If more assessment work is done as requested by the staff, that is the logical, normal next step in the process when trying to use this code for an application. We accept all that.

CHAIRMAN WALLIS: And he has to be able to figure out how to use it, too.

MR. SWINDELHURST: Certainly.

CHAIRMAN WALLIS: So that's sort of my second question. First question is: Are the methods valid? What are they, and are they valid? The second one is: How do you use it? That's another question.

MR. SWINDELHURST: And this is the way it's always been. It's always --

CHAIRMAN WALLIS: If it's not clear how to use it, then you can't very well make it the responsibility of the user.

MR. SWINDELHURST: We don't believe we have that problem with documentation.

CHAIRMAN WALLIS: It's like driving a car

where steering wheel isn't connected to the front end. It's rather awkward to ask the user to be responsible or that.

DR. POWERS: In fairness, Graham, I mean, don't they have several hundred users of this code, and it's been used by a lot of people?

CHAIRMAN WALLIS: Apparently.

MR. SWINDELHURST: Tens of users.

DR. POWERS: Tens of users, okay.

CHAIRMAN WALLIS: Okay. So you're going to explain to us how the equation applies to, say, that plenum model and --

MR. SWINDELHURST: Certainly.

CHAIRMAN WALLIS: Okay. Thank you.

MR. SWINDELHURST: And just the last point: When we shift in the future to the best estimate/realistic, we realize that's a different world, and there will be different rules we'll be playing by when we are doing best estimate plus uncertainty type analyses.

CHAIRMAN WALLIS: I go back to Dr. Powers' point, though, and it may be that a lot of people are using this thing. But how are they using it, if it's not clear how to use it? Maybe you can explain that to us. But if it isn't clear, if our view is that it

isn't clear, and you can't tell me how to explain it, then it's baffling.

MR. SWINDELHURST: I think the explanation is that there has been hundreds and hundreds of people who have learned how to use this code in various organizations, and they learn it from the documentation. They learn it from training sessions. They learn it from mentoring, from people who have gone before them.

When they need help, they go to the vendor, and it's a community of code users who -- just like any other code.

CHAIRMAN WALLIS: So you are going to essentially tell us. We're going to come in as naive code users and say we can't figure out how to evaluate the momentum flux at this end of this box, and --

DR. POWERS: I am not sure that that's the right standard to apply. I guess that's what I'm driving at, is that at least in a lot of the codes that I get associated with, they aren't this mature, and the documentation is spotty at best. But they become -- The codes get internationally used because of this -- what you call it -- mentoring or training sessions or group exercises calculating individual problems, that there is a tremendous -- Like many

engineering disciplines, there's a great deal of oral lore associated with how to use and how not to use the code.

So I think I don't see a need to come in and say is this documentation such that, if I am an obstinate and recalcitrant user, I can find flaws in its explanations and dream up examples that are where it's just not going to work following this.

I mean, I think that's an unfair standard to apply to this. I think you have to have a much more liberal standard applying to the logic, because there is so much of this, and that's not unusual. I mean, all the codes I'm associated with are that.

DR. ZUBER: This is my problem I always had with code users and the documentation. Really, they don't really look what's in the document. They don't understand, and very often they just put it on the computer and then run it and fiddle around.

I think then they show good agreement with some experiments by adjusting some coefficients without really acquiring -- I mean inquiring is it applicable, can I use it, when can I not use it. I think this is my problem, one of the problems with this code.

MR. SWINDELHURST: Let me just give an

example of that as how a user would use this code. First you have to go to your plant model. Okay? You've looked at other people's plant models. You know what they did. You look at your plant design. You adopt the good ideas, and you have to do some initial -- some new type of work.

You go to your plant model. You go through the code manuals. You select every option in the code based on what other options are recommended, what other people are using, what works best to invoke the right equations, right options, right correlations.

You build all your model. Then you have to validate it against something, and we do usually use plant data. A lot of work is done by the code developer and by some contractors looking at, you know, scale data.

We use plant data, and then you have to go play this all in front of the NRC in the form of a submittal saying this is how we use this code, all these options turned on. And if we do some knob turning or some dialing in on something, that is laid out as part of the submittal: We adjusted this parameter, because it didn't match plant response. And that's part of your modeling. Okay?

CHAIRMAN WALLIS: But in setting up this model, someone has to look at this noding and say here's some W's defined here and here, and they have to be somehow put into a structure which then the equation uses.

Maybe you can help us later on to explain how various W's are related to what's in the equation when someone is actually doing the noding and so on. That would help us a lot.

MR. SWINDELHURST: But these activities have been routinely done by many, many people, and it isn't as big a mystery as --

CHAIRMAN WALLIS: Well, many people followed Hitler. I mean, there's no excuse because many people did something that it's all right.

DR. ZUBER: That's a problem, really.

CHAIRMAN WALLIS: That's the sort of naive attitude we have, being outsiders to this business.

Are we going to get to see Dr. Paulsen after the break?

MR. SWINDELHURST: Yes. We've got Dr. Paulsen coming up next. He's got a presentation, plus he's prepared to answer anything you want to ask. We've got Dr. Thomas Porsching here to discuss his development, if you have any interest in that. Jack

Haugh is here as EPRI management.

CHAIRMAN WALLIS: Good. That will be very helpful.

I think what we would like to do is we would like to look at only two or three equations and their derivation and understand it, and also understand how it's related to some of those weird shaped nodes. Maybe that's all we need to know. So it shouldn't take very long.

MR. SWINDELHURST: I think we're perfectly willing to follow your lead as to what you want to hear.

CHAIRMAN WALLIS: That would be great, and it would sort of follow what you send as a response to the RAIs. So we've had a chance to look at all this before. We're pretty well prepared. It's not as if you had to explain everything.

So perhaps we can get most of that or all of it done this morning. Good, thank you. So we'll take a break until quarter of eleven -- Sorry, before I use this gavel, it's going to a break, 15 minutes until 10:30.

(Whereupon, the foregoing matter went off the record at 10:15 a.m. and went back on the record at 10:30 a.m.)

CHAIRMAN WALLIS: We are now going to hear a presentation from Mark Paulsen.

MR. BOEHNERT: Mark, I'm assuming this is going to be open. There is no proprietary information here?

DR. PAULSEN: This is open, yes.

What we hope to cover today is to address some of the concerns that have been raised about the momentum equation, the formulation of the momentum equation, address also some of the issues relative to how we apply the RETRAN equations to complex geometry. What do the users have to do when they want to model a three-dimensional plant using these simplified equations?

DR. KRESS: Can you orient me as to what CSA is and how you fit into the --

DR. PAULSEN: CSA -- We are a consulting firm that is the developer -- We have been involved in the development of RETRAN. We also do the maintenance portion of the work for RETRAN, and we provide user support and training.

DR. ZUBER: Where are you located?

DR. PAULSEN: We are located in Idaho Falls.

CHAIRMAN WALLIS: Now RETRAN actually

appeared about 20 years ago.

DR. PAULSEN: RETRAN actually began probably in about the late Seventies.

CHAIRMAN WALLIS: There was a report from whatever the embodiment then was of Idaho Falls.

DR. PAULSEN: Yes. It began at Energy Incorporated. It was a spin-off from the RELAP-4 code, and it was designed specifically to provide utilities a tool to analyze Chapter 15 transients, because at that point in time utilities were relying solely upon industry.

CHAIRMAN WALLIS: I think what we found in the original documentation that you submitted with RETRAN in 1998 was almost exactly the same as EG&G or whoever they were had submitted in their report in 1980. Very, very similar.

DR. PAULSEN: For which one now?

CHAIRMAN WALLIS: The documentation we first read two years ago, two and a half years ago.

DR. PAULSEN: Oh, okay, the original RETRAN.

CHAIRMAN WALLIS: Was exactly the same for RETRAN as in the report that is now 20 years old from Idaho Falls.

DR. PAULSEN: Yes. It was an EI report.

CHAIRMAN WALLIS: Right.

DR. PAULSEN: That's right. Okay.

DR. ZUBER: This shows the genetic relation.

CHAIRMAN WALLIS: Yes, of the genes.

DR. SCHROCK: Let's see. You are going to clarify Mr. Swindelhurst's comment about the vagary of the terminology momentum equation and flow equation?

DR. PAULSEN: I hope to.

DR. SCHROCK: Good. Okay.

DR. PAULSEN: And the approach I have taken was I went back and looked at some of the concerns that have been raised in the previous ACRS meetings and looked at the RAIs that we had been issued by the staff and tried to put together a cohesive story that starts at the top and goes to the bottom.

So I'm not following the order of the RAI questions. I'm trying to start at the top and make a cohesive story. Now if you have questions as we go, I'm sure you're not bashful, and you will ask questions.

So we may not even get to the RAI question, if we can get things resolved up at the top.

DR. SCHROCK: Does the 2 mean a second

round of questions?

DR. PAULSEN: That's correct. This round of questions dealt primarily with the staff's trying to direct -- or to relay the ACRS concerns about the momentum equation. So there's a lot of overlap in these RAI2 questions with what the ACRS concerns were on the momentum equation.

Most of the concern has arisen on how we use the one-dimensional momentum equation. We start with a 1-D equation, and then we develop what we use as our flow equation, and we are going to try and talk about that, point out the definitions and some of the assumptions we make.

So while we are doing this, we hope we can address your concerns. I hope you don't get the feeling that we've been trying to avoid your concerns for two years. We have actively been trying to resolve them.

CHAIRMAN WALLIS: We have no feelings at all.

DR. PAULSEN: Okay. What this has led to is the fact that we have -- In responding to the request for additional information, we have attempted to make the documentation more usable, more accurate, and we have also identified several code errors which

we'll talk about, and we have corrected them.

(Slide change)

DR. PAULSEN: So as we go through the development of the RETRAN-3D flow equation, first of all, I'm going to start with some general comments to try and point out where we are going with all of this, so that we don't put equations down on the board before we actually know where we are trying to go, and maybe that will help clarify things.

Then we also want to list, as many as possible anyway, our definitions in the assumptions that we make. We will then go through the case where we actually start with a constant area channel, start with the momentum equation, and derive our flow equation, and then go through later how we apply that to variable area channels and then for situations where we may have more connections than just a simple straight piece of pipe --

CHAIRMAN WALLIS: Now your constant area channel you are going to show us is that bend to --

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: That originally had a variable area, because in the first document we saw it had an AEK and an AK plus one, which was different.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And now it seems to have fallen back to being constant area.

DR. PAULSEN: For this initial development --

CHAIRMAN WALLIS: Then it fell back to a more special case?

DR. PAULSEN: This is a constant area.

CHAIRMAN WALLIS: Later it gets generalized.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: To be a variable area?

DR. PAULSEN: That's right, and it's really with the abrupt area change --

CHAIRMAN WALLIS: Without an area change at all, just a tube with different areas on the end. Are you going to list that one?

DR. PAULSEN: Basically, we'll go through three developments, one where we start with a constant area. Then we'll go to one where there is an abrupt area change --

CHAIRMAN WALLIS: Why abrupt? In a variable area it doesn't have to be abrupt. I'm just pointing out that in the original documentation what you now have as a constant area channel was a variable area channel.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: And for some reason it's fallen back, maybe --

DR. PAULSEN: Because in -- There was a lot of confusion about those figures that led to -- and really, that figure was used to develop a constant area equation.

CHAIRMAN WALLIS: But if your equation is right, it should apply to a variable area channel without a sudden change of area.

DR. PAULSEN: Well, we'll talk about that as we go. Okay?

Then we are going to look at complex geometries on how we actually apply these One-D equations, what kind of assumptions do users have to make, what are some of the sensitivities, and how do they apply them? Where do you break a model up to start applying these equations?

We will also identify where some of this guidance is available for users. There is actually documentation available that directs users on how to do some of this nodalization.

(Slide change)

CHAIRMAN WALLIS: What does this first statement mean?

DR. PAULSEN: That it's fundamentally one-dimensional.

CHAIRMAN WALLIS: What does it mean? What do you mean by that? I want to see what he says it means.

DR. PAULSEN: We are starting with a one-D momentum equation.

CHAIRMAN WALLIS: What does that mean?

DR. PAULSEN: We are not going to account for any momentum in the transverse direction.

CHAIRMAN WALLIS: So you mean it's a momentum equation resolved in one direction?

DR. PAULSEN: In one direction. That's correct.

CHAIRMAN WALLIS: So when I -- I want to be clear about this. I don't want to criticize something which is different.

You are saying this is the resolution of momentum fluxes, forces of momentum changes in one direction?

DR. PAULSEN: Yes, and we'll see --

CHAIRMAN WALLIS: And when you get to a bend, you are going to explain how a bend can be one-dimensional and things like that?

DR. PAULSEN: We'll talk about that.

CHAIRMAN WALLIS: Okay. I just want to be clear.

DR. SHACK: You're saying more, though, right? You're saying the flows are all one-dimensional, too. There are no transverse flows --

DR. PAULSEN: That's true. That's true.

CHAIRMAN WALLIS: Your averaging works in a one-dimensional sense?

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: Right.

DR. ZUBER: What do you mean by flow equation?

DR. PAULSEN: An equation of motion.

DR. ZUBER: You conserve three things in thermal-hydraulics. It's momentum, energy and mass. You don't conserve the flow. If this is the conservation equation, then it's the momentum equation.

You see, this kind of elastic --

CHAIRMAN WALLIS: Well, I think -- Let's clarify. What you are going to do is you are going to manipulate this momentum equation resolved in one direction in some way until it looks like something else, which isn't quite recognizable as a momentum equation --

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: -- and you call that a flow equation. Is that what you're doing?

DR. PAULSEN: That's correct.

DR. ZUBER: Am I correct to understand that, even up in your new conservation equation --

CHAIRMAN WALLIS: No. They are going to do some manipulation to get something which isn't immediately recognizable as a momentum equation but came from the momentum equation. That's what I understand you are going to show us.

DR. PAULSEN: That is correct.

DR. ZUBER: They may write new textbooks.

DR. PAULSEN: Okay. I think one of the areas where we've probably introduced some confusion in the past was, as pointed out, maybe trying to be too rigorous with the implication that there was more fundamental physics behind the code than really there is.

We are not really trying to do anything in three dimensions. There's a lot of development where we've emphasized the vector momentum equation. Really, it's a scalar equation, but we carry some vector information along. We'll show the purpose of that in a few minutes.

CHAIRMAN WALLIS: But you have an example which is a 90-degree bend.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: And that isn't in your list here, is it, but it's an example in your --

DR. PAULSEN: Places where we really recommend -- where we would recommend angle information be used.

CHAIRMAN WALLIS: Yes, but you are showing how to use it for a 90-degree bend in your documentation.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So I think we ought to look at that example.

DR. PAULSEN: And I have an example -- I have some discussion of 90-degree bends and what level of detail you go into when you are modeling.

Basically, by carrying some of this angle information along, you can get a more correct representation of the momentum flux in some of these areas where you've got multi-dimensional pieces coming together.

Where we really don't recommend using -- We're not trying to use angles to represent three-dimensional flow patterns in downcomers or lower

plenums. We admit that right up front. And in most models -- One of the examples we gave was the elbow which Dr. Wallis pointed out. That was simply supposed to be there to represent the effects of the angles.

We don't recommend users model individual elbows. In practice, users are going to lump straight sections of pipe and elbows into one section.

CHAIRMAN WALLIS: But you have an example in your first response to the RAIs where you have the cold leg and the downcomer. There's a node that spans both of them. That looks awfully like an elbow to me.

DR. PAULSEN: And we'll talk about that. There's an example that --

CHAIRMAN WALLIS: I think we need to talk about that.

DR. PAULSEN: Yes. Then we don't use the angle information to simulate every turn in the piping sections.

CHAIRMAN WALLIS: You do not?

DR. PAULSEN: We do not.

DR. SCHROCK: What do you do to simulate?

DR. PAULSEN: Pardon me?

DR. SCHROCK: What do you do to simulate the turns in the piping?

DR. PAULSEN: Those we generally account for with loss coefficients.

CHAIRMAN WALLIS: Your claim in one of your documents is that the friction on the wall is balanced by the pressure drop in that situation.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And that that comes from a momentum equation?

DR. PAULSEN: Basically, I think when we get through our momentum -- I keep wanting to call it momentum equation. Pardon me. It's years of incorrect training.

CHAIRMAN WALLIS: But you told us where it comes from. It's your principle you're using.

DR. PAULSEN: That's right, and I'll probably be calling it the momentum equation, but what we are referring to is the One-D or the scalar equation is what we actually get to.

CHAIRMAN WALLIS: Well, I guess we'll get to that, but your claim is that the momentum -- the overall momentum balance simply have a bend in the pipe with no momentum change and stuff that goes around. Frictional forces are balanced by the pressure drop in the momentum balance.

DR. PAULSEN: What we end up --

CHAIRMAN WALLIS: That's not -- I need to question you about that, because I don't think that's correct.

DR. PAULSEN: Because basically, what we end up with when we get our equation, if we drop the time derivative term and we look at just the terms on the righthand side of the equation, it looks like the mechanical energy equation.

CHAIRMAN WALLIS: No, it doesn't.

DR. PAULSEN: It's very similar. We have the Bernoulli terms --

DR. ZUBER: Wait, wait, wait, wait, wait. Do you know how the Bernoulli equation is derived?

DR. PAULSEN: Yes. Bernoulli -- It's a mechanical energy equation.

DR. ZUBER: Okay. How do you derive the Bernoulli equation?

DR. PAULSEN: Well, I don't think that really is relevant here, because --

DR. ZUBER: No, it is.

DR. PAULSEN: -- we're talking about the momentum equation.

DR. ZUBER: No, exactly, because you said that, when you drop the storage terms, the equations are like the energy equations. Then you brought in

the Bernoulli equations. Graham said no. I said no. You tell me -- I'm questioning you how are you deriving the Bernoulli equation?

DR. PAULSEN: Well, let's wait until we see what the equations are.

CHAIRMAN WALLIS: I'd like to see it, Novak. I'd like to see the equations.

DR. PAULSEN: Let's look at the equations first.

DR. ZUBER: He does not know --

CHAIRMAN WALLIS: I think that may become clear later on. We'll find out. I don't think we --

(Slide change)

DR. PAULSEN; Okay. We are going to start with the illustration of the momentum cell shows an elbow, and the primary reason for showing this elbow is just so that we keep track of some of the effects of the vector information on the flow into the momentum cell, because we used that in some of our components -- for instance, T's in plenums, as we'll see toward the end of this discussion.

As I mentioned previously, we don't recommend using angles in every elbow or change in direction in the piping network. What we'll see is, if you include an angle for an elbow, you're going to

see a pressure change there as a result of that angle, but as soon as you get around a bend where you've put in an angle, the pressure goes back the same. It's a recoverable loss.

So the only place it really affects the pressure is locally where you have included that angle effect.

(Slide change)

DR. PAULSEN: So at this point, here we have our momentum cell. Basically, our momentum cell overlaps two mass and energy cells. So here we have an upstream mass and energy cell and a downstream mass and energy cell, which we refer to as control volumes.

Now this momentum cell -- you might refer to it as a control volume also. But in RETRAN terminology, control volumes are mass and energy cells, and we'll call this a momentum cell or juncture.

CHAIRMAN WALLIS: Then let's look at this: A_k user supplied down there, and you have A_k+1 user supplied. So that would make me think they could be different, and they were in your original derivation.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: Yet in your equation you make them the same. Why is that?

DR. PAULSEN: Because we are going to use this to develop a uniform area flow equation.

CHAIRMAN WALLIS: Yes, but your RETRAN equation has different areas in it.

DR. PAULSEN: And we'll get to that as we develop --

CHAIRMAN WALLIS: No, but please, if you are going to say you've got a general equation with two areas in it, it should apply to this shape, too, shouldn't it? Yes?

DR. PAULSEN: If we have two areas?

CHAIRMAN WALLIS: If A_k and A_k+1 are not equal, your equation has A_k and A_k+1 different, your general RETRAN equation. Right? So it should apply to this.

DR. PAULSEN: That's the one where we assume -- after we've gone through the development of having an area change.

CHAIRMAN WALLIS: What you call the RETRAN equation -- right? -- has A_k+1 and A_k in it. Right? What you call the RETRAN equation?

DR. PAULSEN: Is that on the next slide?

CHAIRMAN WALLIS: Wherever it appears, it has an A_k and an A_k+1, which are different. Right?

DR. PAULSEN: They may or may not be

different.

CHAIRMAN WALLIS: They could be different in this figure, right? And your equation -- The RETRAN equation, which you want us to believe, has an A_k and an A_k+1 which are different in it, in general.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: It doesn't have a step change or anything, and you originally had a derivation for this shape in which the A_k and the A_k+1 were different, and for some reason you've fallen back to A_k, and I think the reason is you couldn't get rid of the A_k's and the A_k+1s multiplying the pressures. So you just said we won't do it, because we don't know how to do it. We'll just forget it.

DR. PAULSEN: That goes with part of this development --

CHAIRMAN WALLIS: In your original derivation, when we get to the part, the pressures on the ends multiplied different areas. Right?

DR. PAULSEN: They have an area for the node upstream and the node --

CHAIRMAN WALLIS: Well, we'll back to that when you do your derivation. But I'm just pointing out.

Another question I have to ask you: This

bend could be a 90 degree bend or 180 degree end or any kind of bend? Still works?

DR. PAULSEN: In actual practice in RETRAN the bends are usually limited to 90 degrees.

CHAIRMAN WALLIS: This equation development, this theory, would apply to any kind of a bend in a pipe of constant area. Right? Okay. So if I give you a picture of an 180 degree bend, you can tell me how it applies to that?

DR. PAULSEN: A what now?

CHAIRMAN WALLIS: 180 degrees, and 360 degree bend, your pipe comes along, goes to loop and goes off, you will show me how this equation applies to that? It's a general bend? Can we get into that sort of discussion?

DR. PAULSEN: Well, let's get the slides up, and then we'll get the equations up --

CHAIRMAN WALLIS: Can we do that? Is that allowable?

DR. PAULSEN: Okay.

DR. KRESS: Before you take that one off, how is it you know exactly where to place the momentum cell with respect to the two mass and energy cells?

DR. PAULSEN: to the mass and energy cells? In practice, where users generally put

junctions is what we would call this, the momentum cell, is where there are changes in geometry.

CHAIRMAN WALLIS: It's sort of in the middle. It's a convenient place.

DR. PAULSEN: Right. And in some cases, depending on the type of transient, if you want to get spatial resolution, then you may add more nodes where you don't have geometry changes. But most places you'll see junctions will be, say, where the cold leg connects to the downcomer, a surge line comes off of the cold leg.

DR. KRESS: So the junction would be where 1 is on that.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: They tend to be mass and energy cell junctions, but the momentum cell is something else. Was that your question, how do you locate the momentum cell?

DR. KRESS: Yes. You know, you could just place it -- You could leave the junction where you had it, but you seem to -- like you have some freedom to locate the momentum cell.

DR. PAULSEN: That's right.

DR. KRESS: I just wondered what rationale was used to place it anywhere when you go to divide up

your circuit into those cells. Like, for example, one might look at an actual bend and say let's make the angle phi to 1 the same for the inlet and exit between those two. That would be one choice, for example.

DR. PAULSEN: Right.

DR. KRESS: That might help you in how you derive the equation. But I don't know what the rationale was.

DR. PAULSEN: Okay. It's basically where you have area changes, and then in some cases where you have long sections of piping you may put in additional nodes just to get additional spatial resolution so that you come closer to approximating the difference equations.

CHAIRMAN WALLIS: And this phi i -- you are going to resolve in the direction of phi i?

DR. PAULSEN: Yes, of this --

CHAIRMAN WALLIS: Now I notice when you have, say, the downcomer picture, your face at the end of the cold leg is parallel to the upstream face phi k or something. Well, I know that phi is upsized there.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Which kind are they?

DR. PAULSEN: These are phis. All of

these are phis, I think.

CHAIRMAN WALLIS: So that phi i could be parallel to phi k in some cases or parallel to phi k+1?

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: It's not necessarily halfway between it -- somewhere, anywhere.

DR. PAULSEN: That's correct. Somewhere.

DR. KRESS: That was my question, yes.

CHAIRMAN WALLIS: It's an arbitrary angle. Okay.

DR. PAULSEN: But in actual practice, these either will be the same angle or in general 90 degrees.

CHAIRMAN WALLIS: I noticed that with the bend. You had it the same at one end and different at --

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Okay. So it's not defined to be halfway between or anything special. It's anywhere.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Okay.

DR. PAULSEN: And one of the reasons that I think historically that this staggered mesh was used

was because flows were needed to obtain the mass and energy balance on these control volumes and, by overlapping this flow equation, the flow was calculated at that location. That was the rationale.

CHAIRMAN WALLIS: Your CFD was the same thing in many cases.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: Then you have to do some interpolation or upwinding or various different rules which you go into in your effects.

DR. PAULSEN: Right. But in reality, when you start looking at a model, we would never -- Well, I can't say that. In plant models where people are modeling reactor systems for Chapter 15 analyses, you wouldn't see someone modeling an elbow this way. An elbow would be lumped into a long section of piping.

DR. KRESS: Your L where you have one-half L, where is it on this?

DR. PAULSEN: These are geometric properties. This would be the flow length of this control volume. So, basically, our momentum cell covers half the length of the upstream volume and half the length of the downstream volume.

DR. KRESS: So that does fix where you place this momentum cell?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So it's a little problematic if the volumes are of changeable area.

DR. PAULSEN: That's right. In fact, if you have something like a nozzle -- and this really gets into comparing with experimental data. If you are going to look at comparing a nozzle, then you are going to have to put in some kind of representative geometry that is representative of the section spatially that you are --

CHAIRMAN WALLIS: Right. I think in the reactor you try to choose these things so that they are essentially constant area on both sides of the junction.

DR. PAULSEN: That's correct.

DR. SCHROCK: You don't show the forces on the diagram, the gravitational force, for example.

DR. PAULSEN: That's right. This is just basically geometric information.

CHAIRMAN WALLIS: -- forces downwind?

DR. SCHROCK: That is what I'm commenting on. How do these -- What's the justification of the balance without specifying more clearly what these f's mean?

DR. PAULSEN: Okay.

DR. SCHROCK: I mean, the f gravitational passes through the center of mass.

DR. PAULSEN: That's correct.

DR. SCHROCK: How does it align with other forces?

DR. PAULSEN: Okay.

DR. SCHROCK: And how does that become a one-dimensional equation? They are in different directions.

DR. PAULSEN: Okay. That we'll show on the next slide. Maybe you've already looked at the equation.

CHAIRMAN WALLIS: You need to get there, but we need to understand this.

DR. SCHROCK: Oh, yes. That's what I'm looking at, in fact, is the next slide.

DR. PAULSEN: Okay. And one thing worth noting before we move to that equation is that, with this momentum cell, we are going to have terms where we have momentum that moves across this boundary and the downstream boundary. So there will be velocities at these two surfaces, and these velocities in a straight piece of pipe will align with the normal vector for the REA, but in general they can be at some other velocity -- or other direction.

DR. KRESS: Is this intended for a single fluid or two-phase fluid?

DR. PAULSEN: The momentum equation or this flow equation looks at the mixture of fluid.

DR. KRESS: As if it were one fluid?

DR. PAULSEN: As if it were one fluid. Then there's a separate equation that actually calculates the velocity difference, if there happens to be two-phase.

DR. ZUBER: It is a two-phase mixture, not a single phase. It's a two-phase mixture.

DR. PAULSEN: It can be, yes. If you have two-phase conditions, it will be a two-phase mixture.

DR. ZUBER: I think this was a question. You have a two-phase mixture going out the densities, and then you have another equation where you have the difference in velocities.

DR. PAULSEN: That's correct. This is basically the mixture equation.

DR. ZUBER: Mixture equation.

CHAIRMAN WALLIS: Now this pressure you talk about -- what is that, this p-i -- or p_k? What is p_k?

DR. PAULSEN: Well, maybe that will come out on the next slide, but we do have pressures that

are defined for the mass and energy cells. So we will have a pressure, a representative pressure, for our upstream mass and energy cell and a different pressure for our downstream mass and energy cell.

DR. ZUBER: And they act where?

DR. PAULSEN: They act where?

DR. ZUBER: Where does the pressure act?

DR. PAULSEN: Well, let me put the next slide up, and I'll leave this one out for just a minute.

(Slide change)

DR. PAULSEN: Because we have -- First of all, this is just kind of introductory material to show how the equations are closed. We have the mass and energy cells where we actually do a mass and energy balance. So we will have total mass in those cells, and we will have total energy, and then based on water properties, we have a pressure equation estate where for our fixed control volume, given the mass and energy in a node, we can calculate the pressure.

DR. KRESS: Now the energy that's in that thing includes the energy that's due to friction -- You account for that energy in another equation that adds in the friction.

DR. PAULSEN: That's right. In fact, we have -- In RETRAN-3D we use an internal energy equation, and in general the viscose terms, the dissipation terms, are small compared to the others. So we've currently neglected that viscose dissipation in the energy equation, but it includes the convective terms in and out of the volume, heat addition from various either heat conductors or decay heat.

So we, in effect, do our internal energy balance to come up with our internal energy and mass, and then we have a pressure for that control volume. That pressure, we assume -- Well, let's go on here for just a minute.

DR. KRESS: Well, it's an equilibrium assumption?

DR. PAULSEN: For the three-equation model it is equilibrium, and we have the pressure as a function of total mass and total energy. When we go to our five-equation model which has -- constrains nonequilibrium, it's developed primarily for applications in BWRs where you have subcooled boiling.

One phase is constrained at saturation, if we have two-phase conditions, that being the vapor phase. The liquid phase can then be subcooled or superheated, and this pressure equation estate then

changes so that our pressure is a function of our total mass, total energy, and then our vapor mass that's in the volume.

So depending on the governing equations, this pressure equation estate can change. If we have noncondensables in the system, it can also change. But for the simple case, our pressure is determined by the mass and energy for the simple three-equation case.

DR. SCHROCK: So one-phase is constrained to be equilibrium, and the other is not?

DR. PAULSEN: That's right.

DR. KRESS: So for noncompressible fluids that are flowing adiabatically, your pressure becomes a constant, a constant area?

DR. PAULSEN: It should effectively do that. Right now we would actually do a separate mass and energy balance for each node and, if the specific volume and specific internal energy don't change, then we should end up with the same pressure.

DR. KRESS: That's why I was asking what you did with the friction term?

DR. PAULSEN: Okay.

DR. KRESS: Never mind. Go on.

DR. ZUBER: Can you explain those terms on

the righthand side?

DR. PAULSEN: I think you ought to explain every one.

DR. PAULSEN: Yes. Okay. So this -- We've talked a little bit about the momentum cell geometry where we are using a staggered mesh. What we are hoping to get from this place we're starting is an equation that will allow us to calculate flow at the boundary between those mass and energy cells.

So we have our time rated change of momentum for the momentum cell volume averaged over the momentum cell volume, and then at this point we have the, in effect, momentum that's being transferred through the flow surfaces, the ends of --

CHAIRMAN WALLIS: So assuming they are parallel to the -- the surface is perpendicular to the velocity there?

DR. PAULSEN: The assumption that we have here is that this area is the normal area. It's perpendicular.

CHAIRMAN WALLIS: Forces normal to the area.

DR. PAULSEN: Right.

CHAIRMAN WALLIS: Because in some earlier derivation of this, you had some a-primes and all

that.

DR. PAULSEN: Well, you pointed out there were some errors in there, and we agreed that there were some problems there.

So at this point in this --

CHAIRMAN WALLIS: -- flow rate out of j?

DR. PAULSEN: That's right. This ends up being the velocity that's the normal component of the velocity. This would then be the true velocity crossing that surface, which may or may not be normal. For most applications in RETRAN, it will be.

Then we have our forces. This is our wall force that's parallel to the wall, our viscose friction term. This is a term which --

DR. SCHROCK: I asked you about the forces in the diagram. You're writing single forces here now in this balance relationship. Where are these forces in this diagram?

DR. PAULSEN: Okay. This force will be parallel to the wall.

DR. SCHROCK: Well, the wall isn't everywhere parallel.

DR. PAULSEN: At any point along the wall, it will --

DR. SCHROCK: But this is an equation for

the control volume.

DR. PAULSEN: Yes. Basically --

DR. SCHROCK: So you don't get it by taking the point differential equations and integrating over the volumes. You have an ad hoc equation, and you're trying to explain your way out of the terms in the ad hoc equation.

Now what I'm asking you to do is show a force diagram.

DR. PAULSEN: And basically --

DR. SCHROCK: You've shown a control diagram. Now show a force diagram.

DR. PAULSEN: And basically, these wall forces are, like you said, ad hoc models.

CHAIRMAN WALLIS: They are frictional sheer stresses on the wall, but then it's the integral of all that over the whole volume.

DR. PAULSEN: That's right. And basically we'll apply something like a Moody model where we know the length of the flow path. We will use that --

CHAIRMAN WALLIS: Moody doesn't tell you that. If you have, say, a -- I'm going to give you this 180 day bend in a little while. But if you look at the sheer stresses on a 180 degree bend, you find their resultant is in the direction which is right

angles to the end faces of the bend. It's completely orthogonal to the pressure forces on the ends.

I mean, the pressure drop in the pipe is not the same as a momentum balance for a pipe. The Moody -- except for a straight pipe.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Not the same thing. So it is obscure, what your Fs are here.

DR. PAULSEN: And basically, what we are trying to show here -- and I appreciate your point about where those forces are applied. When we end up doing our next operation, we are going to have some kind of a scaler term for our friction.

CHAIRMAN WALLIS: Well, this isn't scaler yet.

DR. PAULSEN: It's not scaler yet.

CHAIRMAN WALLIS: One-dimensional. It's a misnomer? Okay. I'm sorry, because I thought that's what you were talking about.

So this F tilde is the integral of all the sheer stresses on the wall over the area?

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: Whatever direction it happens to be.

DR. PAULSEN: That's right. It's

uncalculable but general.

CHAIRMAN WALLIS: It's a big arrow, the resultant force from all due to friction. Okay.

DR. PAULSEN: And these forces are normal sheer forces that you will see when you have changes in geometry were obstacles in your flow pattern somewhere in here.

CHAIRMAN WALLIS: That's the same thing as integral PBS, isn't it? What's different about it?

DR. PAULSEN: These may be from internal.

CHAIRMAN WALLIS: Same thing. Surfaces, whatever the surface is, wiggles, squiggles.

DR. KRESS: Yes, that's what bothered me.

CHAIRMAN WALLIS: There's nothing different about F_{loc}. Right?

DR. PAULSEN: F_{loc} is --

CHAIRMAN WALLIS: The sheer stress of pressure. right?

DR. PAULSEN: It's another viscose loss term.

CHAIRMAN WALLIS: Well, I think that's where there's a misleading thing. You see, now you're going to an energy balance when this is a momentum balance. F_{loc}, it seems to me, is either incorporated in FF or in integral feed --

DR. PAULSEN: Let me tell you where we are trying to get to.

CHAIRMAN WALLIS: I know where you're trying to get to.

DR. PAULSEN: All right. Now we're trying to get to somewhere that looks like --

DR. ZUBER: The Bernoulli equation.

DR. PAULSEN: -- the Bernoulli equation.

CHAIRMAN WALLIS: You are trying to fudge your way to Bernoulli's equation. Right? And we're just trying to keep you honest.

DR. PAULSEN: That's fine.

CHAIRMAN WALLIS: But if you go back to fundamentals, which you do -- I mean, you try to establish the fundamentals, because you do a lot of hairy math later on -- there's only the integral of the sheer stress tensor with the surface and the integral of the normal stress, if you want to break it out from the sheer stress. That's all.

The only thing the surface does to the flow is via sheer stress and normal stress integrated over it. There are two forces, and really one, if you put them together.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So this -- I think what

you are doing -- What I find throughout all your derivations, you sort of mix up these ideas of energy losses with momentum, and F_{loc} really doesn't have any business in the momentum equation.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: That's what confused me.

DR. PAULSEN: So maybe we would be better off taking this out and then letting it appear when we actually apply mechanical energy --

CHAIRMAN WALLIS: Maybe if we work together, we can come up with something.

DR. PAULSEN: Yes, I can see where you're coming from. And some of this is historical.

CHAIRMAN WALLIS: Yes, I know, but some of it is because people didn't understand properly in the first place.

DR. PAULSEN: And some of what was understood by the people that have gone by the wayside and retired wasn't documented, and so we're trying to reconstruct history and maybe leaving out some steps.

DR. ZUBER: Well, why did you have to reconstruct? You can start from correct formulation and forget about history. It's almost like going to the Neanderthals to derive something.

DR. PAULSEN: Okay. The next term that we

have here is just from additional things that are very complicated that we can't really model at a fundamental level, things like pumps and turbines.

CHAIRMAN WALLIS: Electromagnetic forces?

DR. PAULSEN: That's right. We know that there's going to be some additional forces, and then we have the body force term, the gravity.

DR. SCHROCK: You put secondary flows in that category? I mean, in this geometry you induce a secondary flow.

DR. PAULSEN: That's right.

DR. SCHROCK; It's not specifically thought about.

DR. PAULSEN: No. If the secondary flows are an important part, then that's a limitation.

CHAIRMAN WALLIS: It wold appear in F_{fw}.

DR. SCHROCK: That is where that would show up.

CHAIRMAN WALLIS: It captures it all.

DR. SCHROCK: Yes.

CHAIRMAN WALLIS: So this is momentum equation. It has to be resolved in some direction.

DR. ZUBER: Wait, wait, wait. What is this S_{tot} for the pressure?

DR. PAULSEN: The what now?

CHAIRMAN WALLIS: S_{tot}?

DR. ZUBER: That last term.

DR. PAULSEN: This one?

CHAIRMAN WALLIS: S_{tot}.

DR. PAULSEN: This is for the total surface area.

CHAIRMAN WALLIS: That's a new development. You used to have it over the ends, and now you are going to -- This is a completely new development in your theory?

DR. PAULSEN: That's right.

DR. ZUBER: Well, how do you differentiate the second term -- I mean the F_{fw} from this integral --

DR. PAULSEN: These are viscose forces. They've been separated out from the pressure terms.

DR. SHACK: The sheer and the normal you can resolve. It's F_{loc} and the integral of p that become confusing.

CHAIRMAN WALLIS: The sheer you can't resolve or amend.

DR. SHACK: Well, but you can get an integral result. You can calculate it.

DR. KRESS: You can apply an integral equation that's derived or based on the data or

derived some other way.

DR. ZUBER: What you are really deriving are new dynamics.

CHAIRMAN WALLIS: Well, that's interesting. Let's go ahead.

DR. KRESS: I'm still confused about that last term.

DR. ZUBER: That's the point.

DR. KRESS: Because what I view that as is the effect on the momentum in changing direction.

DR. PAULSEN: That's what that is.

DR. KRESS: And it seems to me like in a one-dimensional equation, you don't have that, because your direction is along the stream line, and that's what confused me.

DR. PAULSEN: Do you have some insight, Tom?

DR. PORSCHING: Well, first of all, that equation is -- It's a misnomer. At this point it's a three-dimensional lumped equation that you've gotten by taking a --

CHAIRMAN WALLIS: Sir, could you get to the microphone and identify yourself for the record?

DR. PORSCHING: Sure. I am sorry. I am Tom Porsching. I'm an Americus Professor of

Mathematics from the University of Pittsburgh.

Just by way of insertion here, introduction, I was asked a year and a half or so ago by EPRI to examine the equations of motion and fluid dynamics and see if there was a rational way to derive a scalar balance or a scalar relationship of the type that is used, as it turns out, in the RETRAN equation. So that's my role. That's a role I've played in this, and just recently received from Mark four or five days ago copies of these slides.

So I haven't had a real chance to digest them, but I notice that the equation that he is discussing right now is an evolved version of what you could get by taking the Navier-Stokes equations or, if you want to lump the viscose terms in a term such as that F_{fw} term, the Euler equations, and integrating them over a control volume.

The term that you see at the very end there, that pndS term over S_{tot}, can be derived, can result from the first relationship that I mentioned by viewing the pressure gradient term that shows up in the Euler equations as really a tensor, a divergence of a tensor where the tensor is, in fact, the identity tensor.

That allows you, after you've done the

integration over the volume, to use the divergence theorem to convert that to a pressure -- to an integral over a surface.

CHAIRMAN WALLIS: There's no need to do that. This is simply an overall force balance, and it's straightforward.

DR. PORSCHING: Well, maybe. That's my view. That's the way I view it.

CHAIRMAN WALLIS: You would need no Navier-Stokes equations to do this. The thing which is confusing to us, I think, is when we first saw this, Bert, Stuart and Lightfoot was involved, and Bert, Stuart and Lightfoot make it quite clear that they've got pressures over the end areas, and they've got a pressure and an S. That's what you wrote in your first documentation that we reviewed.

Now we've got something different.

DR. ZUBER: Well, but they have the same result. They have the same result.

CHAIRMAN WALLIS: Well, this, I think, is a different story than we saw, because you're invoking Bert Stuart and Lightfoot. You're not invoking something that everybody believes. You're invoking something new.

DR. ZUBER: But more than that. They are

developing something completely new, because last time they obtained relations which are completely different from the Bert, Stuart and Lightfoot.

CHAIRMAN WALLIS: That's what is so interesting.

DR. ZUBER: It's interesting, wrong, amusing or sad.

CHAIRMAN WALLIS: Maybe it's all of the above.

DR. KRESS: Well, the only place I would need that last term, it seems to me like, is if I'm trying to determine the response of the pipe to the flow and, you know, trying to get the support forces. When I'm looking at the flow itself, I don't need that term.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: You don't need that term? The pressure drop between the ends that accelerates the flow.

DR. KRESS: Oh, I thought that was in one of the other terms.

DR. PAULSEN: It's included in this term. It's part of this term.

DR. KRESS: I do need that term then, if that's what it is.

CHAIRMAN WALLIS: But we'll buy this as long as we understand what we're looking at. But this is so obvious, as long as we are clear about what we mean, I think we can go on.

DR. PAULSEN: I think the part of the term that you were talking about is going to be the integral over this surface area.

CHAIRMAN WALLIS: That's Bert, Stuart and Lightfoot have.

DR. SCHROCK: I'm afraid anybody reading the record of this meeting would be very confused by the composite of the statements that have just been made.

You admitted when I suggested that it's an ad hoc equation that, yes, indeed it is an ad hoc equation. Dr. Porsching stood up and told us it's not a one-dimensional equation; it's a three-dimensional integral representation of a three-dimensional situation; and in fact, it is derivable from first principles. But if that is the case, then it's incumbent on you to show us how that happens. How is it derived from first principles?

So I think the sequence of things that I heard in the last five minutes are absolutely self-contradictory.

DR. PAULSEN: You want this equation derived?

CHAIRMAN WALLIS: This is just momentum and force balance. I think we can move on, as long as we are clear what you mean. S_{tot} is the integral over the whole surface, which is the ends and the walls of the pipe.

DR. PAULSEN: That's correct, and --

CHAIRMAN WALLIS: And the sheer stress -- resultant of the sheer stresses is f-squiggle, and we can forget about F_{loc} and F_p. Right? So we've got sheer stresses, pressure forces, gravity, momentum fluxes, and they are balanced or not balanced. If they are not balanced, there's got to be an acceleration by Newton. We're not going to question him.

DR. PAULSEN: Right.

CHAIRMAN WALLIS: So what's the problem? Can we go on?

DR. PAULSEN: Sure.

CHAIRMAN WALLIS: But now this is going to be resolved to make it one-dimensional?

DR. PAULSEN: I hope so.

CHAIRMAN WALLIS: Okay, let's resolve it. You're going to resolve every term in one direction?

Are you going to resolve the momentum fluxes in that direction?

DR. PAULSEN: Yes. And I'm going to have to apologize here. I think your hard copies are correct, but when I printed these slides, the Greek characters disappeared. So your slides are going to be correct --

CHAIRMAN WALLIS: So this says the change of the momentum in the I directional, the p to whatever you call it -- end direction, whatever. It's the psi direction, right?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Is equal to the change in momentum flux in that psi direction. I notice here A_k+1 instead of A_k. So A_k, I think, is different from A_k. You're going to make it the same for some reason?

DR. PAULSEN: At this point --

CHAIRMAN WALLIS: No reason it has to be the same.

DR. PAULSEN: At this point, we are doing it for a uniform area.

CHAIRMAN WALLIS: No, you're not. You've got A_k+1 that's different from --

DR. PAULSEN: That's right. That's simply to show that where it came from is from the downstream

--

CHAIRMAN WALLIS: Well, I think you're hiding from the fact that if you put in an A_k+1, you can't make it go away, you know. That's what you said before. Dr. Porsching's paper has an A1, n A2 and A0, three different areas. You only have one. And if you use his equation, you get a different answer than you get by generalizing your equation.

So we have a problem with that. But anyway, this is resolved in the direction m, right?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And that F_w is some resolution of the forces from the wall sheer stresses in that direction.

DR. PAULSEN: That's right, or along the wall.

DR. PAULSEN: And the T_g is resolved as well?

DR. PAULSEN: The what?

CHAIRMAN WALLIS: The g is resolved as well? Should be, right?

DR. PAULSEN: That's right.

DR. ZUBER: What is that delta-p, sub-p?

DR. PAULSEN: Was it this term, Dr. Zuber? It's the pump. Yes, it's just a source term that gets

added for volumes that have pumps.

So here we have the momentum coming in, and this will be the momentum going out the other end. What we have effectively done at this point is dot this equation then with the junction normal vector to make this a scalar equation.

DR. KRESS: But you don't know that angle in general.

DR. PAULSEN: That angle is input.

CHAIRMAN WALLIS: You're free to chose it.

DR. PAULSEN: The user would input that angle in his input description.

DR. KRESS: Well, if you are going to then take the -- invoke the divergence theory, then doesn't that fix that angle for you?

CHAIRMAN WALLIS: You're getting too complicated for me, Tom.

DR. KRESS: Well, the divergence theory fixes the point at which the mean value -- I mean the mean value theory. It fixes -- When you invoke the mean value theory, that fixes that point and that angle.

CHAIRMAN WALLIS: But you can resolve in any direction. Now this next statement is really weird: "Pressure assumed uniform." How can you have

a pressure difference if it's assumed uniform?

DR. PAULSEN: Within each of the control volumes --

CHAIRMAN WALLIS: Now you get into a sort of a logical --

DR. PAULSEN: This upstream side and the downstream side, we're assuming that we have one pressure and that it's uniform in --

DR. ZUBER: Well, what difference is that interface?

CHAIRMAN WALLIS: So you're assuming something incredibly unphysical. Right? In order to get on with the problem?

DR. PAULSEN: Well, we really don't know the pressure distribution --

DR. ZUBER: Hold on. Hold on. What is -- You mean where you have the arrow in the middle?

DR. PAULSEN: This arrow?

DR. ZUBER: Yes. You have a pressure discontinuity?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: You got into something absurd here. Your flow goes around the bend. The bend is like a turbine bucket, and the pressure on the outside of the bend is different from the pressure on

the inside, and that's why it turns. If you are going to assume it's uniform pressure, it's got to go straight.

So the whole idea is contrary to physics.

DR. ZUBER: Look, Graham, you see that middle point, middle dotted line. It has a pressure difference.

CHAIRMAN WALLIS: That's right. I guess he has that.

DR. ZUBER: He has. I mean, this is like you have a supersonic flow.

CHAIRMAN WALLIS: But also he assumes the pressure on the inside of the bend and the outside are the same. So there's no force to turn the flow to the right. There's nothing that stops the flow from going straight up in the air there.

DR. PAULSEN: Except we know that the flow has to go through our junction, and we've defined those angles.

DR. ZUBER: That is unbelievable.

DR. PAULSEN: It's the pressure balance that -- pressure drop balance that really drives the flow.

CHAIRMAN WALLIS: But you see, you -- But you're using a momentum balance. So you've got to

keep track of forces and directions.

DR. ZUBER: You know, if you really follow fluid dynamics, if you have a pressure discontinuity across an interface normal to the flow -- I usually call it shock or something -- then you have a velocity difference.

DR. PAULSEN: yes.

DR. ZUBER: And this is what I get.

CHAIRMAN WALLIS: -- because in the original documentation you had a pressure on the bottom area and the top area which were the P_k and the P_k+1. All the books do it.

DR. PAULSEN: And if you do the mean value theorem or apply the mean value theorem, you can get the pressure at that --

CHAIRMAN WALLIS: You take everything as mean. You lose some of the physics, because the only reason it goes around the bend is because the pressure is bigger on one side than the other, and taking the mean pressure doesn't capture that at all.

DR. PAULSEN: We know that we can make fluid flow by using the Bernoulli equation where we're just looking at --

CHAIRMAN WALLIS: That's not what we are talking about here.

DR. PAULSEN: That's where we're trying to get to.

CHAIRMAN WALLIS: Why don't you just use it then? I mean, giving a bogus derivation of Bernoulli equation is worst than just invoking it, if it's bogus. Now maybe it's good. I don't know yet. We are obviously having some difficulty with it. So --

DR. PAULSEN: One of the differences is what we have for our time derivative, but the steady state form of the equation looks a lot like the --

CHAIRMAN WALLIS: So your equation -- I'm going to give you this right angle bend there. There's a 180 degree bend, and you can tell me how your forces work for that, if you like. Would you want to do that, because I claim that the momentum fluxes are in one direction, the net wall sheer stresses in the other. What's the momentum? What's the direction of momentum? It's in this direction.

DR. PAULSEN: In RETRAN the momentum will be in the direction of whatever you define the junction angle to be.

CHAIRMAN WALLIS: But you're not looking at pressure forces on the ends anymore. It doesn't matter what the orientation at the ends is? It's

irrelevant? Seems to me, the orientation of the ends in terms of pressure is irrelevant in your model.

DR. PAULSEN: The orientation of the ends has to be normal -- or perpendicular to the walls of the pipe.

CHAIRMAN WALLIS: Okay. How does that -- Just put another coil in the pipe. Doesn't make any difference to your equation. A little bit more curl or something doesn't make any difference. Yet the pressure is acting on a different surface.

DR. PAULSEN: We will definitely get different flows in a situation like that if you model the actual flow lengths and then the losses that you would normally get through a form loss type term.

CHAIRMAN WALLIS: Well, would it be appropriate for you to take my 180 degree pipe and show us the Fs and the forces and the momentum fluxes and so on? Would it be appropriate? He's got something you can draw with here.

DR. PAULSEN: Well, I think what we ought to do is maybe look at the equation we end up with.

CHAIRMAN WALLIS: But I'm just saying that your model should apply to any bend, and you're going to resolve it in some direction. I think, if you look at 180 degree pipe, you'll find that the momentum

fluxes and the pressures that are orthoganol to the friction forces in the momentum change.

Since yours is general, it ought to apply to that, oughtn't it? I'm just trying to clarify it. if it's general, you've got that thing at the top there. Just put the arrows for the momentum fluxes in there.

DR. PAULSEN: Are these control volumes or is this a momentum cell?

CHAIRMAN WALLIS: It's a momentum cell. Put in the momentum fluxes as you would have them going in the ends there. Maybe you'll be right. Maybe we'll be convinced here. I don't know.

We need one that works. Get the one that works. This is government.

DR. PAULSEN: Let's see if this works.

CHAIRMAN WALLIS: You've got momentum fluxes coming in there. Right? And then going out there. Where is the -- what's the average momentum? It's an incompressible flow, and let's say A_1=A_2. What's the average momentum in the pipe? What's its direction?

DR. PAULSEN: Is this -- Okay, so this is our momentum cell?

CHAIRMAN WALLIS: Yes, the whole thing is

a momentum cell.

DR. PAULSEN: At some point we have to assign an angle for this thing.

CHAIRMAN WALLIS: Well, let's do that later, because we would solve for the overall thing. What is the direction of the overall momentum in the pipe there? It's horizontal, isn't it? Okay, so it's horizontal.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: So it's horizontal. Now what's the direction of the net sheer stresses on the wall? By symmetry, it's also horizontal.

DR. PAULSEN: Right.

CHAIRMAN WALLIS: So your F_{FW} is horizontal. How can that, in the momentum balance, balance the pressures at the end which are vertical, which you claimed it does. You said that Moody -- pressure drop in the pipe is balanced by the sheer stress, you said, in the trivial case. Yet they are in opposite direction. How does it happen?

DR. PAULSEN: Basically, what we have done is made this one dimensional so that, in effect, we have a straight pipe.

CHAIRMAN WALLIS: You straightened it out.

DR. PAULSEN: That's right.

DR. KRESS: Or another way to say it is you've resolved all these things along the stream line.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: You had to resolve each little bit around the whole thing, but when you resolve the whole thing, you've got absurdities. if you take that loop at the bottom there, you've got even more absurdities. You've got that there's no change in momentum flux, and the pressures are all -- There's nothing to accelerate the flow, but we know it isn't true.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So you haven't done the momentum balance, it seems to me. You've done an integration of little pieces of momentum or something or you've done a Bernoulli type flow, which is also historic with RELAP and all that.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: But you've really confused us by this kind of hybrid, which is neither fish nor fowl. It seems to be a mixture of the two.

DR. ZUBER: Graham, it's violating everything we have learned in fluid dynamics.

CHAIRMAN WALLIS: Well, not necessarily.

DR. ZUBER: Graham, look, they develop a discontinuity of pressure -- how can this be? If you have a discontinuity in pressure, you must have then a discontinuity in velocities.

DR. PAULSEN: If you look at any code, and they can assume node-wise pressure --

DR. ZUBER: Forget code. Don't try everybody is cheating, therefore I can cheat also. That's another argument here.

DR. PAULSEN: No, that's something that comes with difference equations.

DR. ZUBER: No, no, no.

DR. KRESS: It's a finite difference representation.

DR. ZUBER: No. They assume the same pressure, you see, at the entrance, and then a different at the exit. The discontinuity occurs in the middle, and you have a pressure jump in the middle. You have to have that independence in velocity. Those are called the jump conditions.

CHAIRMAN WALLIS: You have a real problem mathematically to relate the integral of pressure around a surface to the integral of pressures throughout a volume. There's a real -- It's not as if you've got a gradient of pressure or anything.

The volume integral of pressure is a different animal from the surface integral of pressure, and yet you are saying your volume integral of pressure you used for your code in the thermal-dynamics can somehow be borrowed and immediately transported into some surface integral of pressure, which is the kind of thing that the Porsching influence has led you to, because the other one didn't work out very well. But you just have another mathematical problem then, I think, when you do that.

It may be that, if you really acknowledge these and really say, well, we made that assumption because that's the only thing we knew how to do, then Novak can get as blue in the face as he likes, but at least you've said that's what we've done.

DR. ZUBER: Oh, no. I agree. If they would say, Graham, this was wrong; the effect of this error is such and such, and it took us many calculations to show that this is not the important one.

The problem I have here, they don't want to acknowledge candidly the wrong formulation, the wrong results, and I don't agree that they have done sufficient sensitivity calculations.

CHAIRMAN WALLIS: The difficulty, Novak,

is that the code has some formulation in it, and all this story has developed and ways to try to justify what someone has put in the code for reasons which the present users may not even believe.

DR. ZUBER: Well, the trouble is then you have to say to the public we have really codes we have to believe in that you flunk a junior student on that.

CHAIRMAN WALLIS: Well, let's see now. I don't know. Do you see the problem I have with the 180 degree bend?

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: It's that the forces are in different directions, and I don't know how you resolve them in any direction to get your equation. That's all. Maybe you can think about that after lunch or something.

DR. SCHROCK: It seems to me that that problem is present for any degree of bend, isn't it?

CHAIRMAN WALLIS: Anything except a spring pipe.

DR. SCHROCK: The fact that the forces that are described in these what I'm calling ad hoc equations are simply not in the same direction. Therefore, it's a little difficult to understand how they can represent a force balance.

DR. PAULSEN: And in fact, we may be better off just saying that we are doing it for a straight piece of pipe and elbows are handled --

CHAIRMAN WALLIS: You could use what I call the two-pipe plus junction model, which is what you almost do.

DR. PAULSEN: That's what we've attempted, yes.

CHAIRMAN WALLIS: But you haven't, because you've tried to then resolve it. You've got the vector thing mixed up. Two-part plus junction model works if the pipes are in any -- Here's a pipe. Here's a junction. Here's not a pipe. Doesn't matter where it is, as long as you've got that, but you've confused everything by calling it a vector equation and resolving it.

DR. PAULSEN: I think I see where you are coming from now.

CHAIRMAN WALLIS: It's taken a long time.

DR. PAULSEN: Well, some of it is, I think -- Well, yes.

CHAIRMAN WALLIS: California is a long way from New England. I know that.

DR. PAULSEN: Well, some of it may have helped if we could have worked with --

CHAIRMAN WALLIS: Well, you've got a Californian here, too.

DR. PAULSEN: Things have been kind of indirect, I guess.

DR. ZUBER: Two years ago, I mean, we discussed some of these things.

MR. BOEHNERT: What's this got to do with California?

CHAIRMAN WALLIS: Well, that's why it takes a long time. I mean time and distance. No, I don't think we want anymore comparisons like that.

DR. PAULSEN: The next step in the development is based on the assumption that we have spatially uniform pressures.

CHAIRMAN WALLIS: Yes, but then you shouldn't be doing this hairy -- You've cast this hairy surface integral when you've already assumed the problem away by having it uniform is really strange.

DR. ZUBER: Well, it's wrong. It's not strange. It's wrong, because if you do that and you have -- discontinuity, and that's not physics.

DR. PAULSEN: Well, with the finite difference codes there is always pressure differences in each node.

CHAIRMAN WALLIS: What you are doing --

Okay, you're going -- you're doing this whole integral, and essentially you are getting some sort of a surface average pressure over the entire surface.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: That's essentially what you are doing, and I'm saying mathematically that is not the same thing as some volume integral of pressure, which is what you use in your thermal-dynamics. So there's a sleight of hand at a different level going on here.

DR. PAULSEN: In the thermal-dynamics we only know mass and energy on a global basis.

CHAIRMAN WALLIS: But you know a thermal-dynamic pressure.

DR. PAULSEN: Pardon me?

CHAIRMAN WALLIS: You know a thermal-dynamic pressure.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So when a flow goes around a bend, it goes around because the pressure on one side is greater than the pressure on the other, and an average pressure of thermal-dynamics -- we will never reflect that. Never.

DR. PAULSEN: Okay.

DR. ZUBER: Okay. Do you agree with the

statement that Ralph made that this derivation is irrelevant?

DR. PAULSEN: Well, I think we can show by comparison with simple experiments, simple thought problems that the resulting equations reproduce reality. We can actually do comparisons of expansions, contractions, T's where we actually reproduce reality.

DR. SHACK : Well, and you can't apply your equations to a straight pipe.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And I think what happens in RELAP, though it's very difficult to get them to say that, but every time that people come up with a -- They've come up with the RELAP documentation. All they do is analyze a straight pipe.

Then they say, well, here's a straight pipe, a straight pipe, a straight pipe. A bend turns out to be a sequence of straight pipes, but they never tell you that up front, we're going to model everything as a straight pipe.

DR. ZUBER: Graham, it is not even that. They cannot even apply to a straight pipe, and we shall come to it, because what you have in this handout, it doesn't apply to a straight pipe. It goes

contrary to whatever we have in Bert, Stuart & Lightfoot. Your results here --

CHAIRMAN WALLIS: Well, let's do this integral over the areas. I guess we're going to have to do it. What you essentially come down to is this P_k, P_k+1 times A_k.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And the P_k is really a definition of a pressure over an entire area composed of the pipe and the end, which does not include the junction. It's that whole surface of whatever it is that wiggles and squiggles and everything which does not include the junction.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: Because it's a very funny pressure. It's some sort of average pressure over all the surface there.

DR. ZUBER: But A_k is a surface normal to the --

CHAIRMAN WALLIS: Well, in Porsching A is A_0. It's different, and that's what I was pointing out to you earlier, that if you take the Porsching equation with an A_0 there, then your equation -- it looks different. Your pressure difference multiplies an A_0. When you divide it through by it, it's not the

same as A_k.

DR. PAULSEN: Right.

CHAIRMAN WALLIS: So his equation is not the same as yours, even if you believe this. But this P_k and P_{k+1} are not the same as the P_k that are in Bert, Stuart and Lightfoot, which are on the ends of the pipe. They are an average over the whole wall and the end, coming all the way back to this.

DR. ZUBER: See, but Graham, it is integrated over one normal area, k, which assumes that A_k and A_{k+1} are equal.

CHAIRMAN WALLIS: Well, it's the junction area, really. In Porsching's paper it's an A_0, which is like a middle of the pipe, not the ends at all.

DR. ZUBER: But you don't know what that A_0 is.

DR. PAULSEN: And then this uniform pipe--

CHAIRMAN WALLIS: Doesn't have to be uniform. All that needs to be is the area of the junction that cuts the middle of your picture. Doesn't have to be uniform pipe for the Porsching approach. But then you can't divide through by A_k and get your answer, because A_0 isn't the same as A_k.

So even if you believe Porsching and even if you are willing to say P_k, P_{k+1} equals the same

pressures as the sum dynamic pressures, you still have a problem with the areas being --

DR. SHACK: Well, no. Porsching is rigorous. It's just that you don't know where the P is evaluated. I mean, it's a mean value over some portion of the surface. There exists a point at which that statement is true.

DR. ZUBER: No, it is not, because here's the equation, and here are uses, and we can't bring it up.

CHAIRMAN WALLIS: There's another Porsching paper, though, a more recent one, which seems to realize that there's a problem here, and it sort of works for a straight pipe and it works for a pipe with a slight bend in it, but you have a problem when you have big bends because of the surface integrals.

So there's a learning process going on here which is fascinating to watch. It's a difficult problem. I think what you have to do is face up to it.

I wrote a tutorial on the momentum equation. I guess you haven't seen it. Here's the momentum equation. Here's why it's very difficult to use and, therefore, you have to make assumptions and

so on, and these are the kind of things people have tried.

I think that would be a much better presentation than this sort of attempt to do something rigorous that gets people a little hot under the collar, because they say, how can you do that?

DR. PAULSEN: But in general, where we are trying to go is to something that looks like the Bernoulli equation.

DR. ZUBER: Well, then you could have started with Bernoulli. Let me ask you something. Are you familiar with a book by Ginsberg, this book?

DR. PAULSEN: No.

DR. ZUBER: It was translated by NASA 30 years ago, and he deals with this problem. It's the best book I saw on this approach, and I would strongly advise you, go and read it, and also, too, NRC.

CHAIRMAN WALLIS: So if this were Porsching, you would have A_k and A_{k+1} instead of A_k in there, and you would have -- They are still resolved in some direction psi?

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: And then you would have A_0 in there, and A_0 depends on what psi is. You change psi, you change A_0. Is that right?

DR. PAULSEN: Yes. They go together. So this ends up being our scalar equation where this is our time rated change of momentum in our momentum cell.

Then we use some definitions, a geometry term. This ends up being the volume of the momentum cell where it's just based on half the length of the upstream and the downstream volumes.

CHAIRMAN WALLIS: But those were in different directions.

DR. PAULSEN: What's that?

CHAIRMAN WALLIS: Those are in different directions. When the cell -- Now it's a bend. Those L's are in different directions. So don't the momenta have to be resolved in some way? And you seem to be resolving the momentum flux and not resolving anything else. The momentum has to be resolved in the two pipes. You got two pipes here, right?

DR. PAULSEN: We have two pipes.

CHAIRMAN WALLIS: And you got to resolve that momentum. Have you?

DR. PAULSEN: Well, we think we have.

CHAIRMAN WALLIS: See, you can't do it that way in general.

DR. PAULSEN: Well, let me take a look at

this next step then.

(Slide change)

DR. PAULSEN: Basically, what we've done then is defined that time rated change of momentum to be basically a flow term. There was a geometry term factored out.

CHAIRMAN WALLIS: It's like a pipe.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: You've got two pipes is what you've really got.

DR. PAULSEN: It is two pipes. That's right.

DR. ZUBER: But the same area.

DR. PAULSEN: Two pipes here with the same area.

CHAIRMAN WALLIS: They don't have to have the same.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: You get an L over A or something, whatever it is.

DR. PAULSEN: That's right.

DR. ZUBER: But then they would not get the pressure.

CHAIRMAN WALLIS: See, and when you -- The thing I find difficult is what am I looking at? The

RETRAN flow equation, when it appears later, has an A_k^2 and it has an A_{k1}^2 in there.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Which is simply written down. Now if you are going to derive it, you better have a pipe which has a different area in and out rather than just generalizing something without any explanation.

DR. PAULSEN: Okay. That's the next step.

CHAIRMAN WALLIS: If you look at Porsching, it shouldn't be A_{k+1}^2 anyway. It should be A_{k+1A0}, even if you believe Porsching. So you can't just say it's a pipe of constant area and then write down an equation with no explanation for a pipe with bearing area.

DR. PAULSEN: Well, the next step is to try and show you how we have come up with the equation for --

CHAIRMAN WALLIS: The way you've done that is with two pipes which are straight.

DR. PAULSEN: Two straight pipes and connect them with the mechanical energy equation.

CHAIRMAN WALLIS: So you are essentially saying we're going to take any old bend of any shape--

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: -- and model it as two straight pipes.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Or any shape of any kind whatsoever.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Like a cobra that swallowed a pig, and it's got a big bulge in the middle --

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: But he still treats it as a straight pipe.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: So I think that's what you've done.

DR. PAULSEN: Yes, it is.

CHAIRMAN WALLIS: All this other stuff is very misleading.

DR. SCHROCK: Was this last equation one that you can put a number on in the EPRI report, RETRAN report?

DR. PAULSEN: I am not sure if I've got the latest copy that was mailed.

DR. ZUBER: I think it's 236 or something like that.

DR. PAULSEN: Must be about 2.3.

CHAIRMAN WALLIS: 2.3.10 is in revision 5.

DR. PAULSEN: It's more like 10. Twenty-six is the one after we get some of the area change.

DR. ZUBER: You are right.

CHAIRMAN WALLIS: It's 2.3.10 in 5. There's 5(b) where it's somewhere else. In version 5(b) it's 2.3.10.

You see, you write down the average momentum of cell is All k over 2 plus All k plus 1 over 2 times W. Well, that's not resolved in any direction. Okay.

(Slide change)

DR. PAULSEN: So what we have come up with then is a scalar equation of motion.

CHAIRMAN WALLIS: Wall forces disappear.

DR. PAULSEN: We have the pressure force in effect and the --

CHAIRMAN WALLIS: You see, the problem with wall forces disappears -- we know that the sort of token bucket turns the flow because of a wall force. You can't make it disappear. Even someone who knows no math at all will tell you the force on the wall becomes as a momentum balance. Don't need to know any math at all.

DR. KRESS: But momentum is made up of direction and mass times velocity. So wall forces generally only affect the direction. If you're talking about integrating along a stream line, I think those wall forces just sort of change the direction, and you don't really need them.

CHAIRMAN WALLIS: As long as you don't have things like changes of area.

DR. KRESS: That's right.

DR. PAULSEN: And that's basically what's being done, is integrating along the stream line.

CHAIRMAN WALLIS: See, you don't use that rationale at all.

DR. KRESS: If you had started with that rationale, I think we would have a lot less trouble.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: See, I don't know what we are doing here. Are we helping you to devise an acceptable rationale?

DR. PAULSEN: Well, I think we're coming to understand maybe where your problems are.

CHAIRMAN WALLIS: I thought they were obvious two years ago, but nobody listened.

DR. PAULSEN: I think we've covered them in a little more depth now, and I think --

CHAIRMAN WALLIS: You went back to the same sort of thing. Except for the Porsching rationale, you really have the same.

DR. ZUBER: Since you see where we are coming from, you know where you are going to? I'm quite serious. I mean, you see our problems, basically dynamics. Hopefully, you said you have that equation you agreed to. Now where are you going?

DR. PAULSEN: Well, that's not my decision. That's up to EPRI, but I think we can relay word that we now understand your concerns, and maybe be able to come up with a resolution.

DR. ZUBER: See, what they said about this -- This was obvious two years ago. For whatever reason, arrogance or ignorance, you never addressed it, and now it's facing us straight, and you are putting kind of a burden on NRR. We are becoming critical, and you are just writing --

DR. PAULSEN: Well --

CHAIRMAN WALLIS: That's very unfortunate.

DR. ZUBER: It is really sad and very inefficient way of using money and time.

DR. PAULSEN: Well, we tried to work with the staff, and I think their intention was to try and relay your concerns.

DR. ZUBER: Well, you were here at the meetings.

DR. PAULSEN: And our intentions were to try and resolve those concerns, and somehow between the two of us we didn't.

CHAIRMAN WALLIS: I was wondering if we could go to the next one before lunch, just to get it out of the way.

DR. SHACK: I still have one problem, even with this equation. That is your momentum term is really a V.NC, and you've lost the V.NC and replaced it with the V-Normal.

DR. PAULSEN: This equation?

DR. SHACK: Yes.

DR. PAULSEN: Okay.

DR. SHACK: If you just go back a step, go back to 11 or go back to 9 --

DR. PAULSEN: Is it on 11 or is it 9?

DR. SHACK: Well, try 9, because that shows the dot product. Okay, now how does V-dot-n-phi end up as V-normal? So it's V-dot-n-phi on this graph --

DR. PAULSEN: On this graph?

DR. SHACK: No, no, on the lefthand side of the equation, V-dot-n-phi. Now go to 11, and it's

just V. You've lost the dot product.

CHAIRMAN WALLIS: Right. He hasn't resolved the momentum.

DR. SHACK: You haven't resolved the momentum.

CHAIRMAN WALLIS: No, he hasn't.

DR. SHACK: You better stick to a straight pipe.

CHAIRMAN WALLIS: That's what I was saying. With two straight pipes, he's got his L1 and L2. He doesn't resolve them in any way.

Now there is a problem. I guess we can't leave it alone. This W that you have here resolved -- W is a scalar.

DR. SCHROCK: That's right.

CHAIRMAN WALLIS: So when you start resolving W, as we'll see if we get to it at the flow around the bend, you get into real problems. I think we totally disagree with your momentum flux terms and even the simple thing of your example of flow around the bend.

DR. SHACK: But his W-phi is just V multiplied by Row A. Then he divides by Row A.

CHAIRMAN WALLIS: Yes, but you see, when you look at his flow around the bend, the momentum

term in there doesn't fit any of the patterns. It's something else. So maybe you have to have lunch first, but we are going to get to that, I think, too.

So there's a danger in saying W resolved in the direction, because W is a scalar quantity. You have to be very careful about it. I think it's possible to do it, but you have to be damn careful that you know what you are doing -- what you mean by it, because it's not a physical quantity. It's something you've artificially contrived.

DR. PAULSEN: One of the things that we have corrected was that there was an error in the momentum flux term that Dr. Wallis pointed out --

CHAIRMAN WALLIS: This was the cosine of something?

DR. PAULSEN: There was a missing cosine or an extra cosine. There was an extra cosine, and that has been corrected.

DR. SHACK; So you got rid of one, and you lost another one.

DR. PAULSEN: And as we have mentioned, we've had Dr. Porsching review this, and --

CHAIRMAN WALLIS: That's very interesting. I found that interesting to read. But of course, there is a long history of fluid mechanics and

attempts to deal with this sort of problem. So either there's a revolutionary insight or -- May be, but strange it comes out of the blue.

I think what the difficulty with the first Porsching paper was that the kinds of averaging to get the pressures somehow got confused. P_k, P_{k+1}, in yours weren't the same as in his, and all that. I think you have tried to resolve that now.

DR. PAULSEN: I think so.

DR. ZUBER: Did you say tried?

CHAIRMAN WALLIS: Tried to, yes. I said tried to.

DR. PAULSEN: And this was basically the incorrect term where this -- we basically had that P_k resolved in that psi direction squared. As a result of that, we have looked at what effect that might have on users in the field using the code.

We filed a trouble report probably about two years ago that identified that to users, and we went back and looked at how that error might effect situations. As it ended up, it was probably fortuitous, but most user models have angles of zero or 90 degrees where that error doesn't actually show up.

CHAIRMAN WALLIS: I think, when we get to

-- I think this afternoon we should look at sort of your bend model and your downcomer and so on. I think I still have real troubles with your angles, because you have sort of momentum, if it's going out in this direction, it's resolved -- disappears, because it's in the Y direction and not the X direction; whereas, in reality the momentum in the whole thing has to be accelerated somehow.

So we have some problems with angles of 90 degrees.

Can we very quickly look at the abrupt area change, because I want -- Your original figure was better than the new one, because it actually showed the sort of discontinuity, implying that these were long pipes.

DR. PAULSEN: That these are?

CHAIRMAN WALLIS: This sort of model of one-dimensionalizing this problem only works if the pipes are long.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And then there's a junction in between. So it's what I call the two-pipe-plus-junction model.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And you use a straight

pipe theory, which everyone can agree on, for each pipe. So we don't need to go over the equations. Then you do some -- You say the pressure drop is given by some sort of empirical thing. Then you eliminate the pressures, and this is two pipe plus junction model.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: It's simply saying that everything is straight pipe and junction; putting two pipes and a junction together is just a generalization of something more fundamental.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: But then you say you're going to resolve these Ws in the psi direction. You don't do that for the straight pipe, and you can't do it now.

DR. PAULSEN: Well, that's the junction. Yes.

CHAIRMAN WALLIS: You can't do it now.

DR. PAULSEN: Do we say that?

CHAIRMAN WALLIS: Yes. Your slide number 20 has the Ws in the psi direction, and that's inappropriate for the two pipe plus junction model.

DR. PAULSEN: Basically, for straight pieces of pipe.

CHAIRMAN WALLIS: No, that's the only thing you are analyzing, is two straight pieces of pipe.

DR. PAULSEN: Yes, that's right.

CHAIRMAN WALLIS: And if you start --

DR. PAULSEN: These will be the same.

CHAIRMAN WALLIS: If you start resolving in the psi direction, you get the wrong answer. You don't get Bernoulli's equation. You've got to get these squared over two. You don't get it, if you start resolving in a psi direction.

In fact, if you start saying that -- Say, if it's a momentum balance in the X direction, anything in the Y direction gets thrown away, you get the wrong answer.

DR. PAULSEN: For the straight piece of pipe, this would end up being -- All angles would be the same.

CHAIRMAN WALLIS: So you've got two pipes here.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And you are now going to resolve -- You are mixing up two ideas of the bend and the two pipes. Two pipes can be joined with a junction, but these squareds are the P squareds in

those pipes and not resolved in any way whatsoever.

DR. PAULSEN: The what now?

CHAIRMAN WALLIS: Two pipes like this.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: You analyze this one. You analyze that one. You analyze the junction. You eliminate the pressure drops of the junction. You get the pressures at the end. You end up with P squared. You don't end up with Wk, Wk over Ak^2, WK-phi. You end up with P^2 here and P^2 there, and not resolved anywhere.

That's why you need Bernoulli's, because you are going to take that final thing there with the W^2 over 2, combine it with the first two terms, and show that it looks like Bernoulli's equation for a last list system.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: That won't happen if you have a psi in there.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: You've got to have a W^2 there.

DR. PAULSEN: These cases, that psi would all be the same angle.

CHAIRMAN WALLIS: Shouldn't be there.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: No, it shouldn't be there at all. If you have flow coming in and going out at different angles, you don't resolve those terms for the two pipe model.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: Think about it. Just do it. So you've somehow mixed up your idea that you are resolving momentum with something like this, which really is a flow equation --

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: -- which is blessed by the NRC since time immemorial, because they didn't know what else to do, but it didn't have the psi in there.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And in trying to do something better, I think you've produced something which logically doesn't make sense anymore.

DR. PAULSEN: And as we'll see maybe after lunch, there are several places where we use angles, and --

CHAIRMAN WALLIS: Well, maybe after lunch we should look at that bend model where you actually take -- you lead us through, and you actually develop

the momentum in and out, and you have this strange thing, the Wx is W over 2 and Wy is W over 2, all that stuff. Can you lead us through that?

DR. PAULSEN: Which case is that now?

CHAIRMAN WALLIS: That's the simple bend which we had as an example, sort of the first thing I tried to understand, this one here in the documents to RAIs, momentum cells for an example elbow. And you have statements such as W-4Y is a half-something or other and all these things. You have things about W2 being a half-W-3. W2y being half-w-3, all those things. Can you lead us through that?

DR. PAULSEN: Okay. Where are we heading with that, I guess?

CHAIRMAN WALLIS: I think with that, it shows a fundamental misunderstanding of how to evaluate these momentum flux terms. But maybe you can convince us.

You see, the difficulty I have is you may be doing something using a different logic from what we are used to, and we are trying to figure out what that logic is. It may first appear to be wrong. It may be that, when we follow your logic, we say, well, maybe if you think in this way, which may be unusual, one could justify it or something.

DR. PAULSEN: Where there's an assumption made that's not apparent.

CHAIRMAN WALLIS: Right.

DR. PAULSEN: Okay. I don't have a slide on that.

CHAIRMAN WALLIS: I think you ought to think about this over lunch, this psi thing with the two, because I think we are -- ACRS might accept the two pipe plus junction model if that's the only thing anyone knows how to do, and you got to get on with the problem, realizing that it contains assumptions. But this sort of mixture of things where it doesn't really make sense, and there are statements that, you know, say that the pressure drop is balanced by the friction and all the other terms disappear is not true, if you're just making a momentum balance. But it is true if you're making a stream line.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So it's those kind of untrue statements that bother us. The answer may be something which is usable.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: So is it time to break for lunch?

DR. PAULSEN: And the stream line argument

kind of carries over into the complex geometry modeling.

CHAIRMAN WALLIS: But you've got to be careful. You know, when stream lines get mixed up, they are no longer stream lines.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: They don't follow a stream line. So you can get bogus answers by trying to follow a stream line. But I think we'll all agree that there isn't a simple answer to this momentum balance problem when you try to write a code, and you've done -- You've made a valiant attempt.

DR. PAULSEN: Okay. More after lunch.

CHAIRMAN WALLIS: So we will adjourn until one o'clock. We'll have a break, a recess until one o'clock. Thank you very much.

(Whereupon, the foregoing matter went off the record at 11:57 a.m.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

(1:00 p.m.)

CHAIRMAN WALLIS: We will come back into session and continue our discussion of the RETRAN-3D code. We have a request from Jack Haugh of EPRI to make a statement at this time.

MR. HAUGH: Thank you, Dr. Wallis. I appreciate that. Again, for everyone, my name is Jack Haugh. I'm the Area Manager, which is EPRI-speak for program manager for a variety of areas, including most of the safety work, and the RETRAN work rolls up to me in a managerial sense.

I think my remarks were intended to say, well, I always like after a couple of hours of discussion going on to kind of say where are we in all of this? I think the message I would like to convey is severalfold.

The first is that, regarding RETRAN itself, as has been pointed out, this code was developed as an offshoot or a derivative from older RELAP versions and so on, and there is historical material in the code development and documentation, and there are equations written and so on.

Clearly, the results of the in depth considered review by the ACRS, for example, has

demonstrated that there are places where the approach taken to try and derive a set of equations that can be used has its shortcomings.

There have been points raised, exceptions noted, etcetera, to point out that it doesn't quite do the job that it needs to do, and that there is a seeming rigor or academic rigor to it that is, in reality, not really there.

Had we to do this all over again, 20 years ago, knowing what we know now and thanks in great part to the critiques and the study given by the ACRS, it would have been done differently.

I think -- You know, I heard some comments before dealing with the momentum equation. According to Graham, it's a very difficult thing to do, that we have made, I think he said, a noble attempt. Novak said an heroic attempt, which I must say heroism is wonderful, but I don't know.

If it gets you into trouble in the end, maybe it's not so smart, but the bottom line is, you know, I think your observations had, had you started with something more simple -- you know, go to friend Bernoulli, make a few statements that you're connecting a bunch of linear segments -- Assuming you have a straight pipe, you accommodate some of these

things like the bends and the separation around the bends and the awkwardness with pressures and so on. You take a loss term in there, and you try and just fit it in there, and you come up with this quasi-empirical sort of thing which you tune to the plant and which you utilize or demonstrate its applicability to your own minds by how you match the plant conditions. What else needs to be said?

All right. Now --

DR. ZUBER: Sensitivity analysis.

MR. HAUGH: I beg your pardon?

DR. ZUBER: Sensitivity analysis.

MR. HAUGH; Yes. I mean, that's always an important thing, because you need to know the range of applicability of things.

CHAIRMAN WALLIS: There is something else that needs to be said. I've said it this morning. There's a public out there watching. It's not just you and the plant and the NRC that are in this. There is a theater as well of public opinion.

So it has -- you have to say things in a way which is not going to give people qualms.

MR. HAUGH: Yes. Well, we certainly appreciate that, and I can assure both the committee and the public that that is certainly always our

intent as EPRI.

Now at this point now it becomes where do we go from here, having said what I just did. I had thought that, rather than belaboring the point by my assuring you that we understand the message that has been given to us, that continued working our way the equations and finding the exceptions or the confusions and so on is perhaps not the best utilization of your time this afternoon, nor is it mine.

CHAIRMAN WALLIS: Well, there is one thing I would like to do, though. I would like to look at this bend example, because it seems to show -- You know, it's actually how you use something. It's not just a derivation.

MR. HAUGH: If you wish, we would be very happy.

CHAIRMAN WALLIS: I have some problem with even if you believe the equation, how do you use it the way you use it. So I think we need to do -- That's the second part of my thing.

First, you have to establish the equations. Then you have to sort of show that they can be used in a sensible way, and then you have to show that they give good results for a plant.

MR. HAUGH: Yes. And that is where, from

my perspective, I would like to see the discussion ultimately move today. That is to say, we finally come up with some formulation that we believe works and can be utilized in a computer code and can be utilized to replicate the plant transients within ranges of applicability, and that if those ranges are understood by the users -- and we take pains to be sure that they do understand those ranges of applicability -- that the demonstrations that we can match the plant data are very important, a very important consideration to see that the tool is useful for its purported purposes.

That's all I would like to leave you with at the moment, and hope that we can get onto that first presentation that the Chairman has asked for, and then to what we have done by way of validation.

CHAIRMAN WALLIS: So we've already -- Perhaps you are suggesting -- We forget the first question I asked, which is what equations you are using and are the derivations valid. We've already been over that terrain. You don't want to go over it again.

MR. HAUGH: Yes. I think, you know, it's been made quite clear today that there are shortcomings.

CHAIRMAN WALLIS: Right. And now we've got to look at how they are used. I think the bend is an example. I would personally like to see how you propose to use them for something like this, you know, the downcomer and the lower plenum, because that was all that we got response to the RAI is this is how we set up the cells.

I couldn't figure out in any way how you write a momentum equation for those cells as set up. If we could get some guidance and if you are ready to do that --

MR. HAUGH; Well, I'll ask Mark to come up here. I'm not sure to what degree of completeness he has that laid out, but we'll ask him to do so.

CHAIRMAN WALLIS: If it's not completed here and then you want to come before the full committee next week, we are going to have to say that we still have a lot of unresolved issues, and it might make more sense for you and us to agree that these are the unresolved issues, and then for us to meet as a subcommittee so before we go to the full committee with all that's implied there and letters to the Commission and all that stuff, we actually have some better understanding of what you think in the final version of things is sort of an acceptable

presentation before that committee. I think we need to do that.

MR. HAUGH: Well, perhaps that is the better way to proceed at this point.

CHAIRMAN WALLIS: It would really be premature to go next week with something which is still -- it still has all these unresolved issues in it, which I don't think we are going to resolve fully today.

DR. ZUBER: I am gratified that you recognize our concerns. The only questions I have is what are you going to do about it?

MR. HAUGH: The first thing is, if we can agree that the code does work and does do its job properly -- Well, perhaps before shaking your head no, you'll let me finish. Okay? Body language speaks reams, Novak.

DR. ZUBER: Look, I want for you to be successful.

MR. HAUGH: I know you do very much, and we certainly appreciate that.

If it is simply a matter that the derivations, again, purport a degree of rigor and correctness that is not there, there are easy ways to alert all of our users to this fact. The RETRAN

newsletter can carry that in depth.

If it is necessary to revise the code manuals, that can be done. But I wouldn't make an ad hoc commitment to do so at the moment. It depends on the nature of the need.

CHAIRMAN WALLIS: Well, maybe it will show up. It will be clearer to you when we look at something like this bend. Here you are saying, okay, we can accept this equation as being usable, let's use it.

MR. HAUGH: Yes.

CHAIRMAN WALLIS: Then when we use it for the bend, you seem to get results which are very peculiar; and if it doesn't work for this simple bend -- results look really peculiar for that bend -- how can we sort of say that this is now going to be good for other geometries. So maybe we need to --

MR. HAUGH: Well, I appreciate the nature of the comment and, hopefully, we are going to be able to address that to your satisfaction this afternoon.

CHAIRMAN WALLIS: So even if we accept the equation, then the way it's used seems to raise some other questions.

MR. HAUGH: Yes. I appreciate that.

CHAIRMAN WALLIS: I don't think we are

ready to move on to the question of does the code as a whole fit some plant data or something, because that could be for lots of other reasons, that someone has tweaked this or chosen this. You know, there are options in the code to make things work.

That's a big whole other --

MR. HAUGH: Well, let's take this in the next step, as you have proposed, and let's go from there. Upon completion of that, perhaps we'll know whether it's advisable to proceed to the full committee.

CHAIRMAN WALLIS: I don't think we're going to be ready for the full committee. I don't think this subcommittee will know what to write. I'm not sure you will know what to say.

DR. SCHROCK: I'd like to just address a point that came up earlier today that I think is one that you need to pay attention to. That is this idea that these codes have to be in the hands of experts, people who know what they are and what they do and how to make them function correctly in their application.

The difficulty that you have with the group of people that are out there that know how to run these codes is that they have been oversold. That's my experience in talking with many of them.

They have been oversold on the rigor that's in the code, and so many of them really believe -- I mean sincerely believe that they learn physics by operating these codes.

That's a dangerous situation. That's a dangerous situation.

MR. HAUGH: Well, if there are misperceptions of that sort, we'll do our best to disabuse them of that.

DR. SCHROCK: I don't know if you recognized that.

MR. HAUGH: I appreciate the nature of your comment, certainly.

DR. SCHROCK: All right.

MR. HAUGH: With that, I'll ask Mark to come back and resume his presentation, but to focus it on the matter raised by Dr. Wallis.

CHAIRMAN WALLIS: Thank you. That was very helpful. Thank you.

DR. PAULSEN: The point I was thinking about resume this discussion was starting at the point where we have what we call our RETRAN flow equation and then discuss how it's applied to more complex geometries.

CHAIRMAN WALLIS: I'd like to see it

applied to simple geometry first.

DR. PAULSEN: A simple geometry?

CHAIRMAN WALLIS: Like this bend here or the T, because this business of I's and J's, you can just get lost in generalities. But if you would show us how it works for this sort of thing -- I have real problems with that and, unless I get an answer, I'm going to have to write it up in some form to form some other record, which we don't want it to be.

The same thing with the T, the treatment of the T is very strange from a momentum balance point of view, too, and it's a simple thing. I think it's much better to do these examples than it is to go into something where you have some generalized math, which -- it's hard to get hold of.

DR. PAULSEN: Okay. so the T -- You're looking at the newer write-up, I believe.

CHAIRMAN WALLIS: Whatever your latest version of the bend is.

DR. PAULSEN: Okay. Which revision, I guess?

CHAIRMAN WALLIS: This is revision 5.

DR. PAULSEN: Revision 5? Okay.

CHAIRMAN WALLIS: I think the answer is the same as in revision 1. No, I think you've got a

factor of root 2 in there.

DR. PAULSEN: There was an error in the first one where we were missing a cosine.

CHAIRMAN WALLIS: You changed the other root 2 in there. Right. So either version you could look at and explain to us how you get the terms and what's going on.

Are you prepared to do that? Do you have transparencies of --

DR. PAULSEN: Okay. I don't have transparencies of that example. I do have a sample problem where we actually ran an angle. That might address your question. Shall we take that approach and then --

CHAIRMAN WALLIS: No. I mean, I have questions about how W-2X is a half-W-2 and things like that. I mean very simple questions. If you can remember the problem, maybe you can answer that.

DR. PAULSEN: Basically -- Let me just put this elbow up.

CHAIRMAN WALLIS: I thought you would have this ready, because I -- Maybe I responded to Lance Agee and said you guys should come with transparencies of all the RAI answers. I know that message got through. I don't know quite who reads the messages.

DR. PAULSEN: I didn't bring transparencies for that T example, but basically -- Let's start here. I think I'm losing my battery.

CHAIRMAN WALLIS: You see, the problem is, when I made the presentation two years ago, I had a detailed critique of the bend, the T and the Y. I have problems with terms in all of those and, unless there's some sort of answer, those difficulties will remain, and they shouldn't remain.

DR. PAULSEN: My impression of your critique of the Y initially was the fact that we were missing a -- that, basically, there was an error in what we had.

CHAIRMAN WALLIS: I think I had about six critiques of the Y.

DR. PAULSEN: I mean of the elbow.

CHAIRMAN WALLIS: Oh, the elbow, yes.

DR. PAULSEN: For the elbow.

CHAIRMAN WALLIS: Well, let's look at the example you actually work out, this one here.

DR. PAULSEN: Okay. So we'll just go back then.

CHAIRMAN WALLIS: You can get started on this.

DR. PAULSEN: Is he going to make a Vu-

graph?

CHAIRMAN WALLIS: Well, yes, he is, but you might get started on it. So we have W_1 and W_2 and W_3 defined at the edges of mass balance.

DR. PAULSEN: Can you hold that up? I'm just trying to remember --

CHAIRMAN WALLIS: You don't have a nodalization. You could take the one that Ralph has given you there. So the 1, 2, 3s are the boundaries of mass and energy cells, and then the 1-circle, 2-circle are the boundary of the momentum cell.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: Right?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And you have to decide what your W_1 and W_2 bar are, because they are in your momentum equation?

DR. PAULSEN: That's correct, and they happen to be the -- Then if we were looking at this momentum equation at this point here, we have a boundary in the way this is drawn at that these two locations.

So at those points we need to know those velocities.

CHAIRMAN WALLIS: Right. So I think what

you do is you say W_1 bar is a half-W_1 plus W_2. It's sort of an interpolation of --

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: Then you suddenly say it's equal to W_2. So you're assuming some sort of--

DR. PAULSEN: That's at steady state, I think.

CHAIRMAN WALLIS: But it isn't steady state. The whole thing is a transient analysis.

DR. PAULSEN: This was just a steady state example.

CHAIRMAN WALLIS: No. This is the example of a transient -- Okay. Well, that's what really confused me, because you seemed to invoke the steady state all the time. But, really, you are showing us how to do a transient.

DR. PAULSEN: That's correct, and --

CHAIRMAN WALLIS: So what you put in your transient is a half-W_1 plus W_2. It's not W_2.

DR. PAULSEN: That's correct. We put in the one-half, and the specific case we were looking at was a steady state.

CHAIRMAN WALLIS: That's very misleading. I think you don't -- Well, but the whole purpose is to develop a dynamic transient equation, and it's very

misleading if you suddenly invoke steady state, which is not valid in a transient.

So we should take this to be half-W_1 plus W_2? All right.

DR. PAULSEN: Yes. And in fact, the way -- We need a model, and you can call it interpolation or whatever. You need something to get the boundary velocities or flows at these --

CHAIRMAN WALLIS: Okay. So let's say you've got W_1, W_2 and half-W_1 plus W_2 going in. Right?

DR. PAULSEN: Right. So for this one we just do -- There's actually a model where we can either use a donor cell approach or --

CHAIRMAN WALLIS: But you used the half-W_1.

DR. PAULSEN: And that example uses the half. So it would use the average --

CHAIRMAN WALLIS: So what goes in as a halfW_1 plus W_2? Could you write that on there or something so we can see what we are doing?

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: So that's called W_2, that one there.

DR. PAULSEN: This one here?

CHAIRMAN WALLIS: All right. And W_1 is

what goes in, and at your point at the momentum cell it's a half-W_1 plus W_2, that lefthand thing. Okay. That's going in.

Now we need to know -- Now you say W_1 psi is W_{1x}. What does that mean? It would be 1-bar-x. You're saying that psi is in the x direction.

DR. PAULSEN: That's in the direction of this angle.

CHAIRMAN WALLIS: So you are making a momentum balance in x direction?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Now for coming out you say W_{2x}-bar, that's coming out of that 45 degree thing there.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: W_{2x}-bar is a half-W_2. Where did that come from?

DR. PAULSEN: It would also be half of this other flow.

CHAIRMAN WALLIS: Well, is the idea that it's a half of W_2 in x direction plus W_3 in x direction, and there is no W_3?

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: But you can't resolve flow rates that way. The flow rate across that is a

$1/2W_2$ plus W_3, same way as for the other, because flows are continuous. They don't -- When it goes around the bend, flows are conserved.

DR. PAULSEN: The flows are conserved. That's right.

CHAIRMAN WALLIS: You don't conserve just the x direction of the flow. You can't say that W_2-bar is a $1/2W_{2x}$. It doesn't mean anything. You can't average the x direction velocities flow rates in a pipe. The flow is continuous. It goes around the bend. All of W_2 goes around the bend, not half of it.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So how does W_{2x} get to be $1/2W_2$?

DR. PAULSEN: In fact, I think what we end up here is that this flow will be oriented in this direction, and it will end up being equal to the steady state -- for the steady state --

CHAIRMAN WALLIS: But you say W_{2x} is a $1/2W_2$, and W_{2y} is $1/2W_2$. So that, to me, says half the flow is going in the x direction and half of it is going in the y direction. You've got a statement here: W_{2x}-bar is a $1/2W_2$ at that boundary. I'm trying to understand what it means.

DR. PAULSEN: Which equation is that that

you are looking at?

CHAIRMAN WALLIS: It's in the middle of page II-93. You've got the same edition that I have, Revision 5, an non-numbered equation, the fourth one down: W_{2x}-bar is a $1/2W_2$.

So you are explaining how to use the code. That's why we are going into this, and I don't understand that statement at all. Then W_{2y}-bar is a $1/2W_2$ is the next line.

What it seems to say is that the flow in the x direction is half the total flow. A flow in the y direction is a half the total flow. Is that what it means?

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: But that doesn't make any sense. If you draw a boundary in the y direction, you've got the whole flow going across it, and equally true for the x direction. You can't resolve flow rates in x and y directions. You just cannot do it. It's non-physical. Flow rates across any section in that pipe are the same.

DR. SHACK: But these are his closure relations, not his conservation equation.

CHAIRMAN WALLIS: They are what he is going to put into his equation to use.

DR. SHACK: He's going to eventually end up conserving mass, but at the moment he's not doing that.

CHAIRMAN WALLIS: No. He's using -- These are the terms that go into the momentum equation, this $1/2W_2$.

DR. SHACK: Right. But he's calculating them from his closure relations, not from a conservation relation.

CHAIRMAN WALLIS: But what do they mean? Where are they coming from?

DR. PAULSEN: It is simply an average. It's an interpolation.

CHAIRMAN WALLIS: But you can't average -- W doesn't have components. So you can't average x direction component of a scalar.

DR. KRESS: I thought they come about because it's a 45 degree angle and --

CHAIRMAN WALLIS: That comes later.

DR. KRESS: -- and that gives it one-half.

CHAIRMAN WALLIS: No, there's a 1 over root-2 that comes later for that.

DR. KRESS: Oh, there's another one?

CHAIRMAN WALLIS: Yes.

DR. SHACK: But if you go back to this 3-

28, those are his closure relations. Those come from --

CHAIRMAN WALLIS: I'm saying it doesn't make any sense.

DR. SHACK: Don't ask if it makes sense. Just follow the rules and see where you end up. Give him a chance.

CHAIRMAN WALLIS: No, but what does the rule mean?

DR. SHACK: He defines the closure rules. Let him do that.

DR. ZUBER: What does it physically mean?

CHAIRMAN WALLIS: It doesn't mean anything.

DR. SHACK: It means he's saying the velocity is the average of the -- you know, the in and out velocities.

CHAIRMAN WALLIS: It's not. It's not a velocity. It's a flow rate.

DR. SHACK: Well, the quantity.

CHAIRMAN WALLIS: But he's saying it's the component of a flow rate in an x direction, which I say doesn't exist. Flow rates don't have components.

DR. SHACK: Just think of it as a variable, and he's averaging the variable.

CHAIRMAN WALLIS: You can define any variable. It means nothing.

DR. SHACK: But you know, we're doing mathematics here now. You know, we've got a quantity that's varying. So we know what it knows, and we have to find -- interpolate a value somewhere else.

CHAIRMAN WALLIS: No, because we are going to use it in a momentum equation. It's got to mean something.

DR. SHACK: Ah. When he uses it in a momentum equation, it means something. But the equation he is writing down now is simply how he is going to interpolate these discrete values.

CHAIRMAN WALLIS: What you are telling me is you understand the logic that he's using, albeit it may be unphysical. Right.

DR. SHACK: Yes. You know, it's the sort of thing you would do in a mathematical thing when I've got discrete quantities and I need to get a value somewhere.

CHAIRMAN WALLIS: But I'm saying that I don't know what then W_{2x} is. If you are going to average something, you better tell me what it is.

DR. SHACK: Well, in this case it's just a variable. You know, when he goes to his momentum

equation or he goes to his conservation equation, he had better end up conserving mass.

CHAIRMAN WALLIS: This has nothing to do with conserving mass.

DR. SHACK: No, this doesn't. This is an interpolation scheme.

CHAIRMAN WALLIS: So let's go back to where we were. We've got W_{2x} is $1/2W_2$, and let's then explain that in terms of interpolation scheme.

DR. PAULSEN: Okay. I'm trying to get my diagram here to match.

CHAIRMAN WALLIS: W_2-bar is across the 45 degree. Right?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And W_2 is coming in there, and W_3 is going out the bottom, and I'm asking what W_{2x}-bar is.

DR. PAULSEN: Okay. The model that we have used, there's either the donor or the average, and you've picked the average.

CHAIRMAN WALLIS: Right. You picked the average.

DR. PAULSEN: Yes, that's right. I'm sorry. So for this particular case, what we would call the flow that's normal to that surface --

CHAIRMAN WALLIS: In the x direction.

DR. PAULSEN: -- in the x direction is going to be basically -- well, it will be $1/2W_2$. Is that what we've got?

CHAIRMAN WALLIS: Yes, $1/2W_2$ you say it is. Right. Why is not $1/2W_2$ plus --

DR. PAULSEN: It's $1/2W_{3x}$, but W_{3x} is equal to zero. The W_{2x} back at the ranch is W_2, because it's in that direction. W_{3x} is zero, because it's straight down. So when you do the average, you get half.

CHAIRMAN WALLIS: But in the momentum equation we need to know the mass flux across the area. We don't need to know some strange W_x.

DR. SHACK: At the moment he's just interpolating. He's not doing momentum yet.

CHAIRMAN WALLIS: No, but he is going to.

DR. SHACK: Yes, when he does momentum, then nail him momentum, but at the moment let him interpolate.

CHAIRMAN WALLIS: Well, let's say now -- My critique would be you can't resolve flow rates in x and y direction. So what you are doing is something fantastic rather than representing physics.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: I mean, you could do it

if that's the rules you are going to play by, according to Dr. Shack, but it's a very funny game.

DR. PAULSEN: And what we are doing is trying to resolve things in the x and y directions.

CHAIRMAN WALLIS: Yes, I understand that's what you must have been thinking you were doing. Right.

DR. PAULSEN: So the flow in the x direction for this particular surface would just be 1/2 of W_2.

CHAIRMAN WALLIS: And in the y direction it's $1/2W_2$.

DR. PAULSEN: In the y direction it's $1/2W_3$.

CHAIRMAN WALLIS: What does flow in the x direction mean, though? How do you define a flow in the x direction?

DR. PAULSEN: That's going to be what we take to be the velocity divided by the density.

CHAIRMAN WALLIS: Times some area?

DR. PAULSEN: Times an area.

CHAIRMAN WALLIS: But then it would be a root-2, wouldn't it, if it's a velocity?

DR. PAULSEN: It's a what now?

CHAIRMAN WALLIS: The square root of 2, if

it's a velocity, rather than a half.

DR. PAULSEN: The half is simply the averaging scheme that was developed. If we use a donor approach, then it's just the upstream turn.

CHAIRMAN WALLIS: Let me say this. In steady flow $W_2 = W_3$ --

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: -- equals W_1-bar equals W_2-bar, all the same. Right?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So W_2-bar better be W_2, and then its x component is $1/2W_2$?

DR. PAULSEN: This term? The x component at this location will be half.

CHAIRMAN WALLIS: All the Ws are equal.

DR. SHACK: Part of the problem is he thinks of W sometimes as a mass flow rate and sometimes it's a velocity.

CHAIRMAN WALLIS: But it's neither in this sense. It can't be either. The flow rate is W across that surface. The x direction velocity is x over root two. It's not a half.

If you are using a mass balance, the flow rate over there is the total flow rate, not half of it. So when we get to the momentum equation, I guess

we'll see that.

So when you get down to the bottom of the page, you are going to take W_2 over 2, which is your W_x-bar, divided by A^2, and you are going to multiply it by the velocity it takes with it, which is W_2 over A^2.

I guess we would agree that the velocity component resolved is 1 over root two, but I would maintain, if you are going to make a momentum balance, you've got to multiply it by the whole flow rate, not the flow rate in some direction. I mean, your whole momentum equation was the flow rate times component of velocity, not flow rate component times component of velocity. So that half shouldn't be there.

The problem I have with this is that there seems to be a fundamental conceptual mistake in a very simple example, and this presumably is in all the more complicated geometries, too, to some degree, but even more difficult to figure out because they are more complicated.

If you are giving the user advice to do this for this simple bend, then I don't understand how we can believe the advice for a more complicated geometry. This doesn't make sense.

DR. PAULSEN: The point is that we don't

really use this in modeling RETRAN.

CHAIRMAN WALLIS: Well, why do you present it then?

DR. PAULSEN: Well, that's a good question.

DR. ZUBER: Well, how do you use it?

DR. PAULSEN: It was going to be an illustrative example to show simply that, once you go around the bend, you get the pressure back. You will see an increase in pressure as you go into the bend and, once you are around the bend --

CHAIRMAN WALLIS: That won't wash. I mean, the user has to write a momentum equation for this cell, 1-2. Right? It has to be there somehow. So what does RETRAN use for the momentum equation, the actual equation used for that cell?

DR. PAULSEN: For this cell? In most cases, if the user does not input angles, he is simply going to use that momentum equation -- that flow equation that we looked at earlier.

CHAIRMAN WALLIS: So there won't be any 2 or root two in there?

DR. PAULSEN: Unless he puts in an angle.

CHAIRMAN WALLIS: So you are making it arbitrary whether or not there is a factor of $1/2^2$?

Could be there or not there, depending on what the user chooses to do?

DR. SHACK: Well, I think what he's saying is that, by the time he gets to the end of the elbow, it won't make any difference whether he modeled it as an elbow or as a straight pipe --

CHAIRMAN WALLIS: If you get to the end of the elbow. But you might not. You might discharge into a container.

DR. SHACK: If he had that geometry, you would do something different. But if he's just doing an elbow versus a straight pipe --

CHAIRMAN WALLIS: You see the problem I have. You have a fundamental equation, one is to believe can be used. You use it for something like this half an elbow, and it doesn't make sense.

DR. PAULSEN: Okay. I guess the point we were trying to show here was that once you get around the elbow, everything comes back, that since it's a recoverable loss, and you really don't need to include the detail of elbows in loops.

CHAIRMAN WALLIS: I don't think that's necessarily true, because then you would have to use your y component of momentum or something on the other side of it.

DR. PAULSEN: That's right, and it ends up canceling out.

DR. SHACK: He's got his momentum equation 3-37-C to show his pressure drop in the first -- you know, as he coming through there in the first part. Then he is going to get a pressure recovery when he computes pre-3 minus T-1.

CHAIRMAN WALLIS: That's not really kosher. I mean, you can say we calculated this whole thing wrong up to 2, and we make the same error in reverse from 2 to 3. So the error is irrelevant. That's -- I don't think that is really respectable.

Now maybe if you went around in a complete circle, you might find the errors build up instead of recovering.

DR. PAULSEN: Well, I guess it looks like maybe that we haven't addressed the issue here on the elbow example. We'll have to go back and look at that --

CHAIRMAN WALLIS: I think it's really fundamental. This is supposed to illustrate the use of an equation, and doesn't reinforce the equation at all.

DR. ZUBER: And then if you cannot explain the simplest case, how can one believe -- at least,

how could I believe or Graham or anybody else -- then you got a more complicated case.

CHAIRMAN WALLIS: What would be on the lefthand side if it were a transient? You have a d by T of something with a L_1 and L_2 in there?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Then you would have Dr. Shack's problem, that the L_1 and L_2 are not in the same direction; are they resolved in some way? That's not explained either.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: So it seems to me that you can't explain this simple thing. How should the user use it for something more complicated?

DR. PAULSEN: Well, let's go on and look at some of the more detailed cases.

DR. ZUBER: This is the simplest detailed case, and you cannot explain why --

CHAIRMAN WALLIS: We can look at the T, too. I mean, the T has this peculiar one-fourth of W_1 minus W_2^2 in it. If you make W_2 zero, you find Bernoulli's equation has a quarter in it. Now Bernoulli's equation doesn't have a quarter in it.

So again -- I mean, I don't want to go into all these details, but I've found that in writing

my review of this stuff, I was writing page after page of stuff saying that this doesn't make sense.

DR. PAULSEN: Okay. It sounds like we still have something to do with the elbows.

CHAIRMAN WALLIS: You must have a reasonable excuse for the equation you are using, and you must have a reasonable exposition of how it applies to some simple geometries that doesn't appear to have some logical disconnects in it. Then I think it's acceptable.

DR. PAULSEN: Okay. The point that I would like to make at this point is the fact that initially we started out trying to show rigor and including the angles, and that was probably a mistake; because we don't really use angles in a code.

CHAIRMAN WALLIS: But even so, if you are going to use the two pipe plus junction model, how does it apply to a bend? Still the same issue. How does it apply to the downcomer?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: You're just going to say there's two straight pipes and a junction up there? Maybe there is there, but I don't see any two straight pipes here. I see a bend. So I don't know how to define my two straight pipes.

DR. PAULSEN: Basically, it does use a straight pipe model, a two straight pipe model.

CHAIRMAN WALLIS: But it isn't, because it's got this root 2 --

DR. PAULSEN: And that comes from the angle piece that we normally would not include.

CHAIRMAN WALLIS: See, the genuine -- If you model this as two straight pipes, you wouldn't have the factor 2 or the factor root 2 in there at all. That's my contention. If you simply took two straight -- Excuse me -- with a 45 degree bend like that and said the bend is a junction, you wouldn't have any of those root 2s and 2s in there.

DR. PAULSEN: That's right. Because normally we would model an elbow as a node -- straight node that way and a node in that direction.

CHAIRMAN WALLIS: Right. And there wouldn't be any of these 2, root 2s and stuff.

DR. PAULSEN: No. There's none of the root 2s.

CHAIRMAN WALLIS: So you have an equation which differs from the other one by a factor of -- what, 2.8 or something? Well, in that case we should do sensitivity studies to see when the factors vary between half and 4 or something. Does it make a

difference or something?

DR. PAULSEN: Right.

CHAIRMAN WALLIS: And it may well be that what you've just said is that when you are really worried about a circuit, everything sort of washes out in the end anyway, and random fluxes don't matter because what you lose here, you gain there may well be true.

DR. PAULSEN: In this particular case, most applications where we have elbows would not use that 45 degree angle. We would do something either like that nodalization or something like that nodalization.

CHAIRMAN WALLIS: So I guess we get back to Ralph Landry's point, that what's in the code and how it's actually used is different from the exposition in the documentation, and the code seems to work, and the documentation in that context is irrelevant.

DR. PAULSEN: And I guess maybe what we need to do is focus on that. There are --

CHAIRMAN WALLIS: But you see the problem I have. I'm coming from the outside. I'm like the naive sophomore student trying to understand this, because my professor says go and figure out what they

are doing with this bend. I come back, and I say, prof, I just can't figure out what they are doing. And that's not good.

DR. SCHROCK: Do I understand you put a loss coefficient in when you do what you've shown here?

DR. PAULSEN: Yes. In something like this there would be a loss coefficient.

CHAIRMAN WALLIS: And there is no pressure from the wall. There's no force from the wall.

DR. PAULSEN: No.

CHAIRMAN WALLIS: So there's nothing to turn the flow to the other direction. There is no force in the x direction to turn it around the bend?

DR. PAULSEN: In this case?

CHAIRMAN WALLIS: There's no force from the wall.

DR. PAULSEN: Just the pressure difference that we would see.

DR. SCHROCK: So that is strictly modeling straight pipe -- stringing together straight pipes to represent the actual geometry.

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: Maybe you better go back and say that's just what you are doing.

DR. PAULSEN: That's probably the best approach.

CHAIRMAN WALLIS: And make all the excuses -- Well, don't make excuses. This is engineering. We understand engineering approximations. We understand you do the best you can do, and that you test to see if it works, and we would buy that.

We cannot buy what appears to be logical, sort of non sequiturs. So you see, I have a problem not just at the formulation of the equations but in the examples showing how they are used. If that's not the way you really use them, then you need to show us examples of how you do really use them.

DR. PAULSEN: And that is kind of where I was headed.

CHAIRMAN WALLIS: And that's where I had a problem with the T, because the T seemed to me to give some funny results, but maybe it's okay for nuclear safety.

DR. PAULSEN: Well, I've got some examples of a T where we might need to include some of the effects of angles.

DR. SCHROCK: There is also the downcomer.

DR. PAULSEN: Yes. Shall we just skip over the 1-D stuff. I think you probably --

CHAIRMAN WALLIS: Well, yeah, I guess we can. We're going to spend a lot of time -- The T is not 1-D, because it comes in one way and goes out the other.

DR. PAULSEN: Right.

CHAIRMAN WALLIS: And you have this mysterious magnitude of the volume sent at the flow, and you have again this mysterious W_{1x}, W_{1y}. Stuff is coming in in this direction, but it seems to have a component in that direction even though it's all going in this direction.

DR. SCHROCK: Then there's issues of flow -- or phase separation in Ts.

DR. PAULSEN: That's right, and none of that is really handled. That all has to be done with sensitivity studies or constitutive models.

CHAIRMAN WALLIS: Frankly, everybody knows you cannot model a T with a simple momentum balance. You cannot do it.

DR. PAULSEN: And basically, what we have -- the form that we have after responding to one of the NRC questions is a form that pretty much maintains the Bernoulli had the p plus rho-v, one-half rho-v.

CHAIRMAN WALLIS: What you need to do is you need to do experiments. You need to define some

empirical coefficients reflecting how much it's like Bernoulli and how much it's like momentum and capturing that, and then you have to have coefficients that come from experiments. You energy loss depends not just on one flow rate but the ratio of the flow rates and things like that.

When you have flow going all the around the bend instead of carrying on, the pressure recovery is quite different from when it was going straight on. It's not a simple problem.

DR. PAULSEN: And the real problem during an application is that those flow patterns can change, and the relative magnitudes can change. So you have to try and capture something that bounds the --

CHAIRMAN WALLIS: But there's nothing of bounding in your -- You see, your example is presented as if this is right, and if you had qualified is and said that in reality it's doing something like this and in order to get on with the problem we make this assumption which we think is bounding or something, that would, I think, help a great deal. When you just put it down as if it's right --

DR. PAULSEN: I understand your concern now.

CHAIRMAN WALLIS: -- then this psi thing

is sometimes x and sometimes y. I thought it was some intermediate angle in the bend somewhere.

I would think it needs to be fixed up. Otherwise, we may have to write a critique based on what we see. It's all we've got to go on.

DR. SHACK: Who are you going to believe, your eyes or what you hear?

DR. ZUBER: Well, my advice would be really to go and go through the entire document and really address point by point. State your assumptions, the equations, and proceed from there. This is really arm waving -- really arm waving.

CHAIRMAN WALLIS: You are still constrained to what's really in the code, and that's where we still have a bit of a mystery as to what it really does with these things.

DR. PAULSEN: And I guess that was kind of the purpose of going over these next few slides, is that --

CHAIRMAN WALLIS: But these are much more complicated things. So I have difficulty.

DR. PAULSEN: These will be some arm waving.

CHAIRMAN WALLIS: You lose me in this arm waving completely, because it gets even -- it

obfuscates the issues even more. Which one did you want to go into?

DR. PAULSEN: Well, let's just kind of go through this quickly and see if --

CHAIRMAN WALLIS: Did you want to go through 29 and 30? Okay, that's fine.

(Slide change)

DR. PAULSEN: One of the things that we have to do in RETRAN is we've got our flow equation which basically looks like the Bernoulli equation, and it came from 1-D information. We don't have anymore information than that, and now we have to try and model a complex system where we've actually got some 3-D geometry and some different flow paths.

So what we have to do is use a number of approximations on how we apply that equation then to these three-dimensional geometries. There's a whole volume of RETRAN documentation that's devoted to setting up a model for a plant that provides specific guidance for how do I model a plenum, what do I have to consider, how do I calculate a length, how do I calculate diameters when I've got these weird geometry changes.

That's all discussed in the modeling guidelines for RETRAN-2. Now that document hasn't

been rewritten for RETRAN-3D, because what is given there is equally applicable to RETRAN-3D in terms of how you set up nodalization and how you set up your input parameters for that flow equation.

So, basically, that modeling guideline provides us with some general rule as to how we would define the input. In many instances, it will provide alternate methods for calculating some of that input data.

One of the things that is required, though, is that we typically require some sensitivity studies, because we are doing approximations.

CHAIRMAN WALLIS: Well, you responded to that by the next slide, 30. That's a question, was one of the RAIs: How do you model these kinds of geometries?

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: And frankly, I looked at the tables, and I couldn't understand what any of the terms in those tables meant. So I was left none the wiser than I was before as a result of the response to this RAI.

DR. PAULSEN: There was also some -- a reference to this modeling guidelines document --

CHAIRMAN WALLIS: And if you had said,

look, here is the node, let's say the downcomer to low plenum. Let's say we've got this complicated thing we have to model. We are going to use the RETRAN momentum equation in some form. This is how we evaluate P_k, P_{k+1}, W_k, $W_{k\ psi}$, and this is the final equation we come up with; this is how we get the Ls, you know -- None of that is in this reply. So I have no idea.

DR. PAULSEN: Okay. for that information we actually referred to this modeling guideline document. It's NP-18.50, volume 5.

CHAIRMAN WALLIS: See, you're replying to an RAI or I guess it's also one we stirred the staff up to ask this question. The Table 1, Table 2 didn't help at all. I don't know what you are talking about. There are junctions which are labeled 1 and 2, and there are junctions which are labeled 2-circle and so on.

DR. PAULSEN: Okay. The circled quantities are the volumes.

CHAIRMAN WALLIS: But they seem to be the same. There's no distinction between the two kinds of junction. Then I couldn't understand these $1/2W_2$s and $1/2W_3$s. They seem to be something like the halves that you have in the bend.

DR. PAULSEN: They are.

CHAIRMAN WALLIS: Then you get this quarter-W_3^2. Well, so these have the same strange features that we didn't like about the bend.

DR. PAULSEN: Those are those boundary flows that you need at the momentum cell boundary.

CHAIRMAN WALLIS: So I guess, to be happy, it will be nice to see how you did it. When you've got, say, the lower plenum -- Look at the lower plenum downcomer. We've got four boundaries to the outside world. We've got 2 and 3 and 4 and 5. How do you get away with two pressures, P_1 and P_2 when you've got four boundaries to the outside world?

DR. PAULSEN: Okay. Let's put that slide up here for just a minute.

(Slide change)

DR. PAULSEN: That may be confusing where we actually have these two flows shown. But basically in this case, when we write the momentum equation or our flow equation, it would actually be written for just this one junction, and then we actually have to have a boundary rho vA at this surface and one at this surface of the momentum equation.

CHAIRMAN WALLIS: So is it they are in the same direction at 2 and 3? So what happens to 4 and

5 then?

DR. PAULSEN: Four and 5 are factored into this boundary condition here. They are factored into this flow with this boundary.

CHAIRMAN WALLIS: There isn't any flow at that boundary, is there?

DR. PAULSEN: That's the rho vA on this surface.

CHAIRMAN WALLIS: I understand there's no flow going into the bottom of the lower plenum.

DR. PAULSEN: What's that now?

CHAIRMAN WALLIS: No flow coming out that bottom line across there.

DR. PAULSEN: At this one?

CHAIRMAN WALLIS: Yes. Is that flow coming out of there?

DR. PAULSEN: What this boundary is is the net. It's sort of an average based on the conditions in these junctions, and I think --

DR. ZUBER: How do you determine that?

DR. PAULSEN: I have an example that shows.

CHAIRMAN WALLIS: Your momentum equation is assuming it is coming in at 2-circle and going out to 3-circle?

DR. PAULSEN: The 2-circle.

CHAIRMAN WALLIS: That's the inlet W_k, and the W_{k+1} is --

DR. PAULSEN: And then there will be a boundary on this surface, yes. There will be a surface flow on this surface.

CHAIRMAN WALLIS: And then what do the other flows do, the W_4, W_5?

DR. PAULSEN: These W_4s and W_5s are actually used to -- It's actually W_3, 4 and 5 are used to calculate this value.

CHAIRMAN WALLIS: See, if I were to use Bernoulli, I would use it from 2-circle up into the core. It's going from 2-circle up to W_4, W_5. It's turning the corner.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: It's not going from 2 into the lower plenum, is it? You seem to say that the inlet is at 2 and the outlet is at 3, and the rest of it is --

DR. PAULSEN: What we should do is, when we start looking at a momentum cell, it's really this part that we have written for.

CHAIRMAN WALLIS: You shaded it, right?

DR. PAULSEN: The shaded part.

CHAIRMAN WALLIS: And the in is the top, and the out is the bottom?

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: That's a very funny cell.

DR. PAULSEN: And we don't have those explicitly included. They are included in that surface flow.

CHAIRMAN WALLIS: I guess, if we looked at the details of this equation, if you developed it for us, we would have a whole lot of questions about it probably. It would be nice to see it, though.

DR. PAULSEN: What we still apply here is that two pipe equation.

CHAIRMAN WALLIS: I can't see two pipes. The two pipes are from 2 down to W_3 and from W_3 down to the lower plenum? That flat thing is a pipe going downwards?

DR. PAULSEN: This is the lower plenum.

CHAIRMAN WALLIS: That flat thing is a pipe oriented downwards?

DR. PAULSEN: That's half -- Yes, half the lower plenum.

CHAIRMAN WALLIS: And that's a good model of that part of the system? See, the key thing is

it's coming in W_3 and going out at W_4, W_5. The pipe should be horizontal or something to connect between W_3 and W_4, W_5, shouldn't it?

DR. PAULSEN: Some of this has to do with the level of nodalization, but in this simple nodalization this is the way that pipe would be modeled.

DR. SCHROCK: Does that vertical leg on that thing represent the entire downcomer or some section of it?

DR. PAULSEN: In a very simple model, this could be the whole downcomer. In some cases, the downcomer may be nodalized vertically.

DR. SCHROCK: No, no. I'm not concerned with vertical nodalization but as it represents the entire downcomer?

DR. PAULSEN: In a lot of cases it is modeled with one downcomer. In some cases, models will have multiple downcomer volumes, depending on the type of transient that is being modeled.

CHAIRMAN WALLIS: So what I'm supposed to do is take some of these terms in Table 1 and Table 2 and just substitute them into your equation 5, which is your RETRAN momentum equation, and that's going to be a momentum equation for that shaded volume?

DR. PAULSEN: That's correct.

CHAIRMAN WALLIS: Well, there aren't enough terms. I think sort of a commencing argument, you have to complete the loop. You have to say, right, we are going to show you how to evaluate P_1, P_2, A_k, A_{k+1}, all the things that appear in that equation, because it's not transparent in any way at all.

I wouldn't have a clue how to evaluate A_k, A_{k+1}.

DR. PAULSEN: And I think some of the problem is because we haven't given the preliminaries on how that's done, and we have referred just to that modeling guidelines where all that information exists.

CHAIRMAN WALLIS: Seems to me, this is very important.

DR. ZUBER: But that was for another code.

DR. PAULSEN: What's that?

DR. ZUBER: That was for another code, not for this one.

DR. PAULSEN: Those terms are unchanged. The mixture momentum equation is unchanged. You model the nodalization the same way.

CHAIRMAN WALLIS: This is for what code?

DR. PAULSEN: RETRAN-2. It was the

predecessor to RETRAN-3D. So that we basically have the same momentum equation formulation.

DR. ZUBER: I have a problem. Really, throughout your presentation you use basically -- basically. I prefer something more definite.

DR. PAULSEN: The momentum equation is the same. The mixture momentum equation is the same.

CHAIRMAN WALLIS: If I had to write a review of this today, I would write that the description in this reply to this RAI is completely incomprehensible.

DR. PAULSEN: Well, yes. And I think part of the problem is that we relied on what was in the modeling guidelines without specifically including some of that.

CHAIRMAN WALLIS: Well, maybe there is a good option, but it just isn't here.

DR. PAULSEN: Yes. I think --

DR. SCHROCK: I have a sort of simple question. In talking about pipes, elbows, etcetera, we finally ended with a conclusion that what the code actually does is calculate flows in straight pipe segments and then puts loss coefficients for the junctions between those.

DR. PAULSEN: That's right.

DR. SCHROCK: That's what is programmed into the code. Now you are talking about this more complex system. You've got this set of variables defined on the board. It seems incomplete to include flow into and out of the lower part of the lower plenum, but what isn't clear to me is are you showing us something that is actually programmed into the code or is it again a situation where you are trying to illustrate in principle what you think the code does, but the code has actually got equations that are not from this? Which is it?

DR. PAULSEN: Trying to illustrate what the code does. This is not hard wired into the program.

DR. SCHROCK: And what does user guidelines in choosing nodalization mean for these complex geometries? What is the user actually doing that influences what the code calculates? That's one question.

The other question is what are the equations that are programmed into the code?

DR. PAULSEN: Okay. Basically, the equation that's programmed is that equation with the area change included in it. So it has momentum flux terms. It has the form loss terms, the pressure

gradient on the righthand side. The lefthand side has a thing that's factored out that is called geometric inertia. It's basically the L over A, and that's multiplied times --

DR. ZUBER: What is the L for this? You have a volume.

DR. PAULSEN: Okay. That's the next step in this discussion, is what the L is. For the 1-D case that we've talked about, the L and the A are just geometric terms. They are the geometric length and the geometric flow area.

CHAIRMAN WALLIS: What are the Ps? The Ps and 2 and 3 or 2 and 4? What are the Ps?

DR. PAULSEN: The Ps in this case are at 2 and 3.

CHAIRMAN WALLIS: That's absolutely naive. The pressure that pushes this up around it is between 2 and 4. Three is irrelevant. Three is just a token bucket. The pressure that accelerates this flow is between 2 and 4.

DR. PAULSEN: And if sum those equations, you can show that, too.

CHAIRMAN WALLIS: Oh, you sum them?

DR. PAULSEN: No, if you were to.

CHAIRMAN WALLIS: This is one equation.

You have one equation for that entire shaded area.

DR. PAULSEN: We have one equation for this path.

CHAIRMAN WALLIS: I would put the pressure.

DR. PAULSEN: And we have another equation for this path.

CHAIRMAN WALLIS: It's a shaded -- I understood that 2-circle is a volume for mass conservation, and 3-circle is the lower plenum. 2-circle is the downcomer. Take half the downcomer and half the lower plenum, make a momentum cell.

DR. PAULSEN: For this path.

CHAIRMAN WALLIS: It is not divided at all. It's one equation for that whole shaded thing. Right? One equation for that whole shaded thing in the middle.

DR. PAULSEN: For this?

CHAIRMAN WALLIS: Yes. One equation, one RETRAN equation for that whole shaded thing.

DR. PAULSEN: That's right, and that's for --

CHAIRMAN WALLIS: And now you are telling me it is subdivided in some way.

DR. PAULSEN: No. This one equation that

we've just talked about is for this flow from the downcomer to the lower plenum.

CHAIRMAN WALLIS: And that's between 2 and 3. In terms of pressures it's the top surface and the bottom surface.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: It's driving the flow.

DR. PAULSEN: Two and 3, and then we write another equation for junction 4 and another one for junction 5, and basically this equation looks at the pressure between 3 and 4, and this other one would look between 3 and 5.

CHAIRMAN WALLIS: So the fact that the flow is coming out at 4 and 5 doesn't figure out somehow in your momentum, though in the bend we had going in and coming out. That coming out is somehow different from the coming out at 3.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So I'm trying to figure out what the two pipe model is saying. It's saying that there is actually a pipe between -- this flat thing, this disk-like thing is a pipe between the top and the bottom, and the flow is coming in and going out.

DR. PAULSEN: Right.

DR. SCHROCK: I can't read the subscripts on it, but on the last picture right there you've got a W, looks like 2 going down.

DR. PAULSEN: This one here?

DR. SCHROCK: That one. The flow going into the horizontal surface on the top of that flat segment, going down there; on the other side, it's going up. One of them is out of the downcomer. The other one is into the downcomer. How do you square that with the other picture?

DR. PAULSEN: That's basically -- This may be misleading by including these, and it appears that maybe it is, because this is the situation we have where we have the downcomer flow and then the core and bypass flow or two core flows.

For this particular momentum cell, we only worry about that case, and these flows --

DR. SCHROCK: 5 is bypass flow?

DR. PAULSEN: It could be core bypass. It's just one of the parallel paths through the core at this point or it may be another core channel. But we would write one equation for this path, and then another equation for this middle path, and it would probably be less confusing if we had left those flows off, and then a similar equation --

DR. SCHROCK: Or put them in the middle. I mean, the downcomer is modeled as one pipe.

CHAIRMAN WALLIS: No, there are two downcomers. One is going up; one is coming down. There's two different cells for the downcomer.

DR. SCHROCK: What?

CHAIRMAN WALLIS: Two and 5 are different.

DR. PAULSEN: Yes. This would be a core channel, and it may be a bypass or a second core channel.

DR. SCHROCK: Well, it's not the downcomer.

DR. ZUBER: No, the downcomer would just be one on the left.

DR. PAULSEN: Just the 2 is the downcomer.

DR. SCHROCK: 2 is the whole downcomer, and you do that as one pipe. Then the upflows are in the core and in a bypass. You make it look in this picture as though 5 is into the downcomer.

DR. PAULSEN: At this flow?

DR. SCHROCK: Well, I mean your picture -- it just geometrically looks like a part of the downcomer, and that's not what you mean.

DR. PAULSEN: No. No, this isn't part of the downcomer. This flows both --

CHAIRMAN WALLIS: Well, I think all this illustrates that we need more explanation. It may well be that the whole thing you've put together has a kind of modular structure, which at some level makes sense, but it's difficult to figure out what it is.

DR. PAULSEN: And I think we have sometimes difficulty seeing the forest for the trees, because maybe we are too close. I don't know, but the --

DR. ZUBER: The trees -- The forest doesn't make any difference. No, really. I can see that you have two pipes and you connect them. If it's a pipe flow here, you really approximate the whole downcomer by horizontal pipe. Right?

DR. PAULSEN: By a vertical pipe, in this case. Yes.

DR. ZUBER: Downcomer. Then in the lower plenum it's another pipe.

CHAIRMAN WALLIS: It's a vertical pipe.

DR. ZUBER: No, the horizontal --

CHAIRMAN WALLIS: It's a vertical pipe. I think the lower plenum is a vertical pipe. Its horizontal momentum isn't --

DR. ZUBER: Well, what determines this horizontal line? Where is it?

DR. PAULSEN: This one? That's just half of this normal volume.

DR. ZUBER: Well, can it be three-quarters, five-fifths?

DR. PAULSEN: No. It's half.

DR. ZUBER: Why?

DR. PAULSEN: That's just the way the code is formulated, is that you get half of --

DR. ZUBER: No. Look, the code doesn't formulate anything. It's you who formulate the code, and you tell the code what to do.

DR. PAULSEN: Let's back up to the inertia, because that's really where -- There's some of these terms that you input for these things that really aren't 1-D, and it's really not the length. Maybe that's what you are getting at.

DR. ZUBER: I would like to see what are you doing.

DR. PAULSEN: I think that's maybe what you are getting at.

DR. SCHROCK; If you were just dealing with steady state, the net flow across that horizontal surface would be zero, and if would have no impact on the rest of your equations. But you are dealing with a transient. So you have to account for accumulation

and depletion in that volume.

The only way to do that is to account for the inflows and the outflows through that horizontal surface. You're not doing that.

DR. PAULSEN: I think that's what we are, and I'll show you in a slide.

CHAIRMAN WALLIS: But the pressures -- You're saying the pressures on the end, the top and bottom, determine the flow, but there is a pressure on that other boundary there going to W_4, W_5, which is not the same as either of the other two pressures. It doesn't seem to appear in there at all. There's a pressure across that boundary where W_4, W_5 come out that affects the balance on that box. No, the bottom thing. Look at that shaded thing there.

DR. PAULSEN: This one here?

CHAIRMAN WALLIS: Your two pipe equation says everything is going from 2 to 3. That's where we evaluate P_1 and P_2.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: There's a pressure across that top there that doesn't appear in the equation at all.

DR. PAULSEN: Across this one?

CHAIRMAN WALLIS: Right.

DR. PAULSEN: Right. Now where we only use that simplified momentum equation, we only have coupling with one upstream volume --

CHAIRMAN WALLIS: So physically it doesn't make any sense.

DR. PAULSEN: -- and one downstream volume.

CHAIRMAN WALLIS: -- post-balanced the pressure across there has got to come into the balance. Right?

DR. PAULSEN: So the flow equation we write is simply for this pressure, this pressure.

CHAIRMAN WALLIS: Well, I think it would be good if you could go through and actually derive the answer for this problem, all the way through to the final equation, showing how you evaluate the Ls and the As.

DR. PAULSEN: That's sort of what I've got outlined here.

DR. SCHROCK: Is there a version of this slide somewhere where you can read the subscripts? I can't read them -- the one that's up there.

DR. PAULSEN: The one that's up there?

DR. SCHROCK: Where can I find that where I can read the subscripts?

CHAIRMAN WALLIS: They are lost in the shading.

DR. PAULSEN: It's in the RAI and it's an attachment.

DR. SCHROCK: Is it legible there?

DR. PAULSEN: It should be.

CHAIRMAN WALLIS: When it's FAX'ed, it's not legible. Well, it's fascinating, because if you've done this, you've done something which is very challenging.

DR. PAULSEN: Well, the users do this all the time. So they've done the challenging work.

DR. ZUBER: Are you implying they are doing it correctly?

DR. PAULSEN: Pardon me?

DR. ZUBER: Are you implying they are doing it correctly?

DR. PAULSEN: I think they have demonstrated in most cases that they are.

CHAIRMAN WALLIS: This is a discussion of length here?

DR. PAULSEN: Yes. That's what this deals with.

DR. SCHROCK: See, all of this that you are telling us seems to me to govern the choice of

equations that are going to describe the system, but those equations have already been programmed into RETRAN. What I'm having difficulty understanding is how your user guidelines on nodalization can influence what has been programmed. I don't see that there is any way that it can do that unless you are going to tell us that there are a number of different things that are programmed and that the user chooses among various options.

DR. PAULSEN: For the most case, the user will use the compressible form of the momentum equation that has the momentum flux terms, and then there will be area changes on the upstream and downstream volume for these kinds of geometries. So there is basically an equation that's programmed that they use the same equation, and their input then will affect various terms in that equation.

As I mentioned, one of the primary terms in this equation is the inertia. For one-D components, it's a geometric inertia. For these 3-D components, it's something else.

In effect, if you imagine where you have flow coming into a downcomer, the flow first has to kind of wrap around the downcomer and then turn and go down. So what the user has to do in determining the

inertia then is to estimate via some engineering judgment or hand waving -- it's not an exact calculation -- be able to calculate what that flow path might be in determining what the geometric inertia is.

CHAIRMAN WALLIS: Some kind of average length of a stream line or something?

DR. PAULSEN: That's one way of doing it. One of the complications you run into there is that stream lines may change during the transient.

CHAIRMAN WALLIS: See, in the Porsching paper it says it's volume divided by area, which I don't think is really the right answer. I convinced myself, if I had a pipe that went around a complete circle, that the momentum in that pipe is zero, because everything balances, and it can be a long circle. If I take a pipe and bend it in a circle, that circle has no momentum in it, if it's a steady flow or incompressible flow.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: If you are following the length all the way around, that makes sense.

DR. PAULSEN: So you follow, in effect, the flow path of the stream lines.

CHAIRMAN WALLIS: That's different from

looking at the entire momentum, because the actual momentum added up is zero.

DR. PAULSEN: Right.

DR. ZUBER: Do you contend that this code is a best estimate code or what?

DR. PAULSEN: A best estimate? In some senses, yes. There aren't an awful lot of conservatisms built into the code itself.

DR. ZUBER: There are?

DR. PAULSEN: There aren't. One area -- You know, there may be a model here or there like a critical flow model that's a conservative form of the model, but because of the way that model is used--

CHAIRMAN WALLIS: So you showed a picture here. The answer is it's the length, the average length of a stream line or something, and there is some rationale for that?

DR. PAULSEN: That's right. So you have to kind of visualize what the flow path might be.

CHAIRMAN WALLIS: Does it matter if it's fatter at one end than the other?

DR. PAULSEN: Yes, it does, if you want to account for all of those effects. Basically, in the user guidelines it spells out whether you've got parallel paths that you've got lumped into your

junction or whether you have serial paths.

CHAIRMAN WALLIS: Okay. So you could walk us through, if you had the time, how you actually calculate L and A for those three geometries you just showed us?

DR. PAULSEN: That's right. Basically, all I wanted to point out was that there are not rigorously developed equations for how you do it but some rationale for how you actually calculate those.

CHAIRMAN WALLIS: See, the concern I have is I couldn't understand what you say, and I still don't. But maybe a user gets enough training that he or she can do it. If it's so much up to the user, the users might choose all kinds of different Ls and As, depending on their own preference. So you get all different answers to the same problem, depending on who happened to use the code.

DR. PAULSEN: Well, and in fact, that's why you have to do some sensitivity studies to find out where the sensitivities are in the model. You know, some -- Inertia on some junctions may not affect this solution --

CHAIRMAN WALLIS: Does this mean that the NRC has to review how a particular user has chosen to work out these things and provide some kind of

validation of it every time?

DR. PAULSEN: There are a lot of guidelines that people routinely follow and standard sensitivity analyses that people do. A lot of things that are common in models, although they are not exactly the same, but people learn from previous use.

For instance, a report for a particular transient may identify that there's a particular inertia that is sensitive. So you may have to use some kind of a more representative inertia in a particular area for a given kind of transient.

CHAIRMAN WALLIS: So there's a whole lot of evolution of how to use the code which we don't know about, which is why it works today, because people have learned. You don't just blindly follow some guideline, that you have to do something special with this particular node and with that node.

So all of that is missing when we simply look at some documentation.

DR. PAULSEN: Yes. A lot of that information is like in Volume 5.

CHAIRMAN WALLIS: But we need to know that. I think, if we are going to make a judgment, we have to know that, and we can't just base it on our assurance that this 30 years of experience, therefore,

has to be good.

DR. PAULSEN: I can appreciate that.

CHAIRMAN WALLIS: Sorry, Novak, you had a point.

DR. ZUBER: I agree completely with you. But it is distressing that the code which we developed years ago, 20 years, 30 years ago, I realize to be poor, and we wanted to do something better. Now you are developing a best estimate code which essentially has the same shortcomings as those codes of 20 years ago and 30 years ago.

And we are really not -- to say, look, this is how it is done and this is what it's for. You have kind of an arm waving argument, and you passed it back to NRC and to the customer, and this is not a good way to evaluate safety.

CHAIRMAN WALLIS: But it may not -- You know, it's evolved. So there may not be equations that describe the workings of your knee, but your knee has evolved until it works. So something like that is happening here with this code.

DR. ZUBER: Well, the thing is -- the simplest thing, look at the downcomer -- Even for the pipes, on the straight pipes we have problems. There were problems you were not able to explain. With the

downcomers, it's purely arm waving.

DR. PAULSEN: There is no doubt about these three-dimensional geometries. They --

DR. ZUBER: -- if it was just the elbow, I mean, that Graham brought up. That's a simple one. I can always make it more complicated and say I cannot solve it, and we have to agree on that.

DR. PAULSEN: One of the points I would like to make, though, is the fact that elbows normally aren't modeled. In a model you may have something that looks like an elbow where the hotleg or the coldleg connects to the downcomer, where the hotleg leaves the upper plenum.

You may have a T where the surge line connects. I've got some examples that kind of show the types of pressure differences we see there by including these momentum effects, and then an example of what it does to a typical Chapter 15 transient that might kind of give you a flavor for what's going on.

CHAIRMAN WALLIS: How much stuff do we have to look at to go through all that?

DR. PAULSEN: There's just a little bit. I don't want to spend a lot of time, because I think we understand where your concerns are.

Basically, I just wanted to point out that

when you go to this three-dimensional, modeling the three-dimensional components,t here's some guidance in terms of rules, but there is nothing absolute. There is nothing as definitive as the equation for the 1-D or for the straight pipe.

CHAIRMAN WALLIS: So the staff in evaluating a code like this would be quite within their purview and all that to say we think that L should be twice as long for this node; let's try it and see what happens.

DR. PAULSEN: And I think past reviews have done things like that. Past reviews have done things like that or asked what's the sensitivity in this particular loss coefficient or inertia.

DR. ZUBER: Had you done the thing correctly two years ago, we would not have this discussion. If you had addressed all the concerns and then even using the same equations addressed the sensitivity of each term, and probably you could get some of these problems to rest. Now it is just plan arm waving.

DR. PAULSEN: When it comes to coming from the downcomer into the lower plenum, then the inertia terms and the flow length terms, you have to kind of visualize what the flow --

CHAIRMAN WALLIS: You see, that's the problem I had, because you told me it was coming in and going out into the lower plenum. So you in was at the top, and your out was at the bottom.

Now you are saying your in is at the top and your out is at the top again. That's a different model from what you just described.

DR. PAULSEN: This is how we would calculate the inertia. We actually -- For the inertia we actually look at that path.

CHAIRMAN WALLIS: But your two pipe thing -- you just explained to me it comes in at the top and it goes into the lower plenum. That's the in and the out. Now your in and out is a different in and out. It can't be both.

DR. PAULSEN: Yes, I see what your concern is.

CHAIRMAN WALLIS: Yes. It's a very simple concern. I mean, my seven-year-old grandson would probably have the same concern.

DR. ZUBER: Let me ask you, how do you determine that it is one-half of your downcomer? Again, why not one-third or one-fifth?

DR. PAULSEN: Oh, it isn't. For a situation like this, it isn't one-half. For a

situation like this, the user has to look at how he's got his model nodalized. If he's got one node, then he has to kind of look at what the flow path might be through the hardware.

In fact, normally, this flow length is going to be much longer than the one-half.

DR. ZUBER: Okay. Then let me ask you: Did you do a sensitivity analysis on that to see what is the --

DR. PAULSEN: Users do these kinds of sensitivity --

DR. ZUBER: No. Look, users -- I am not talking to the users. I am merely talking, did you? I have concerns about your approach and assumptions, and then you want to defend it. And my question is you tried to explain how you determine -- My question is did you perform some analyses, calculations, or take twice that length, half that length and see what is the effect?

DR. PAULSEN: Those are pretty common things that we do when we do analysis.

DR. ZUBER: Well, the question is -- My question is did you, and what is the effect; and if you did it, then where I can read it?

DR. PAULSEN: Okay. We haven't run any

specific analyses right now that we could point a finger to, but --

DR. ZUBER: You answered the question. You see, the problem we have is you have these assumptions you cannot really defend. You always say this was done 30 years ago, this was approved, and then you explain something and you don't run the sensitivity analysis.

DR. PAULSEN: For a specific application, these sensitivity studies are run quite often.

DR. ZUBER: See, but you want to have a code approved, and this is something which is questioned in the analysis. You have two pipes. You want to model a very complicated -- my own guess is an engineer would be, okay, I should then run L to see what is the effect, and if the effect is important, I would address it. If it's not important, I would say, Zuber, shut up, I have done it and here is the result. And you didn't do it.

CHAIRMAN WALLIS: Well, I just wonder --

DR. PAULSEN: This term will vary, depending on the kind of transient you are having.

CHAIRMAN WALLIS: I'm wondering where we could be. I mean, we could simply say that as ACRS we appreciate there's a 30 year law of how to interpret

all these things so that they work, and there is no way that we can possibly penetrate this tribal knowledge by simply saying we don't really have much to say.

DR. SHACK; Well, we've passed a lot of other codes that had the same problems.

CHAIRMAN WALLIS: And that's part of the difficulty.

DR. KRESS: That is exactly the difficulty.

DR. ZUBER: Wait, wait just a moment. Wait, wait, wait. No, you have to answer your question. These codes were designed to address one problem, where we have quite a different era. We had quite a bit of conservatism. Now we are getting into the regulations. That conservatism is going to decrease. We have to have better codes.

What I hear from this presentation and previous, we won't have them. We don't have them, and the worst irritation to me is you don't even appreciate what this will mean to this technology.

This intervenor could really run rings around the NRC in the analysis like that, and I hope it doesn't come. But --

CHAIRMAN WALLIS: I think we have to say

that there is no way we can penetrate the lore, l-o-r-e, of 30 years. But we can look at something like an example of following a flow around a bend and say does this establish credibility. That's about the only level the ACRS can penetrate to, because there is so much other stuff that you have to sort of been in the business for years to --

DR. ZUBER: But, Graham, but the point is that first simple thing you cannot really even get a positive answer to it, and the question is then -- my judgment would be have a letter, list the concerns, and it's up to the NRR to make a decision.

DR. SCHROCK: I am still struggling with the problem of the simplest technical communication here. We have something on the projector there at the moment which is unclear, unexplained, and it's being talked about as though we all understand what it means.

I don't think we have the same understanding of it. I certainly don't understand what you mean by that picture. Have you divided the downcomer into four segments, and you are showing what projects onto the -- Here you got a --

DR. PAULSEN: That's right.

DR. SCHROCK: -- cut through the thing,

and now it's projecting down into a vertical view of the lower plenum, and --

DR. PAULSEN: That's right.

DR. SCHROCK: -- you are showing the flow which is in that one-fourth of the whole downcomer?

DR. PAULSEN: That's correct. It would be flow coming down --

DR. SCHROCK: Did others understand that?

DR. PAULSEN: -- down this portion of the downcomer. So it would be --

DR. SCHROCK: But the whole downcomer is represented as one pipe.

DR. PAULSEN: That's right. And so if you've represented this as one pipe and you've got four parallel paths that you have -- in this case, they might be symmetric parallel paths. So there are guidance on how you would combine inertias for these four parallel paths for one effective path.

DR. ZUBER: Which you evaluate the sensitivity of, how you calculated.

DR. PAULSEN: That's the recommendation, is that we do sensitivity studies on these.

DR. ZUBER: And you didn't do them yet, did you?

DR. PAULSEN: I'm trying to point out that

those sensitivity studies are model-specific. We have done sensitivity studies on a number of models, but the sensitivities may be different when you move to a different model.

DR. ZUBER: What you mean, model? It's the same equations or what?

DR. PAULSEN: The level of nodalization.

CHAIRMAN WALLIS: I am going to backtrack to this morning when I showed you a 180 degree bend, and I wondered if it was fair to do that. But it seems to me, you are showing it to me now in something you prepared before I showed it to you. I had a lot of trouble figuring out how the size and he momentum fluxes and things applied to a 180 degree bend, and I think that's still a problem.

You know, that equation doesn't clearly apply to something like this picture, and this isn't two pipes. So I'm not quite sure what you are showing me. Do you claim that your RETRAN equation works for this sort of a --

DR. SCHROCK: He is going to show you how to calculate the equivalent pipe through the lower plenum.

DR. PAULSEN: That's right.

DR. SCHROCK: By looking at this flow

pattern.

CHAIRMAN WALLIS: It's the length of that pipe?

DR. ZUBER: Yes. That pipe can be anything.

DR. PAULSEN: It's the length of this flow path.

CHAIRMAN WALLIS: And the pressures are at the top of each side and all that, and clearly the momentum balance doesn't work, but you have sort of imagined that if it were straight, it would work out this way.

DR. ZUBER: Let me ask you something. I'm sorry. What kind of guidance -- What kind of peer review groups you had in conducting this?

DR. PAULSEN: In doing this?

DR. ZUBER: I mean developing this RELAP -- or RETRAN-3D.

DR. PAULSEN: This portion of the code really is not new. This modeling technique has been used and is a carryover from RELAP-4.

DR. ZUBER: And RELAP3.

DR. PAULSEN: And in some cases -- The momentum flux terms, no, but these inertia terms are carryovers from RELAP3. The other systems' codes do

this type --

DR. ZUBER: The problem is this was a different requirement, different environment, and you are developing code that should be used for the next ten years when you have increase of power, decrease of --

CHAIRMAN WALLIS: That's why we need lots of assessment if it is going to be used.

DR. ZUBER: Well, I don't see it here, but in doing even this most trivial one, just to see what is the effect of that length, and you leave it to the user to the NRR to calculate it.

DR. PAULSEN: All I'm trying to say is there is no way we can do one sensitivity study on an inertia in a given model and give blanket coverage of what the --

DR. ZUBER: No, just for your intellectual -- Granted, I mean, it will take twice as long, three times as short, and see what the result is.

DR. PAULSEN: We have done those in years past on numbers of cases when we were doing loft and semi-scale experiments, when we were doing plant transients to look at responses. Those are the kinds of things that we do and that we tell users to do, is to look at the sensitivities of those terms.

DR. SCHROCK; But what do you do about phase separation in this imagined u-bend representing the plenum?

DR. PAULSEN: The case that we've shown here would be for a case with no phase separation. You know, if you start getting phase separation or your flow pattern changes significantly, then that inertia can change during the transient, and then that's another sensitivity that you are going to have to consider.

DR. SCHROCK; Well, of course, it's the inertia that causes the phase separation.

CHAIRMAN WALLIS: So check several of those works for a 180 degree bend like that?

DR. PAULSEN: In most cases, we wouldn't apply that down here.

CHAIRMAN WALLIS: Well, you've got to use something.

DR. SCHROCK: But in some cases, you would.

DR. PAULSEN: For the transient, Chapter 15 transient analyses that we typically use RETRAN for, we wouldn't encounter that kind of a situation. That would be more of a small break.

CHAIRMAN WALLIS: I think we know where we

are now with all this, and we're not quite sure where we are going. I think, since some of us are leaving at three, we ought to have a discussion between us and you folks and NRR about where we want to go from here.

DR. PAULSEN: I guess I have one question. That's if this last information kind of completes the picture or if there's still something missing?

CHAIRMAN WALLIS: Well, what you've sort of done is I think that you've assured me, and I believe it, that people have worked with these things, whatever their weaknesses, for 30 years, and they have evolved a lore and a way of learning how you have to fix things up so that all these things work out for the kind of problems they have been solving.

I think you do have a real problem with documentation as it is, establishing credibility of the methods for anyone except someone who is one of those people familiar with this 30 year lore. I think that is a real problem when you face the intellectual community, professors at universities, the students in universities, the engineers out there who become engineers who see this stuff and say, gee whiz, I don't want to be part of that because it doesn't make sense to me, I'll go and get a different job, all that kind of stuff.

That's where the problem is. That's where we have the problem, but we are not sure that we are in the position -- NRR can evaluate the lore and say we believe that's fine, we understand there's been a big learning experience.

We have much more difficulty with that. But we can evaluate much more readily the worked examples, the justification for the equations, and I think that's where you fall down. It's not a convincing story.

I wonder what you wanted to do about that in terms of fixing it up, and do you really want to go before the full committee next week where some of these questions may come up again in exactly the same form. I 'm not quite sure -- I don't think they are resolved, really, are they?

DR. PAULSEN: I don't think all of them are, no. Before we move from here, I guess, if we were to revise the documentation to kind of point users in the direction of how you model more complex geometry with some of the illustrations that I've just presented, and then refer them to modeling guidelines, do you think that would be an improvement and address some --

CHAIRMAN WALLIS: That would certainly

convey much more information which would be helpful. It might give us the same qualms about the momentum balance, because we would look at these complex geometries and say, gee whiz, the same way we do for the simple ones.

DR. PAULSEN: But at least put together the picture of how the whole plant would be modeled and how the pieces go together.

CHAIRMAN WALLIS: Well, of course, that is the engineering problem you address. My critique of all these codes is they launch into Navier-Stokes equations, blah, blah, blah. They should define the problem first and say this is what we need to do, and these are the kind of assumptions we may have to make, because these are the variables we are dealing with and these are the things that matter; this is why we are going to do it.

Developing sort of equations in a vacuum and then saying, we think they apply, is just not quite perhaps the way to do it. I don't know how much you want to rewrite.

I think we have a real concern with SERs being issued before the documentation has been fixed up.

DR. PAULSEN: Okay. And I guess we have

taken the position that we have told the Commission that we are going to make particular revisions.

CHAIRMAN WALLIS: See, we have told the Commission that there appear to be basic errors in these momentum balances, and you have told the Commission they are out to lunch, they are fine, everything is great about these momentum balances, and we are going to show them it's all right.

That was about the dialogue that was presented at the beginning of today, and I don't think we are much further ahead there. We still have the same reservation. The only thing that we are doubtful about is, well, in spite of all that, is this still a good code.

DR. PAULSEN: Okay. But I think we have come to -- at least that the equations that we are using in the code seem to predict the physics reasonably well in terms of expansions --

DR. ZUBER: I didn't see that. I didn't see it.

DR. PAULSEN: Okay.

DR. ZUBER: It seems convincing. You were not able to explain the simple examples. When I asked you how you did out of the Bernoulli equations, you were not able to see the difference between the

Bernoulli equations and the momentum equations. It's an ad hoc approach, and if you use this approach, and it's up to you to say up front this is what we did and, therefore, we have done this and this and this sensitivity analysis to address this and this and these questions, and I didn't see that either.

This is my summary.

CHAIRMAN WALLIS: So we may end up, if we have this meeting next week, about where we are now. I'm not quite sure how we would come out.

DR. KRESS: I can't see much of a possibility of us coming out in the full committee any different than where we are right now.

DR. SHACK: What are our questions? I mean, is it how do you nodalize a three-dimensional flow for a one-dimensional code? When we approved S-RELAP last time, it didn't bother us then.

DR. ZUBER: It is a little different environment. We did this approach 30 years ago, because we addressed a different problem. Now you are decreasing the -- you want to obtain better, more efficient blend, and they should do it. But they should really correct the approach.

I won't do the same approach with the same shortcoming by decreasing the margin of safety, and

that's a problem I see. Otherwise, I wouldn't be complaining, because we have enough margin. But this code is going to be used for the next 15 years, and in 15 years you can imagine how much the margin will be reduced, and this is the problem which ACRS has to address.

CHAIRMAN WALLIS: Well, we were careful in RELAP. We said that this is -- we don't disagree with the staff, because the staff is in a box. It's approved RELAP for other purposes; they can't very well turn it down for Siemens. That was the kind of thing. We were in the box. But then we had a lot of qualifications in saying the documentation had all of these errors and things we point out before and, when this is done for a best estimate code, that's got to be fixed.

DR. SHACK: Let's separate best estimate codes -- You know, there we had the explicit requirement to evaluate uncertainties, and that includes all uncertainties, whether it's, you know, how do you nodalize a three-dimensional problem into a one-dimensional problem. But as I say, to suddenly at this point bring up how do you nodalize a three-dimensional solution into a one-dimensional problem, as though, you know, we've been doing it for --

CHAIRMAN WALLIS: I don't think it's unfair at all, and we are members of the public looking in at how things are done, and if it's been done this way for 20 years and it still doesn't make sense to us, we have every right to say it doesn't make sense to us. There must be some mysterious lore practiced by this industry which makes it work. We have every right to say that.

DR. ZUBER: And as technical men, it was all right to go to the public at technical meetings.

CHAIRMAN WALLIS: But we don't want to give the public the wrong impression.

DR. ZUBER: Okay, fine. But don't --

CHAIRMAN WALLIS: We don't want to give them the impression that, because there are all these things that you wouldn't accept in undergraduate homework, the whole structure that's evolved over 30 years is hopeless. We don't want to give that impression.

DR. ZUBER: No, you can leave it, because you have quite a bit of conservatism. I mean, you can always argue that point. But now we are going to decrease it, and we should. But then you should do it correctly. I think this is the change of environment. This is what the ACRS has to consider.

On the other hand, I'm not concerned with the 3D. I'm really concerned with the other momentum equations and --

CHAIRMAN WALLIS: There are bigger questions, though. It's this working entirely in this regulatory environment that bothers me. I go back to the question of the student. If I have students working on fluid mechanics and they start to say I want to be a nuclear engineer, and they start to look at this stuff, if all they see is this sort of documentation, I think you turn them off, because they wouldn't see all the other stuff which is the 30 years of experience that it works. I don't want that to happen.

DR. ZUBER: There is something worse. Sometimes when I read reports like this, I feel sorry that I have put my technical life in this technology.

CHAIRMAN WALLIS: Well, I have trouble sleeping sometimes, and that shouldn't happen.

DR. SCHROCK: I'd like to point out that in this last little bit of discussion here, you, Graham, were saying, well, we can maybe accept a lot of this fuzziness, but when we go on to best estimate codes, Bill made a comment about best estimate codes which implied to me that you didn't hear what Mr.

Paulsen had to say about what he views this code as being.

He says it's best estimate.

CHAIRMAN WALLIS: It's the best they could do.

DR. SHACK: You know, people have different meanings to the meaning best estimate.

DR. KRESS: He meant there were no purposeful conservatisms in that.

DR. SHACK: But from the NRC's point of view, a best estimate code means one where you explicitly address all the uncertainties.

DR. SCHROCK; It means one that is going to be submitted under the new rules and required uncertainty evaluation, precisely.

CHAIRMAN WALLIS: Well, I admire your struggling with the problem. It's a difficult one, and you may have got something which works for the kind of things we've done up to now in nuclear safety. But I can't get over the business of just looking at this thing that, if it were on undergraduate homework, I wouldn't like to see that kind of an answer. That shouldn't happen, and I can't reconcile these things.

DR. PAULSEN: We'll go back and reexamine those.

CHAIRMAN WALLIS: Do you guys want to come in next week? What are you going to say?

DR. PAULSEN: Jack?

CHAIRMAN WALLIS: Usually, we give someone advice about how you should present yourselves to the full committee. Is there a hurry? You've taken two years. Do we have to rush to judgment next week?

MR. HAUGH: Certainly, the schedule is yours to set. I mean, if this is locked in concrete beyond --

CHAIRMAN WALLIS: No, there was another presentation on water hammer where the EPRI presenters decided they didn't like the critique they had had, and they wanted to go back and work on it and come back with something better. That happened a month or two ago. You don't have to meet this schedule.

MR. HAUGH: Well, perhaps we could reconsider that date, as you are suggesting, but there's a question of just, you know, how much work can be done in any one given time, and that's going to be a question of trying to define exactly what we need to bring back to you, and that would determine the length of time needed.

We can't, in the space of a week or so, completely re-derive everything, reformulate all the

documentation, etcetera, etcetera. So I mean, there has to be some specificity as to what would be needed.

CHAIRMAN WALLIS: That's not realistic for you to reformulate everything in a week.

MR. HAUGH: Yes. That's what I'm saying.

CHAIRMAN WALLIS: So in a week, we would have to write a judgment based on what we see, and if we felt so moved to, we might write a detailed critique of all these twos and root twos and lack of forces on bends and stuff, and put it all in writing as the report next week. I just wonder if you want to see that happen, if we have to critique what we've got. I'm not sure that gets anybody any benefit.

MR. HAUGH: I think I would agree with you on that statement, certainly.

CHAIRMAN WALLIS: But if it gets no one any benefit, why are we doing it?

MR. HAUGH: Right.

CHAIRMAN WALLIS: Well, I think you perhaps need to think about it in the next day or two or something.

DR. KRESS: Keep in mind, you don't lose anything at all by delaying it and not showing up. There's nothing you lose except a little time.

CHAIRMAN WALLIS: Well, he's sensitive

that Dana is no longer the Chair. We don't have this person keeping us on track all the time, we have to do things on time.

DR. POWERS: If they choose not to come before the full committee, all that would happen would be that the subcommittee Chairman would give a summary of what their status was on things, which to my mind is -- I apologize that I've been over meeting with the Commission, so I haven't heard everything, but that there is -- you are on a path, closer pathway to resolution than I've ever seen before.

CHAIRMAN WALLIS: I think we could say that we had a very good meeting, that now we understand each other. Now we think EPRI understands the concerns, and we believe that they understand them well enough that there's hope that they address them effectively.

That would be what we would say, something like that. We would hope we would be able to say that, because you've been far more responsive in this meeting than the last time we had a meeting with EPRI, and we are not on some treadmill that says next week we have to do what was on the schedule.

MR. HAUGH: Okay. To have complementarity in terms of the good feelings on leaving the meeting,

we would like to request an opportunity to present at least one more piece of information here.

It shows when you make these different cases and ways of doing it, does it really make a difference or not? And perhaps that's something that needs to be considered as well in terms of crafting what it is that we would be expected to do by whatever time. We would appreciate your indulgence on that.

CHAIRMAN WALLIS: That is useful information, too.

MR. HAUGH: Okay. Thank you.

CHAIRMAN WALLIS: Do you want to say that now?

DR. PAULSEN: There are just a couple of quick slides that I'd like to show, just for illustrative purposes on what some of the effects might be.

I think this was the reason we got caught in the trap of trying to carry the vector information along, which did nothing but add confusion. For a situation like this where we have a coldleg and a pressurizer with a surge line, if we have a situation where we don't account for the effects of angles, in this particular case where we have no angles, if we were to input a pressure of 2200 in the pressurizer,

our pressurizer in the hotleg would end up being 2205, which is less than the hydrostatic head for that particular path.

When we actually put in the angle effect in this junction, it in effect knocks out this velocity head upstream so that it doesn't affect this piece that goes off at 90 degrees.

CHAIRMAN WALLIS: But if it were a true Bernoulli, it might affect it.

DR. PAULSEN: If there were some flow, yes.

CHAIRMAN WALLIS: And of course, in this case you might have flow coming from two and one, and I had a problem with that T when you had your W_1, W_2. Two actually could be negative, and I didn't quite understand how you handled that.

DR. PAULSEN: So this is just an example showing at steady state where these angular effects in some cases need to be included to get the right pressure distribution.

CHAIRMAN WALLIS: It indicates to me, though, that you got to be careful, because the delta p, the difference in the pressure here, is 5 and 26.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: Depending on what

assumptions you make. That's a big change.

DR. PAULSEN: That's right. But it's only at local pressure. But in the case where we specify the pressure in the pressurizer, this could give us 20 psi wrong in the rest of the system.

DR. PAULSEN: It's the delta P that drives the flow and, if it's five times as big, you might get a flow in the surge line which is wrong by a factor of two and half or something. That might make a difference to the transient.

DR. PAULSEN: That's right.

CHAIRMAN WALLIS: So there are cases. We were a bit concerned about these dP 600, 1000 type things where the pressure, hydrostatic balances throughout these different bathtubs that Novak talks about makes a difference to whether the water goes this way or that way. You have to get your delta Ps right more accurately than perhaps you do in some of these things where there's a big hole and everything--

DR. PAULSEN: Where you don't have as large forcing function, those hydrostatic heads there are what drive the system. That's right.

DR. SHACK; Now let me just understand this a little bit better. In the case one you sort of arbitrarily set the angles to zero.

DR. PAULSEN: This is if we neglect all of the angle information and just treat everything as straight pipes. Then in effect, this pipe is going to be, you know, downstream of this pipe. So it's going to see the velocity term upstream from this piece, which will then --

CHAIRMAN WALLIS: Turn around the corner?

DR. PAULSEN: Yes. It makes it think it's going around the corner, where it is really not. So --

CHAIRMAN WALLIS: But the two pipe model would do that to you, because a two pipe model is energy conservation, and Bernoulli would do that, wouldn't it?

DR. PAULSEN: This is a case -- I probably didn't give enough conditions. This is the steady state case where we have no flow in the surge line. So that's something I missed.

So I just want to point this out, that there are some cases where you really need to account for some of these --

CHAIRMAN WALLIS: What I did with your T was I said what happens if W_2 is zero. That's where I got my V^2 over 4.

DR. PAULSEN: Oh, that one?

CHAIRMAN WALLIS: And I couldn't see how I took this V^2 over 4 and the other and compared it with Bernoulli.

DR. PAULSEN: Okay.

CHAIRMAN WALLIS: So I think you are illustrating that there might be -- it might be important if you do this right.

DR. PAULSEN: Right. This just happens to be something that looks like an elbow where we have actually included -- This is horizontal. So it's laying at a plane. So we don't have any gravity. We've turned off all the friction, and we have a uniform pipe, no heating.

So you can see that we have a uniform pressure until we hit this bend, and then it looks sort of like a stagnation point.

CHAIRMAN WALLIS: Right.

DR. PAULSEN: So the pressure elevates. But as soon as you get around the bend, that recoverable pieces come back.

CHAIRMAN WALLIS: What this would do, though, is it would squirt flow out and prevent flow coming in, so that it would rob the corner of mass, wouldn't it? It would unofficially rob the corner of mass, because these pressure differences would then

drive a change in flow if you put this into the code. So it would rob that corner of mass.

DR. PAULSEN: I'm not sure it would really have any effect unless you had some other connections.

CHAIRMAN WALLIS: It would calculate a dw/dt.

DR. PAULSEN: Yes.

CHAIRMAN WALLIS: Probably.

DR. SCHROCK: In that picture, you have the junction 21, junction 21 and -2 in your little tables, but in the picture you have a 19 and no 20.

DR. PAULSEN: These angles would be for 20. This is 20. This would be 20, 21. So these would be these two, this path, and this one and two then would be the hotleg path. So that's a 20.

CHAIRMAN WALLIS: Well, this is why for some of these T junctions RES is actually doing research and measuring some of these things.

DR. PAULSEN: We are actually --

CHAIRMAN WALLIS: That would be the way to resolve some of these questions.

DR. PAULSEN: And we actually have some people in Switzerland that are using the code to actually try and compare with some data for T's. So, hopefully, we'll have some data in the -- or some

actual comparisons with data to help justify use of the code for T's.

This is an example where we took just a simple PWR transient model. It was a single loop model, and generally users don't model a lot of this angular information. They would even model this as a straight pipe, this as a straight pipe, and then they will angle differences down here.

So what I've got is a case where we have zero angles and then the case where we have actually put in the 90 degree turn here, and then have these two junctions 180 degrees away from this junction.

Basically, the results of this case are that, when you do that -- provide that information, it doesn't change anything in the system except where the angle changes. So we would see a change in the downcomer, a change in the upper plenum, and a change in the lower plenum pressure.

So case one listed here are the base cases with no angles, and then case two was where we have included the effects of angles.

CHAIRMAN WALLIS: Probably means the momentum flux terms are small.

DR. PAULSEN: And that's what the next slides show, is that, you know, at most this affects

pressures by a psi or two. It's probably not going to -- and based on that, I would say it's not going to change the transient much, but I've cheated. We already ran that.

CHAIRMAN WALLIS: I think you should say that right up front. You should say there are difficulties with modeling momentum equation. You have to make some assumptions to get on with it. We've tried various assumptions. They make this kind of difference, and this is what's in the code, and that's why.

DR. PAULSEN: I think we're seeing --

CHAIRMAN WALLIS: This sort of pseudo-academic stuff is not doing much help.

DR. PAULSEN: That's right. And basically, you can see that this is the two cases for a typical transient, and this happens to be the surge line flow for a typical Chapter 15 analysis.

Basically, there was no difference in the surge line flow. There was really no difference anywhere except in the upper plenum pressures where we had about a psi or two that were different, and there's just an offset in the pressure that tracks through the transient.

I think, if you look at the slides, one of

them, there's a slight difference, but in effect these momentum flux terms which for at least this case don't have much significant --

CHAIRMAN WALLIS: The academic reviewer looking at these things tends to regard it as being basically immoral to do a full momentum balance.

DR. PAULSEN: Well, and there are situations where momentum flux may be more important. So you want to make sure it's right.

CHAIRMAN WALLIS: But in reality, it doesn't matter. It's only a small sin.

DR. PAULSEN: I guess I'm going to skip over the RAI questions. I think I wanted to go to this last slide, because this kind of summarizes what we've tried to do.

We've actually, from my personal point of view, tried to make a conscientious effort to address your concerns, but I think we were missing the target, and I think now --

CHAIRMAN WALLIS: I think our conclusion, looking at your replies, was you don't understand what we're talking about.

DR. PAULSEN: So we've made -- We have made some code revisions and error corrections where we identified those, and we've tried to evaluate the

error corrections on what impact they might have, and we've attempted to revise the documentation so it's more complete.

I think maybe we have identified some areas where we could use some further change. But the plan was that we would issue a new code at the end of this review process that would have the updates that had come about as a result of the review, correcting errors and those kinds of revisions, as well as distributing new documentation with it that would resolve the problems.

I think that's still the plan.

CHAIRMAN WALLIS: It would really be appropriate for us to see some new documentation and comment on that, because that's the end of the story, isn't it? It's difficult to comment now when you are still in the process of changing it.

DR. ZUBER: Especially after this meeting, you may consider to revise the documentation. I would really advise you to do this.

CHAIRMAN WALLIS: It is a moving target. I mean, if I look back at the responses to RAIs and I look at your new derivation with the Porschingesque integral with the divergence and all that, that's completely different rationale than we had before.

DR. PAULSEN: Some of this has been as a result of our dialogue with the staff, trying to, I guess, address their concerns, too. So it's been kind of an evolving thing.

CHAIRMAN WALLIS: I think that the effort by Dr. Porsching to introduce some rigor was a good thing, but it seems to sometimes -- You know, you got to be careful then that the definitions of mathematical terms he has are not quite the same as yours. You may give the appearance of being on the same track, but when you look in details, it turns out his equation isn't the same as yours.

So again, you got to be careful about jumping to conclusions here.

DR. ZUBER: Graham, I would like to go on the record that his equation on page 8 where he has two parts, horizontal connected, is incorrect, and it does not agree with the standard equation which is in Bert, Stuart and Lightfoot.

Although I appreciated reading it, somebody on the divergence and the main integral theorem, I was really surprised that she didn't put the section from Bert and Stuart and Lightfoot to compare is results with the standard. I think that analysis was wrong.

CHAIRMAN WALLIS: My conclusion is that probably you don't want to come next week unless you are determined to do so.

DR. PAULSEN: Well, I don't think that we would have anything to gain.

CHAIRMAN WALLIS: If you do, I don't quite know what you would come with. You've condensed this story. Which part of it would you tell us, and --

DR. PAULSEN: Well, I think what we would probably want to be able to do is to revise the development of the equations. Did you want to comment, Jack?

MR. HAUGH: This is Jack Haugh speaking again for EPRI.

I think, given all that has transpired, it would be inappropriate to push this next week, but again I believe we've been given very broad guidance and suggestions as to the nature of the problem, and this could become a very protracted business in terms of, you know, how long this all takes to have a pleasant meeting of the minds when this is all over with, with the ACRS.

So it would be helpful to us to have as complete a set of things to come back with. I think that's not unfair to ask of the committee to assist us

in that fashion.

I really don't want to get into a never-ending process of, okay, now go after this, and now go after that, etcetera, etcetera.

DR. ZUBER: It's too bad that you were not here two years ago to make this statement. We probably would not even have this discussion today.

MR. HAUGH: Well, like the Bible, they save the good wine until last. Okay?

DR. ZUBER: Oh. My advise: You should really look at this book by Ginsberg.

MR. HAUGH: Yes. Well, we'll endeavor --

DR. ZUBER: I think you will get quite a bit of guidance on what it is and how to deal with these things.

MR. HAUGH: And perhaps offline afterwards you might help me on the title as best you recall it, etcetera.

DR. PAULSEN: That was by Ginsberg?

DR. ZUBER: Ginsberg. It was translated in the early Seventies. I had a copy, but somebody borrowed it, and I don't have it. But to my judgment, this is probably the best document which summarized this kind of approach, and you can take some ideas from that book.

DR. PAULSEN: Thank you.

CHAIRMAN WALLIS: I think we've got to be careful about us participating too closely in development of your documentation. We could simply stand back and say you do whatever you believe is right, and we'll critique it and, if we don't like it, we'll say so.

I hope it isn't that you are doing this in response to what we said. I mean, if there is something that we've unearthed which you believe to be not the best you could do, then you should change it, not just because we said so.

DR. ZUBER: Graham, just something. You have a good write-up in your --

CHAIRMAN WALLIS: I've got a tremendous critique.

DR. ZUBER: Wait, wait, wait. That's one. You have your --

CHAIRMAN WALLIS: Oh, the --

DR. ZUBER: The tutorial.

CHAIRMAN WALLIS: -- tutorial on the momentum equation.

DR. ZUBER: And then you had something right in your concerns. I think this should really be -- or could be of great help to them. I don't know

whether this is appropriate or not, but --

CHAIRMAN WALLIS: Well, we can talk about that. But again, I'm not in the business of developing your documentation.

DR. PAULSEN: Well, I can appreciate that, yes.

MR. BOEHNERT: I did have a question, I guess, for the staff. That is, they have issued an SER. So where does this all sit, given the SER being issued?

MR. LANDRY: We will wait and see what is done with the documentation by EPRI, and we will review that material. We are not adverse to issuing a supplement or addendum to our SER.

CHAIRMAN WALLIS: So I think the progress we've made over two years is that it's taken us actually meeting face to face, which hasn't happened for two years, to realize that probably neither of us is completely off the wall, and there's something that has to be worked out.

DR. PAULSEN: I agree.

CHAIRMAN WALLIS: But this should have happened the first day perhaps, if we had any sense.

What else do we need to say? Ralph, do you have something to say at this point to help us

finish up?

MR. LANDRY: No. I think this has been a good process. We've been trying to get through a process like this for over two years now, and I think that in a lot of ways we've been talking past each other, meaning us and the applicant.

Finally, I think we've come to an understanding of one another and are moving toward resolution, at least being able to issue an addendum to an SER that says all of these criticisms or some of these criticisms can go away as long as we have the proper understanding of the code and its use.

CHAIRMAN WALLIS: Well, that may not be our point of view.

MR. LANDRY: We do have a feeling that they have made improvements in the RETRAN family of codes by going to RETRAN-3D. We have not been happy with the course that they have taken in this particular matter.

I think, if this gets cleared up, that we will have a much better position to take on the code.

CHAIRMAN WALLIS: I think we have to have a discussion among the ACRS about what are the criteria for acceptability, and your criteria would seem to be that the code as written, programmed and

tried out, evaluated, assessed, works for reactor transients, and that's the thing that really matters. And ACRS would have to say, well, is it all that matters? How important is it that it have some good justification in terms of the kind of theory that most professional people understand.

So I think we are going to have to discuss among ourselves what weight we give to these various things in terms of the way we would evaluate the code.

MR. LANDRY: I'm not saying that we don't feel that there has to be some justification either. One of the things that I suggested this morning in talking, and have continued throughout this review, to say is the applicant should explain what is in the code and why it is acceptable or why it is -- they should justify it.

What's in the code? Why does it work, and why should we accept it? That's almost a minimum level of justification that needs to prepared for any code.

DR. ZUBER: Ralph, I think the minimum should be that we cannot license actually the code which has errors which are junior. I think this is a bad policy for the NRC.

With the first level, I would say does it

violate a knowledge of a junior; and if it violates --

CHAIRMAN WALLIS: Ralph, you had something you wanted to present about code review in general? But this is really a RETRAN meeting. Do we need to go into that or should we just take it home and read it? It lets us know where we are with the review of these. Do we need to go into that?

MR. LANDRY: No. This was simply --

CHAIRMAN WALLIS: It's simply just a schedule.

MR. LANDRY: This was placed on the schedule, and --

CHAIRMAN WALLIS: Well, it simply a list of where we are.

MR. LANDRY: -- you can take it home and read it. All it basically says is where we are with the codes that we have in-house today under review, and what do we anticipate coming in.

We anticipate RELAP5 Realistic LOCA, and we anticipate W-COBRA TRAC Realistic small break LOCA this springtime. And we anticipate sometime in the future TRAC-G for BWR Realistic LOCA.

So that's really more to apprise the committee on what we have, what we expect to have, so that for both of us we can plan what our interactions

and workloads are going to be in the future.

We do understand the comments and concerns that you expressed on S-RELAP5, Appendix K. We have discussed those with that applicant, and are prepared to push ahead in the review on S-RELAP5 Large Break LOCA, and what is expected of that material.

We hope that the Westinghouse people, who were sitting in that subcommittee meeting, also understand the concerns and, when they come in with their W-COBRA TRAC Realistic Small Break, they will take to heart those same concerns.

CHAIRMAN WALLIS: We would hope that when all this is through that a method is established for making this whole process much more efficient. We don't have to take so long to review things which eventually get fixed up.

Things would come in without elements of the documentation that we even have to question. That would be a wonderful world.

MR. LANDRY: It would for us also, and this process has been a learning process from the RETRAN to S-RELAP5, and now into the Realistic LOCA space. It's been a learning process, and we understand your concerns. We share many of those concerns, and I think we are making progress with

that.

CHAIRMAN WALLIS: Do my colleagues have any wisdom? I'd like comments from the consultants.

DR. SCHROCK: At this moment?

CHAIRMAN WALLIS: Well, you are going to write something on your way home or something, so we have something to go on fairly quickly? I think we have all said a lot today, and I'm not sure -- unless there is something you want to add which you didn't say earlier or I didn't hear earlier.

DR. SCHROCK: I don't think that I would -- I mean, in my mind it's fairly complex, and it is going to take a little time to write it down. But I'll get it to you promptly.

DR. POWERS: I would appreciate it, Virgil and Novak both. In the morning you both brought up topics where you thought Research ought to be providing support to Ralph and his people.

You, Virgil, mentioned codes for doing logic checking as a tool. Novak, I can't quite remember what it was.

DR. ZUBER: Oh, I have quite a few. I can send it again. I wrote it in my last memo to Graham.

CHAIRMAN WALLIS: I asked him to address that question at lunchtime.

DR. ZUBER: There are many things they could do that should help NRR and the industry.

DR. POWERS: Anything that would provide tools to make the processes either higher quality or higher efficiency --

DR. ZUBER: Efficiency, efficiency.

DR. POWERS: -- and I think we should -- Well, I think quality, too.

DR. ZUBER: Well, together, together.

DR. POWERS: I think we need to factor that into our long range thinking about where the research program is going.

DR. ZUBER: Had they used quality, we would not hear this discussion for two years. They could have saved money, and they would have saved time.

DR. POWERS: One of the questions -- It may not be arising here, but one of the questions that continues to perturb me in this general area -- It's a philosophical question. It's one I asked you sometime ago.

Within the realm of physical chemistry, there is something known by various names, but it's basically the Poisson ultimate equation for finding the activity of an ion in solution.

It is manifestly absolutely impossible wrong in its technical formulation. It's an incorrect use of supra position. It is hailed as one of the triumphs of physical chemistry. Everybody knows it can't possibly be correct. It just works very, very well.

I keep coming back and wondering, especially as we move into this best estimate case, what do we do about that case?

CHAIRMAN WALLIS: That's quite different, I think, from the momentum equation.

DR. POWERS: We are talking about supra position in electrostatics. It is as fundamental a thing as I could think of.

DR. KRESS: You are saying this is an analog, that we have these momentum equations that appear manifestly wrong in many respects, and yet when we compare with the data, it doesn't seem to make any difference. You get good results.

DR. POWERS: Here I think you can compare to the data, and the momentum terms are small, and you get good comparisons.

DR. KRESS: I don't think that's ever been shown, though.

DR. POWERS: In the Poisson case, that's

not the case. The terms are huge.

DR. KRESS: The terms are huge, and you still get the right answer.

DR. POWERS: And in fact, it's the other way around. They are so huge that supra position itself gets wiped out.

CHAIRMAN WALLIS: Here we have -- You know, thousands of homework problems have been solved using these momentum equations, and we know which of these are acceptable answers. There's also kinds of engineering experience with them.

So I think it's at a different level altogether from what you are referring to.

DR. POWERS: Well, I would be willing to bet that there have been more homework problems solved in supra position of electrostatics than thermal-hydraulics by several orders of magnitude.

CHAIRMAN WALLIS: Well, we could debate that sometime, not here.

DR. POWERS: I mean, it seems to me -- It seems to me that, as we move to best estimate codes, you pretty soon have to confront this, that if you've got a complex set of equations by Messers Navier and Stokes, I suppose, that cannot be solved, and so people throw terms away and do high handed things

because it fits the data.

CHAIRMAN WALLIS: Yes. Yes.

DR. POWERS: And you can't -- I mean, I don't know what the answer to this question is. I mean, it has perturbed the physical chemists for a long time, but it was fully 80 years after the Poisson-Bothman equation was first used before somebody could come up with something that was rigorous that reproduced things to equivalent exactness and, having done that, everybody proceeded to ignore it and went right back to using the Poisson-Bothman equation.

CHAIRMAN WALLIS: I think the basic question is how good is good enough is the question we have in reactor safety. How safe is safe enough? How good is good enough in terms of momentum equation?

DR. POWERS: Well, or how do you know when it's good enough. I mean, you know -- I mean, I would classify much of what we look at here as irrational proximations. That is, it's not like a finite difference equation. You know, you can't -- you are not starting from fundamental partial differential equations.

You know, when somebody does an idealization of a three-D geometry into a one-D

geometry, you know, how do you quantify the error in that. You know, beyond engineering judgment, you know, seems to me you are kind of hard pressed for a better solution.

Now if somebody goes out and CFDs it to death --

DR. ZUBER: I think a problematic match, kind of a complex level. I would start from the simplest. If I mean something which I know has been working since, let's say, my junior year, the people before and people after, and it's a standard approach, I would expect this approach will be applicable -- And I think if it's not applicable of what the reactor is using, it's not applicable to the simple approach, I cannot defend it.

I could defend things, for example, if something is very complex. I think this is addressing -- you will get it next week. If this code is so complex and we know something is wrong in there, and it still works, then the question should be asked.

I'm very sad that NRC and the industry did not themselves, why is he talking; and there must be a reason why, and try to find it. They could simplify it, they could defend these things, and it would be efficient. This is one thing which was not

done.

This approach, again, is not going to do it either. But this is something which needs to be done in the next two years.

DR. POWERS: But certainly something that Professor Wallis has mentioned as a direction that the industry and the NRC together might want to pursue is why do these things work, even when they have high handed and --

CHAIRMAN WALLIS: Actually, it's in an ACRS letter signed by the previous Chair, I think. We know where the buck stops.

DR. POWERS: He very often signs like that.

CHAIRMAN WALLIS: So I am going to close this meeting. I think we have achieved some things, and I do look forward to a resolution of all of these to the point where everyone thinks that we've said enough and the product is good enough.

So I am going to close the meeting now. Thank you.

(Whereupon, the foregoing matter went off the record at 3:10 p.m.)

CERTIFICATE

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

Name of Proceeding: ACRS Thermal-Hydraulic Phenomenon Subcommittee

Docket Number: (Not Applicable)

Location: Rockville, Maryland

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

John Mongovan

John Mongovan
Official Reporter
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