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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

THERMAL-HYDRAULIC PHENOMENA SUBCOMMITTEE

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MEETING

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EPRI WATERHAMMER STUDY/S-REALP5 SBLOCA CODE

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TUESDAY,

JANUARY 16, 2001

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The meeting was held in Room T2-B1 of the NRC White Flint Building 2 at 11545 Rockville Pike, Rockville, Maryland before the HONORABLE DR. GRAHAM B. WALLIS, Chairman.

PRESENT:

HONORABLE DR. GRAHAM B. WALLIS, Chairman
DR. THOMAS S. KRESS, ACRS Member
DR. NOVAK ZUBER, ACRS Consultant
MR. PAUL A. BOEHNERT, ACRS Staff

A-G-E-N-D-A

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

(8:35 a.m.)

I. INTRODUCTION

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.

The ACRS member in attendance is Dr. Thomas Kress. The ACRS consultant in attendance is Novak Zuber. We expect Professor Schrock to be with us tomorrow intending to explain why he is not here.

The purpose of this meeting is for the Subcommittee to continue its review of both the revised Electric Power Research Institute report, TR-113594, "Resolution of Generic Letter 96-06 Waterhammer Issues" and Siemens Power Corporation's S-RELAP5 thermal-hydraulic code and its application to Appendix K small break LOCA analyses.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, -- I will add that we will also ask a lot of questions -- 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 notices of this meeting previously published in the *Federal Register* on December 28, 2000 and January 9, 2001.

Portions of both today's and tomorrow's meeting sessions will be closed to the public to discuss information considered proprietary to the Electric Power Research Institute and Siemens Power Corporation, respectively.

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 we are looking forward to winding up this matter we heard about about a year ago, I believe. So we hope that that will happen today. So I will call upon Jim Tatum of NRC's Office of Nuclear Reactor Regulation to begin.

MR. TATUM: Good morning. Can everyone see this okay?

CHAIRMAN WALLIS: It looks good.

MR. TATUM: Okay. Good. Good morning.

II. RESOLUTION OF GL 96-06 WATERHAMMER ISSUES

A. NRC/INDUSTRY RESOLUTION APPROACH

(EPRI STUDY) - SUMMARY

MR. TATUM: First of all, are there any members of the public present here today? I just want to check just so if we talk about proprietary information, we will know who hears it.

As Dr. Wallis mentioned, we had come together a little over a year ago now to discuss the work that had been done by the industry. I basically wanted to just provide a couple of introductory comments to kick the meeting off and turn it over to EPRI and the working group to make their presentation.

First of all, the Generic Letter 96-06 waterhammer issue endorsed the analytical approach that is discussed in NUREG TR-5220. We had accepted that as a bounding approach for doing the analysis for waterhammer and asked that if licensees want to use a different approach, that they let us know what that approach is and give us an opportunity to review and approve it.

EPRI took the option of going ahead and establishing the best conservative methodology, recognizing that the NUREG approach tended to be very conservative and could cost industry quite a lot of money for modifications and whatnot to address the conservative analysis that would be required.

So EPRI established with the industry -- and from what I understand, there are about 12 utilities involved with this initiative in establishing a methodology, somewhat less conservative but conservative enough to address the waterhammer concerns that are discussed in Generic Letter 96-06.

The methodology was initially presented to the Subcommittee in November of '99, a little over a year ago. The Subcommittee had a number of questions, as did the staff. EPRI and the working group went back, did some additional testing, reviewed additional data, reformatted the report to make it a little more user-friendly. And they're back with us here today to present the additional information and try to address the concerns that were raised previously.

NRC staff has been involved with the review from the beginning. And we have been in touch with the industry trying to keep on top of the direction they are going so that we could provide a timely review when they make their submittal. They recently provided the report for our review on

December 20th, and we had an opportunity to look at it in some detail at this point.

The individual reviewers involved, myself, Jim Tatum from Plant Systems Branch; Walt Jensen from Reactor Systems Branch; Gary Hammer from Mechanical Engineering Branch; and Dr. Hossein Nourbakhsh, our contractor, are all present here today for the meeting. I would also like to indicate my Branch Chief, John Hannon, is here also for the meeting presentation as well.

Now, the event scenario of interest here I think that you all appreciate was discussed last time. It's very focused, very plant-specific in nature, where we're looking at a large break LOCA or mainstream line break, something that will generate a lot of heat in a very short period of time and cause a very rapid heat addition to the containment fan coolers.

It was an issue that was raised initially with the review that was done at Diablo. Westinghouse issued a sealer, I believe, on that. So we're trying to make sure that the industry is adequately addressing the subject.

The plants involved with this particular initiative are the ones that typically will have steam formation in the fan coolers during the event. And so analysis to address the waterhammer is necessary for them.

Other plants that we have looked at to this point typically do not have the situation where steam will form. Either they have enough dynamic head on the system where steam doesn't form for the given conditions in containment or the fan coolers are not relied upon for accident mitigation and they take measures to make sure that they will not be used.

So we're talking about a certain select group of plants. They have determined for the most part that they will have steam formation. And they're trying to make sure that in the analysis that they do that it's not going to be ultra conservative such that they have to make mods that may be not cost-effective in the final analysis.

So, having said that, let me turn this over to the EPRI working group and --

CHAIRMAN WALLIS: Is the concern just that the fan coolers will be inoperative or that a break would cause a pass for release of radioactivity?

MR. TATUM: Yes. It's a multiple issue/concern. First of all, the break could cause the fan coolers to become inoperative. And these plants typically credit the for containment cooling. So that's one issue.

Another potential problem that you could have is loss of containment integrity. So depending on how the break scenario works, you could have a leakage pathway through the cooling water system outside the containment.

The other potential problem you could have is if you have a break inside containment, it could affect the containment analysis in that you could have additional water added to the containment during the event scenario.

The service water system could be pumping water into the containment. And, in addition to that, you could have water, service water cooling that is needed for other components to mitigate the event being robbed from those systems and pumped into containment. So there's a number of potential problems you could have as a result of this.

CHAIRMAN WALLIS: Which is why I asked because you said some pumps don't rely on the fan coolers that we don't have to worry about waterhammer, but there are other effects of losing the pumping to the fan cooler.

MR. TATUM: Right, yes. To clarify that, what I mean by that is they don't rely on the fan coolers during the event. They remain isolated. So they don't have potential. Even though they may have steam form, they don't have the potential for waterhammer occurring and for starving the other systems, the service water and whatnot.

Any other questions on --

DR. ZUBER: Are you going to develop the end of this report?

MR. TATUM: Yes. We will give you at least our preliminary views coming into the review. We are going to -- we have discussed our preliminary comments with the working group, and we would like to hear their presentation and see what they have to say to address the comments that we have made. Towards the end of the presentation, we do plan to give you our perspective.

CHAIRMAN WALLIS: Is this report supposed to resolve an issue or be a contribution to the resolution of an issue?

MR. TATUM: It's a contribution to the resolution of the issue for the plants that are involved with this initiative.

CHAIRMAN WALLIS: But then the plants themselves have to do a lot of work as well.

MR. TATUM: That's correct. They have to apply the methodology to the extent we approve it and address some additional questions we will ask.

DR. ZUBER: What I would appreciate, at the end of the meeting when you present your assessment, to address this questions, process information in this report, "How would you feel a utility can respond in a responsive way to our concerns?" but that there is enough specific information for a utility to use or the thing is so diffuse that you can pick and read whatever you want.

MR. TATUM: Well, hopefully EPRI and the working --

DR. ZUBER: No, no.

MR. TATUM: -- group address that.

DR. ZUBER: They will. They will. But, I mean, you as the regulator and experienced with the capability of the utilities, how do you feel they will be able to use this information in a responsive way which would meet your requirements of safety?

MR. TATUM: I understand. That is one of our concerns going into the meeting, but I am hopeful that the working group will be able to address our concerns and after their presentation is over, we will be in a better position, I guess, to give you our opinion on it.

CHAIRMAN WALLIS: The working group may be able to explain to us how these results fit into plant analyses or even show that they have been used for some plant analyses.

MR. TATUM: I guess I would want to defer. I don't want to speak for --

CHAIRMAN WALLIS: It would be nice to make that connection, I think. Thank you.

B. REVISED EPRI REPORT - EVALUATION OF GL 96-06 WATERHAMMER ISSUES AND RESOLUTION OF COMMENTS FROM 11/17/99 SUBCOMMITTEE MEETING

MR. WAGONER: Good morning. I'm Vaughan Wagoner, the Carolina Power and Light Company and Chairman of the Utility Advisory Group for this effort that we have contracted with EPRI and others to provide for us.

First, I guess I'd like to introduce the folks on our team, if you will. I think you know most of them. Going down through the list here: Dr. Peter Griffith. Let's see. Fred Moody. I don't need to look at the list: Dr. Fred Moody; Dr. Ben Wylie; Dr. Tom Esselman from Altran Corporation; Greg Zysk from

Altran Corporation; and Dr. Avtar Singh, our Project Manager, with EPRI. They let me say a few words because we provided the money for this effort.

(Laughter.)

MR. WAGONER: I've given you a handout. Frankly, I'm going to blow through the first four or five slides because you have seen this stuff before. Just for the record, the background, we know where we've been and what we have done. We came here about a year ago, talked with you. You asked us to go back and address some issues. We think we have done that. We are prepared to talk with you about that today.

Mr. Tatum mentioned the number of utilities that participated, about 14 utilities, representing somewhere between 25 and 30 plants depending on which day of the week it is.

CHAIRMAN WALLIS: Can I also ask how they participated? Did they define the problem or did they just provide money?

MR. WAGONER: No, sir. First we find the problem because --

CHAIRMAN WALLIS: He said, "These are the things we need to know"?

MR. WAGONER: Yes.

CHAIRMAN WALLIS: Is that stated somewhere? Can we see what the problem is that this addresses?

MR. WAGONER: I think it was stated in terms of the original generic letter that came out. Plants individually provided specific responses and then from that came around, as I recall, a request for additional information.

CHAIRMAN WALLIS: For example, there were problems with, say, face separation in the fan coolers. It has to be addressed by the utility. It doesn't seem to appear in the report at all. Are there things like that which were laid out as to be addressed by EPRI that are not addressed by EPRI?

MR. WAGONER: In terms of the original scope of work, yes, sir.

CHAIRMAN WALLIS: They were? Okay.

MR. TATUM: We recognize that --

CHAIRMAN WALLIS: It might be interesting to see what that was.

MR. TATUM: We may be able to do that. I don't think we can do it today, but --

DR. ZUBER: Well, let me say my problem, in addition to what Graham said, I don't see much relation between what you have in this report and a real reactor. I think you have a discussion and there is a big gap which must be done on faith.

For example, in one place in Section 7.3, I guess, you say that the utility should make it for a balance, equation to balance, presumably momentum to manage, where you don't know what equation and how to do it. I think this is an important question.

Twenty-six years ago I reviewed the work of INEL, and I found that RELAP4 had the wrong momentum equation. That was 26 years ago. Last year Graham found that RETRAN, a product of EPRI, had the wrong momentum equation. That's a balance equation. This year I found that G.E. had a wrong mass balance and energy balances.

So, even these large institutions, which presumably should have the know-how and knowledge, cannot even write these balance equations correctly for courts. And now here I'm reading these reports and you are delegating these to a utility how to do it.

I think this is too loose a way. It's too descriptive. I think if you give it to a utility, you should have more prescriptive descriptions, "Thou shalt use" this and that. I think it will be easier for the utility and it will be easier for NRR to review it. As it is, it's an awkward question.

There are all kinds of questions like it in this report, which are really left open from an experiment to an application reactor. I hope that you and EPRI will really address these questions, how this information from this report can be used by a utility to answer safety issues.

CHAIRMAN WALLIS: Maybe that would fit in at the end, after we have heard the report. Then we could go back and say, "Well, does this really solve the problem?"

MR. WAGONER: Okay.

DR. GRIFFITH: I think the flow chart here will help a lot to clarify what the utility is expected to do and what the report has provided.

DR. ZUBER: Peter, you should not expect something if they don't have the capability. One would have expected EPRI had the capability to write the momentum equations. One would have expected that G.E. would have the capability to write an energy balance equation, a mass balance. And they did not.

And now you are really passing the buck to even a smaller entity to perform something. I think it should be more prescriptive.

CHAIRMAN WALLIS: Okay. You know our expert panel. They have reviewed the report and are here to talk with you about that. You know --

DR. ZUBER: I have got a question just on this.

CHAIRMAN WALLIS: Okay.

DR. ZUBER: How did you use this panel? How often did they meet? What was their input? What was their participation and how it functioned?

CHAIRMAN WALLIS: Would you like it directly from the Chairman or would you like it --

DR. ZUBER: I don't care. I mean either one.

MR. WAGONER: I can certainly give you my perspective. We hired the expert panel to provide an independent assessment of the experimental work that was being done because there were some areas in low-pressure waterhammers that there was not a large amount of technical data, especially low-pressure waterhammers in open systems where they are the kinds of things that we have looked at in terms of cushioning and air training, et cetera, that we did not have the experience or data. And so we hired the panel to help us work with our contractor to evolve the steps, to look at the --

DR. ZUBER: Which contractor?

MR. WAGONER: With Altran Corporation.

DR. ZUBER: Altran? Okay.

MR. WAGONER: Yes.

DR. ZUBER: How often did you meet?

MR. WAGONER: We met at least three times formally and a number of times independently in direct consultation with a contractor.

Peter, would --

DR. GRIFFITH: Yes. I don't think a month went by that I didn't either go over to Altran or talk to them on the phone. And we had something like four or five formal meetings where all of the sponsors were present. We individually reviewed -- well, we all reviewed the whole report, but we spent most of the time on the parts that we were most familiar with. So the report was reviewed any number of times, probably five or six times, one way or another.

CHAIRMAN WALLIS: You folks signed off to this as a useful report to the utilities. Did you look at P&IDs for plants? Did you look at the real scenario in the event of these accidents to figure out what were the problems that needed to be addressed?

DR. GRIFFITH: We looked at some real scenarios, as a matter of fact. When the utility representatives were present, those were the questions that were raised. We had a number of things they were concerned with.

CHAIRMAN WALLIS: So did you ask questions like "Is it one void or many voids?" and things like that and "Where are the voids?" and "Why are they there?"

DR. GRIFFITH: Well, some of the problems, they were so plant-specific we didn't think we could address them in a categorical way and a lot of details which are different -- well, practically every plant is different.

CHAIRMAN WALLIS: That's right. That's right. So there is a lot of work for the plant to do.

DR. GRIFFITH: There is. There is no question about it. And when you see the flow chart, I think you will see what items we identified for the utilities to provide the information.

MR. WAGONER: Okay. I think we have been over these. We know what the system can do for us.

CHAIRMAN WALLIS: With the PIRT complete, you have this wonderful part which says, "These are the things we need to do." Does someone at the end of the project go back and say, "We did all of those things"?

MR. WAGONER: Tom?

DR. ESSELMAN: The PIRT was done at the beginning of the problem. At the beginning of the problem, we checked the plan against the PIRT. And we did go back and rereviewed that as a part of PIRT preparing the list to see that had done everything that we had identified in --

DR. ZUBER: Let me also ask: How do you feel about the PIRT?

DR. ESSELMAN: How do I feel about the PIRT?

DR. ZUBER: Yes.

DR. ESSELMAN: I think the PIRT was very useful. I think we sat down and really looked broadly and asked with Peter and Ben and Fred what things could be affecting this or that. And I think they were doing something very useful.

DR. ZUBER: Let me go back. Especially after I read your blessing of this report, that you agree with the PIRT, I started to read the PIRT. I found geometry, and you rate it high. What kind of geometry? What do you look at in the geometry? This is not addressed.

It's so vague it's almost -- to my assessment, it's almost useless to tell you the geometry is important for this program. I have known this before. How would the utility know what to look, what kind of geometry, what to look in the geometry, what is the most important thing? I don't find it.

So this is the weakness I found in this report, which is the buck is being passed to the utility. And I don't think that they have the capability of doing it.

DR. ESSELMAN: Let me say that a part of what we will present is the specific actions related to the flow chart and what the utilities need to do. I believe that what the utilities need to do the utilities are capable of doing, number one.

And, number two, those are going to have to be specific analyses. They are going to have to be submitted to NRR and be specifically reviewed.

DR. ZUBER: Well, the question is not what they need to do it. You cite look at the voids. Voids are important. So what? I know that how to look at these voids, prescriptive, do this and do that.

Then they can do it. And if they don't want to do that, they can justify not to do it but to say, "Look at the geometry. Look at the voids. Look at the subcooling." We have known this. This is so descriptive it's useless.

DR. GRIFFITH: Well, I don't think we could make a general statement that would cover most of the plants. When you look at the details, they are so different.

DR. ZUBER: Well, the point is there is a -- you cannot do everything, but you should at least give the broad outline. Thou shalt use this and take a look at it, not necessarily look at a void fraction. So what?

MR. ROCHINO: Can I make a comment?

MR. BOEHNERT: Yes, if you identify yourself.

MR. ROCHINO: My name is Lee Rochino. I'm from Rochester Gaart Electric. At one point in time, the utilities that send ultra V configurations of every plant and out plant otherwise -- and Tom and the external, they look at the configurations of the participating plant. And then they went ahead and took that into consideration in considering the --

DR. ZUBER: You see, the thing with that, the geometry is important depending on what property. Then you say, "What aspect of geometry do you have to look at?" I think this is more in detail.

Maybe ten plants will not have it. Maybe about two will have it. So you have to be appreciated. You should look at this and this and that. And then you have the utility that helps NRR.

MR. WAGONER: It's in there.

DR. ZUBER: Where? I cannot find it.

MR. ROCHINO: Let me make another point that as far as the utilities are concerned, we do have stuff to look at, a whole page. We've got these. And people are experiencing in this. So given the proper items, utilities can use it to --

DR. ZUBER: Well, as I said, I like to give you the benefit of the doubt. I said after 30 years in this business, I have seen G.E. fall on its nose a few months ago. I saw EPRI fall on its nose a year ago. I saw INEL with all of their Ph.D.'s and experts make really basic mistakes. And you should really try to avoid this in this industry.

DR. KRESS: One way to put our mind at ease might be to tell us what geometry is important.

CHAIRMAN WALLIS: That's why we are waiting for the presentations.

MR. WAGONER: I guess the point is from a utility perspective, I feel that in the report, the things that we need to look at from a geometry perspective are addressed. We told them to look for dead legs that are in the void here. We told them to look for changes in the sizes. We told them to look for partially open or closed valves. We told them to look for orifice plates.

DR. KRESS: But then you said dead legs weren't important later on in the report.

DR. ESSELMAN: We didn't say dead legs weren't important. We said that if you voided dead legs, they needed to be addressed on a plant-specific basis.

In general, our review of the P&IDs and the drawings show that it was not a predominant configuration that existed in the plants. But, yet, we did not take care of that generic -- we did not provide a method and said that if you had that, you needed to do it.

If your void passed an orifice plate, you needed to do a plant-specific analysis or a partially closed valve you said you needed to do from a specific analysis.

DR. KRESS: So these are the geometry things that you say were important?

DR. ESSELMAN: Yes. The whole condensation, this waterhammer evaluation is related to a vertical line --

DR. KRESS: And a horizontal line.

DR. ESSELMAN: -- transitioning into a horizontal line and what can happen when you get there. From a geometry point of view, the utility from a standard steady state flow transient basis can use a number of codes that they use all the time to model every change in direction and every pipe length to see what are the flows, what happens when you start the pipe.

We don't say, "Evaluate the void." We say specifically, "Calculate" during the 35 seconds or so where the void goes based upon drainage and gravity, number one; based upon pressure in the void; and based upon what your fan cooler is doing. And, as you transition, as your void goes, you need to know where it ends up because that's where the closure will occur. And if it passes an orifice on a partially closed valve, you need to do a specific plant evaluation.

We don't expect that to happen based upon our review of these plants. But we also say that when you uncover a horizontal leg, record from the analyses what your system pressure is because that is going to be your driving pressure for your condensation-induced waterhammer. We have a criteria that says if it is greater than or less than, you are either okay or not okay.

The analyses that have been left to the utility are the analyses that require them to look at the great detail in the configuration, in the pipe layout, in the vertical drop as you go from a containment location.

What we have dealt with is what was the most difficult to deal with. And that is: How does final closure occur? What is happening in the void? And how does final closure occur?

I believe we have left for the utilities to do: number one, the part of this that is very plant-specific because the fan coolers are different. Where the water is and how the drainage will occur is different. But that is also the easy part of this analysis, and that is what the utilities know how to do because they're doing steady state, generally steady state, pump start, pump stop analyses every day.

DR. ZUBER: Well, that is with condensation.

DR. ESSELMAN: Not condensation. That is what we have addressed specifically. And we have said we have asked them. And we will cover this again. So let me just jump ahead to address this specific question.

We have asked them to calculate the closure velocity up to the point where you haven't closed your void but you have nearly closed your void. We then have said once you know that velocity, we have given them the tables with instructions, with example problems so that they could enter the graphs and see how much cushioning they're going to get based upon how much air, how much space.

We have told them how to --

DR. ZUBER: This you got from your experiments?

DR. ESSELMAN: No. From experiments -- well, from analyses mostly with most of the parameters, steam condensation rate being the primary parameter developed from experiment. Other than that, it's derived from a method of characteristics analysis.

And we use the rigid body model only once we have proved it was conservative, number one, and because we needed to do all of these parameters so that we didn't leave that to a utility.

We said, "All that you need to do is figure out what your lights are, how much gas you have in the void, where your steam is, and just enter this table and say that my final velocity is 82 percent of" --

CHAIRMAN WALLIS: We thank you for your contribution. I guess we are just indicating that we feel there are other parts to the problems. And we'll probably come back to them during the presentation. I would like to move on to that.

DR. ESSELMAN: What we plan to do is just to walk through a brief overview of the analyses beginning to end to hit the high points. But the first thing that I would propose that we present is: What is the process, and what does a user have to do?

We have a flow chart. We have taken the flow chart, and we have broken it down step by step. And we will describe what a utility has to do because it is plant-specific and NRR is going to have to do that review. But then where they get guidance, number one, the single active failure criteria, the final closure, how to deal with condensation-induced waterhammer, how to form a loading function with pulse time, all of those things that are in the report but, frankly, are the difficult things to do.

I believe we have left the utilities to do the things that they are very capable of doing and those things that are difficult, challenging, related to condensation and related to some of the specific geometry issues and what is the heat transfer, where is the air, and how do you get your air. Those are the things that are addressed in the report.

We will go through that in detail because I think it is very important. And I think that we have come a long way in the past year putting the user manual together, trying to strip out of that the science and leaving the instructions. And we have worked on sample problems that I know utilities have reviewed and have found very useful also.

We will go through all of that in detail. I appreciate all --

CHAIRMAN WALLIS: I think when we go through the detail, we may be able to answer some of these questions.

DR. ESSELMAN: I think so, too.

MR. WAGONER: That is the slide I thought I was going to blow through.

(Laughter.)

MR. WAGONER: From my perspective, the utility perspective, after spending about a million and a half dollars and looking at this thing for nearly two years, the bottom line is, first off, it's a low rise event.

If we had to stretch this simultaneous loop LOCA to a 24-hour period, even to get to 10^{-6}, we take it down to an hour or 10 minutes, 30 minutes, and the numbers are even smaller. So we've got an extremely low probability of event. And there is no challenge to the safety function.

CHAIRMAN WALLIS: Can I ask you: In the report, we get pressures of 1,000 psi and so on, which seems like that you could get in the plant under some circumstances. Is that not a challenge of any sort?

MR. WAGONER: Well, it looks like to me there's not based on, one, bursting a pipe. That's the bottom line. If we don't break that pipe or tube, cooler tube I should say, we don't have a problem.

CHAIRMAN WALLIS: So these systems are designed for orders of 1,000 psi pressure?

MR. WAGONER: Impulses? After you look at an impulse and look at the ultimate strength of the tubes and pipes, -- and we'll go through that -- I don't believe that there is a safety challenge there.

DR. GRIFFITH: I think we made a good case on that. We'll get to it.

MR. WAGONER: Yes.

CHAIRMAN WALLIS: The cooler is designed for 1,000 psi internal pressure?

DR. GRIFFITH: There is a chart we'll get to.

CHAIRMAN WALLIS: Okay.

MR. WAGONER: And the truth of the matter is these systems have been banged up hundreds of times in the real world.

CHAIRMAN WALLIS: We noticed that.

MR. WAGONER: Yes, for loop-only events. And, to the best of our knowledge, there has never been a failure. We have never ruptured a tube. We have never even deformed a piece of pipe, maybe shaken a concrete allowing some anchor bolts a couple of times.

CHAIRMAN WALLIS: Maybe shaken a few people's confidence or nerves.

MR. WAGONER: Well, that's okay. Back in my start-up days, I happened to be standing beside the main steam stop valves when operators hit the test button, young kids just out of college. I've never seen anything like that one before.

CHAIRMAN WALLIS: We had the NRC down to our lab when we were doing waterhammer tests. They ran for the door.

MR. WAGONER: The point is from our perspective that's a lot of real world experience that we think we are going to share that is worse than any postulated thing that we might get, and nothing happens. So what this really boils down to is a reasonable approach for figuring out hangar loads.

And the truth of the matter is the classic way we do this, we take that 1,000 peak pressure, stick it into our system, and run that through as the static load on the hangars, and do a p times 8. And you end up putting a whole bunch of steel, more steel in the pipe. And I think we all know that adding to steel to handle impulse loads is the wrong thing to do.

I've been there in balancing the plant systems when we had feedwater heaters moving. We thought, "Man, let's put more steel." And we tore up more things. When we started taking steel away and the feedwater heater had been running for ten years, we'd dance around a little bit, a couple of times during start-up. And that's the end of the problem.

I think that's where we are, frankly, in this process. As we go through this thing, is every step of it rigorously defended at the F = MA level? No, it's not.

When we step back and look at it from an engineering approach to figuring out what's the right load to put on these hangars from these impulses, I think we have a reasonable engineering approach. Frankly, I would ask you to look at it from that perspective.

CHAIRMAN WALLIS: I guess the sensitivity comes because there have been incidents where waterhammers have broken pipes which mattered, not in this particular system.

MR. WAGONER: Yes, sir.

CHAIRMAN WALLIS: Waterhammer does happen. It continues to happen. Since the --

DR. GRIFFITH: I guess the key on this system is the pressure is low --

CHAIRMAN WALLIS: Right.

DR. GRIFFITH: -- and there is air in the water. Those two things mitigate the waterhammers. There is no question about they have had waterhammers that are busted pipes, but it has been deairated water and high pressure. All right? And we have airated water and low pressure. And that makes a big difference.

CHAIRMAN WALLIS: Well, they have had waterhammers in fire suppression systems which have entered in the water which were not pleasant in consequence.

So it's not just a question of low-pressure system with air. You've got to look at the loads. I agree it's a lower load.

DR. GRIFFITH: Yes.

MR. WAGONER: But that was what I wanted to get to. It's our perspective. And I would ask you to consider that as we go through some of the details of this thing. With that, I would like to turn over to Dr. Esselman.

CHAIRMAN WALLIS: Thank you very much. Thank you for your patience.

MR. BOEHNERT: Now, is this going to be open session? We're not going to get into closed session?

MR. WAGONER: I'm sorry. I needed to say that. From this point on, we are at a point where the proprietary material is pretty much interwoven with the rest of the presentation.

MR. BOEHNERT: Okay. So we need to go into closed session?

MR. WAGONER: Yes, sir.

MR. BOEHNERT: Okay. Transcriber, we need to go to closed session in the transcript.

(Whereupon, the proceedings went immediately into Closed Session.)

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

CHAIRMAN WALLIS: Now I think we would like to hear from Mr. Tatum.

MR. TATUM: I guess I would like to give you the NRC's staff perspective on this going into the presentation today, which we have heard a lot. We have a lot to think about here based on the discussion, also from the Subcommittee members.

First of all, we view this as a good effort by the industry in trying to address the problem and come up with an analytical methodology, something different from what is provided in NUREG 5220. It's a possible solution for utilities to use, something that we may be able to accept, for addressing the waterhammer issue, specifically low-pressure service water systems.

Notable strengths based on our review and working with the industry on this, I think the PIRT was a good exercise for the group to go through to help I think focus their attention on what needed to be looked at and help to focus their testing.

We think the testing and data collection were also a strength to actually go out and get data where they didn't have the information, although I do understand there are some reservations from the Subcommittee on that point.

I think a very notable strength is the endorsement by the expert panel members. Obviously the industry took a look at what was available to help them out on this issue. And I think they came up with some real experts. I think we can place a lot of credibility in the work that was done based on the people that are involved.

So those are the strengths that I would mention on this. Let me get into some of the weaknesses. First of all, I guess looking at the thermal hydraulics end of it, we also shared some of the similar views that were experienced here by the Subcommittee looking at the scaling.

Some of the things that we were interested in and we will be discussing after the meeting I think is for the condensate-induced waterhammer, the applicability of small test data to the plant so the configuration -- water to pipe size, we have spent quite a bit of discussion here today on that point.

For the column closure waterhammer, condensing heat transfer and compressibility, how well those would apply to the plant-specific situations, larger pipe sizes, the NUREG TR-6519 screening criteria for the condensate-induced waterhammer, specifically the length over diameter ratio and the subcooling temperatures, to what extent they would apply for larger pipe sizes.

Not to belabor this, but we also had questions with regard to the deletion non-condensible gas. And we look forward to hearing back on what the resolution of that is.

Also, we note that there is no guidance for condensate-induced waterhammer analysis for pressures greater than 20 pounds. So we understand based on your survey of the industry, you don't expect that to be a problem in that the plants don't have that situation where the pressures would be greater than 20 pounds.

And also, finally, applicability of models to the plant, actual plant conditions, that was raised here. This is something we'll think about a little more, I think.

The other area I wanted to talk about as far as potential weaknesses has to do with the mechanical/structural area. See, in this area, looking at the different analytical approaches and whatnot, we were questioning the termination of the pulse rise time and duration.

We understand how that was determined by Altran. And we just questioned whether or not they're really conservative enough using the ten percent figure versus maybe some other figure going into the pulse rate, not that I would say that it's definitely a problem but something we need to think about to satisfy ourselves on; use of the single waterhammer pulse versus several cycles in the analysis and whether or not that would make any difference in the outcome and the pressure that you would see.

DR. GRIFFITH: Were you concerned with sort of exciting your resonance?

MR. TATUM: Yes. How if you had several cycles playing into it, how that would affect the overall outcome and the resonance.

DR. GRIFFITH: But the period is around two seconds. So I think if it was a resonance, it would have died out. The oscillation would have died out.

MR. TATUM: Did the data pretty much capture, Gary, on the

MR. HAMMER: I didn't really hear the comment. Basically, the number -- Gary Hammer. Basically we talked to them about the single waterhammer pulse versus several cycles. I think we were talking about resonance on that.

MR. TATUM: Yes. And, Peter, I go back to the figure that Tom presented, where he showed that most of these lobes are founded by the analyzed values when you use this method. But there were a few points that were below that curve. Those were the ones that we think we may have seen some resonance on or something like that.

You can see that on some of these traces, there are multiple cycles. There is a big peak, but there is follow-up by smaller ones. And we're worried about that additional energy that could go into this system from a smaller process.

DR. GRIFFITH: That's what I just wanted to know, what categories you were concerned about.

MR. TATUM: The next item, attenuation due to fluid-structure interaction. We understand the concept and the information that is presented in the report. However, it is a fairly simplistic model that you are referring to. And I don't know that we are really comfortable accepting the attenuation concept.

I think it would require plant-specific analysis, rather than accepting that a licensee would apply the methodology and just come back to us and tell us that they had a certain amount of attenuation. We would like to see probably on a plant-specific basis how it is a credited attenuation.

I think we will be more comfortable just not getting the fluid-structure interaction, recognizing I think the general conclusion that attenuation would be overriding any amplification.

Structural damping value using comparison, comparing the analog versus the measured loads, is not identified. We thought that would be important for user application. We discussed that, I think. You're going to rectify that.

DR. ESSELMAN: He used a half of a percent damping in the analyses. We'll note that report in the revision.

MR. ZYSK: A tenth of a percent.

DR. ESSELMAN: A tenth of a percent. It was essentially zero.

MR. TATUM: A tenth of a percent, yes.

DR. ESSELMAN: We are not advocating in the user manuals how the plants should structurally run their analysis code for piping. That is certainly beyond the scope of what we are doing. We can describe what we used in our code, but, again, identified for user application ins not within our scope of work.

MR. TATUM: Right. We understand that. We just want to make sure that recognizing the information that is in the manual is going to make sure there's no misapplication.

DR. ESSELMAN: We'll make sure that that's in there.

MR. BROWN: Tim Brown, Duke Power.

We've been using the damping ratios that we use for seismic. Now let's just led by our SAAR.

MR. HAMMER: This is Gary Hammer again. I consider damping. Whatever value you use in your licensing basis for any other piping is okay. We just wanted to make sure that for making a comparison and demonstrating that they were showing that analog loans versus measured loans, just to understand what the basis was.

DR. ESSELMAN: He'll look into that.

MR. TATUM: Just one final point I think I'd like to make that's not reflected on the slides. The conclusion here that you all have come to is that the loop-only waterhammer would be bounding.

I think that's a very significant conclusion on your part and one that if it stands, then if we can accept that, I think it goes a long way to resolving the issue, at least for NRR, recognizing, as Vaughan had stated, many plants have already had the occurrence of loop without LOCA obviously, but I mean during pump casts, ESM testing and whatnot.

That has been a very common occurrence in the past. Plants have had problems based on waterhammer from just the loop scenario. And where they have had problems, they have gone in and made modifications. They have installed vacuum breakers and whatnot to correct the problem.

I think that if the conclusion is valid that the loop is a bounding situation, for those plants that can credit that, I think that would go a long way to resolving the issue because at NRR, that is something we have had experience with. We are comfortable with the plants being able to deal with that scenario.

That may leave the closed loop plants with a little more analysis to do, however, because in a loop scenario, they would not have had that kind of experience. So that would be a remaining issue that we would have to credit the analytical methodology, then, for those plants.

Let me ask John Hannon, my branch chief, to give the management perspective on this.

MR. HANNON: Thank you, Jim. This is John Hannon, the Branch Chief of the Plant Systems Branch.

Just to start out, it's been a very interesting experience for me. It's the first time I have had an opportunity to get some technical material in quite a while. I appreciate all the good dialogue that I heard today.

There is a historical perspective I wanted to remind everybody about. This issue has been cooking for quite a while. Originally we were thinking when we generated the original generic letter that all of the SEs would be completed, the safety evaluations for all of the plants would be completed around August of 1998 with the expectation that was the majority and then residuals would be finished sometime during 1999. So we had extended the time period for which we thought this generic activity would be completed.

Joe mentioned earlier this morning I think that the complexion of the environment that we are all working in now has changed over that last couple of years.

We're trying to become more risk-informed in our regulatory decisions. And we are also being held to some different standards with regard to our management decisions from the standpoint of what we call the four pillars now with maintaining safety being the primary one and also enhancing public confidence and being more realistic in our decision-making and trying to be more effective and efficient.

Then there is the one about reducing unnecessary regulatory burden. So I think all of those new criteria have to come into play as we move forward on this particular topic.

So from a management perspective, I can tell you that that I am interested in seeing this item wrapped up. I would like to treat it as an industry initiative with EPRI taking the voluntary action here to come up with a solution that can be applied to the remaining plants generically.

What we are looking to the ACRS to provide is their considered opinion as to what we need to do to provide constraints in our safety evaluations, otherwise restrictions that would need to be applied on a plant-specific basis because we really do need to start moving this into the end game.

DR. ZUBER: I have a question.

MR. HANNON: Yes?

DR. ZUBER: How can the NRC make plant-specific data information when the ACRS doesn't have this information?

MR. HANNON: That's a challenge for us. We think the industry has made a good faith effort, as Jim pointed out, to try to wrap up the technical issues here.

So the challenge is for us to now see if we can move it into a round where we could take a plant-specific application against this methodology to see if it can be considered appropriate or acceptable for regulatory purposes.

Again, we have to take into effect all of these considerations, regulatory burden, and ways. Are we able to say that we are maintaining safety?

So that is a challenge. But I think that from hearing the line of questions that I heard today through the ACRS, I think we are all on the path of coming to a leasable closure on this issue. That is the challenge I think we all have in front of us now.

Any other questions or comments?

(No response.)

MR. HANNON: Thank you, Jim.

CHAIRMAN WALLIS: I think Jim Tatum has reminded me of the loop versus loop LOCA. This report is mostly about loop LOCA. In the earlier draft, there was simply a statement that loops are worse than loop LOCAs, I mean, without much justification at all.

I still don't quite grasp the rationale of why the loop is worse, to we say there is less air produced and so on. But there has to be a technical analysis or something that shows why it's worse. I'm not sure that it's here. It seems to be more of a --

MR. HANNON: We added a section in the PBR on loop versus loop LOCA. The conclusion that we have drawn and provided in the PBR is that if in the loop LOCA case there is no gas given off and no steam in the void, they will be the same because the same number of pumps will start.

There will be no cushioning or the same amount of cushioning with any gas given off, which we believe there will be. With any steam in the void that is pressurized, that final closure has to be cushioned. That cushioning will give you a lower velocity and a lower waterhammer.

CHAIRMAN WALLIS: So there is no air given off in the loop only?

DR. ESSELMAN: We think that whatever air is -- we do think that there is air given off in the loop only. We don't think that it will be less in the loop LOCA. We think that it will be more.

CHAIRMAN WALLIS: I think I know in this thing. Originally I looked at this curve, and it's ground for a cubic meter; whereas, the other one is ground for a liter. It's confusing, different scales.

MR. ZYSK: We've got roughly three orders of magnitude.

CHAIRMAN WALLIS: Right. That's where the orders of magnitude come from. I didn't realize that in the first slides. Maybe it is clearer, but it sort of needs to be clear.

Do you have a question, Tom? Do you want to raise your question or do you need some help? Is it important?

DR. KRESS: Yes. It may or may not be. I was looking at Figure 10-8 in the technical basis document. I don't know if you have a viewgraph of it or not, but it appears to me when you're plotting under these conditions, rise time as defined versus closure velocity, that you're basically plotting two independent variables versus each other, which would be thrown out by the scatter of the data in the first

20 feet per second of closure velocity. I'm not even sure why you get a correlation above that.

If I had questions about the relevance of this particular plot and whether or not indeed those are variables you could correlate with each other because they look to me like independent variables. They have no relationship to each other.

MR. ZYSK: If I could touch on that? The idea is that that rise of pressure over a time period is proportional to the velocity of closure to some extent. In other words, if you have a fairly slow-moving mass of water, then that rise in pressure as you squeeze that final closure would be spread out fairly long. And if you have a rapid closure, the net rise is fairly abrupt. So they're not truly independent in that aspect.

We looked at Configuration 1, which was essentially a cold water on steam closure. So it should be as abrupt as we can get compared to, say, the Configuration 2A or 2B data.

CHAIRMAN WALLIS: There are non-condensibles in there except when they come out of the water.

MR. ZYSK: That's correct. That's correct. So the rise --

CHAIRMAN WALLIS: So they are not voided off or anything, then.

MR. ZYSK: Right. There should be virtually no non-condensibles there. So that should be as abrupt a rise as possible.

We also looked at if you can look at --

CHAIRMAN WALLIS: Well, you could argue it had something to do with the shape of the interface and that the interface --

MR. ZYSK: It could be, but our --

CHAIRMAN WALLIS: -- is tilted because of a certain time to close --

MR. ZYSK: Yes. Our guidance on that from our experts was that that was kind of a secondary effect and that the shape of the interface wouldn't influence the rise time as much as the compression of the wood would.

If you look at also Figure 9-10, which is the same data looking at rise time versus impact velocity, this is model results. This is from our rigid body model prediction, where we actually put a gas concentration. It's on Page 9-13.

We actually put a gas volume or mass of gas in the void. We did tend to see a relationship between the -- you look at the exponent on our curve there. It's essentially a polytropic gas impression.

So based on how we enveloped pretty well all of that theoretical data. We also compared in the Figure 10-8 how we matched up with the most conservative of the test configurations that we ran. It kind of slices through the data in the 10 to 20 feet per second but matches up very well in the higher closure velocities, 25, 30, 40, 17 percent.

CHAIRMAN WALLIS: Looking at 9-10, there are all of these points up above the curve.

MR. ZYSK: Yes.

CHAIRMAN WALLIS: So you could argue, like my colleague was saying here, that these are really two variables. They just don't correlate with each other. It's just that because of limitations on the experiment or something, there is a limit to them, which is what you have got here.

MR. ZYSK: Yes. And I think, again, from an engineering approach, this is a reasonable way to characterize what the rise time is doing. It's conservatively bound what our model --

CHAIRMAN WALLIS: But it doesn't mean to say that in some other facility, there wouldn't be some other limit.

MR. ZYSK: Looking at the column closure event in a pump system as essentially a one-dimensional problem, no, I don't think that the chance of this being vastly different at other facilities was really that big of a risk.

This particular set of model predictions at Figure 9-10 is for 4-inch, 10-inch, and 16-inch data. So it's not --

CHAIRMAN WALLIS: If something were really one-dimensional, there would be no air in there at all. The rise time would be zero.

MR. ZYSK: If there were no air, yes, the rise time would be zero if you didn't get any steam cushion or anything like that. The importance I think is in some of the existing publications. Without any basis to go on, the recommended rise time is one millisecond.

Assume a square width. We think that is wildly conservative. And I think there is a basis for showing that it is 10, 15, 20 milliseconds as a reasonable number for a rise time of a pressure possibility.

CHAIRMAN WALLIS: Now, when something closes in a bigger pipe with the same velocity, if you had, say, a slope to the front, it would take longer to close the front, wouldn't it?

MR. ZYSK: I would guess so.

CHAIRMAN WALLIS: So the rise time may scale in some way with diameter.

DR. ESSELMAN: A slower closing, though, would generally, as shown here, also a slower closing will give you lower loads in a piping system. So using a more rapid closure, even though we know that with cushioning and in larger pipes, it will be slower, bounding it with a curve here is conservative relative to the loads in the piping --

CHAIRMAN WALLIS: So your arguments about scaling seem to be that all the ways you can imagine to scale seem to indicate that it's conservative to assume that the two-inch pipe data is representative.

So although in the one place where you compare experiment there with the two-inch and four-inch pipes in the configuration, which is a variation of one. It's actually the four-inch data which are higher.

DR. ESSELMAN: I guess I don't believe that our conclusion is that two-inch data is always conservative. I think that two-inch data is representative. And by doing things like this when we're taking what we think is the conservative side to rise times, for instance, when we know that has a big impact in the structural loading, that gives you support loads doing things like this. Bounding the data this way I think gives us what we feel are conservative applications for the parameter into the structural loading.

Again, as we started this morning talking about supports and the kind of differential loads and rise times in the -- rise times will give you support loads being important. We think in areas like this, for instance, we have taken a conservative approach.

CHAIRMAN WALLIS: Is there anything else?

(No response.)

CHAIRMAN WALLIS: So we will see him again, I guess. Do you have any idea of the time scale?

DR. GRIFFITH: I think we've got to decide what we need to do before we give you a deadline.

CHAIRMAN WALLIS: Okay. My hope would be it would take less time than the last interval between meetings. I think we are ready to adjourn for the day. Anything else we have to do?

Actually, what we will do, we will come off the record. Then we'll discuss among ourselves. So we'll adjourn. Thank you very much.

(Whereupon, the foregoing matter was concluded at 4:05 p.m.)