Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Reactor Safeguards Materials, Metallurgy and Reactor Fuels
Docket Number:	(n/a)
Location:	Rockville, Maryland
Date:	Wednesday, April 6, 2011

Work Order No.: NRC-819 Pages 1-142

NEAL R. GROSS AND CO., INC.
Court Reporters and Transcribers
1323 Rhode Island Avenue, N.W.
Washington, D.C. 20005
(202) 234-4433

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

\+ + + + +

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

\+ + + + +

SUBCOMMITTEE ON MATERIALS, METALLURGY AND REACTOR FUELS

\+ + + + +

WEDNESDAY

APRIL 6, 2011

\+ + + + +

ROCKVILLE, MARYLAND

\+ + + + +

The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 1:30 p.m., Dr. Joy Rempe, Chair, presiding.

SUBCOMMITTEE MEMBERS PRESENT:

JOY REMPE, Chair
SAID ABDEL-KHALIK
J. SAM ARMIJO
DENNIS C. BLEY
MICHAEL CORRADINI
DANA A. POWERS

HAROLD B. RAY
WILLIAM J. SHACK
JOHN D. SIEBER
JOHN W. STETKAR

NRC STAFF PRESENT:

CHRISTOPHER L. BROWN, Designated Federal Official
RAJ IYENGAR
ANTONIOS ZOULIS
CHARLES HARRIS
SEE MENG WONG
AL CSONTOS
RICHARD LEE
ED FULLER
EMMITT MURPHY
KEVIN COYNE
SELIM SANCAKTAR

T-A-B-L-E O-F C-O-N-T-E-N-T-S

Opening Remarks and Objectives

Staff Opening Remarks

Origin of the User Need

User Need Details and Regulatory Implications

RES Project Plan to Address NRR User Need

Phenomenological Aspects of the C-SGTR

Technical Approach

Committee Discussion

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

1:30 p.m.

CHAIR REMPE: This meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards, Subcommittee for Materials, Metallurgy and Reactor Fuels.

I'm Dr. Joy Rempe, Chairman of today's subcommittee. Subcommittee members in attendance are Dr. William Shack, Sam Armijo, Dana Powers, Dennis Bley, Mr. Harold Ray, Mr. Jack Sieber and Dr. Said Abdel-Khalik. And we anticipate that Dr. Mike Corradini will be joining us later this afternoon.

Oh, excuse me. And Mr. John Stetkar is here. I apologize.

The purpose of this meeting is to receive an information briefing from staff in the Office of Nuclear Regulatory Research and the Office of Nuclear Reactor Regulation on enhanced risk assessment procedures for consequential steam generator tube rupture, C-SGTR, which are events in which steam generator tubes leak or fail as a consequence of high differential pressures and/or tube temperatures that occur in certain accident sequences.

Today we're going to be hearing about

guidance and tools being developed to support risk assessments of C-SGTR. The subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate for deliberation by the full committee.

Christopher Brown is the designated federal official for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting which was previously published in the *Federal Register* on March 22, 2011.

A transcript of the meeting is being kept and will be made available as stated in the *Federal Register* notice.

It's requested that speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

Also, silence your cell phones, PDAs, BlackBerrys, et cetera.

We've not received any requests from members of the public to make oral statements or written comments.

Colleagues, the staff and industry have expended considerable sources over the last few decades to better understand the safety implications and risks associated with C-SGTR events. Key previous activities include an assessment of temperature-induced creep rupture of the reactor coolant system and NUREG-1150 study, a representative analysis of the potential for induced containment bypass by an ad hoc NRC staff working group and NUREG-1570, and recent thermal hydraulic analyses and risk analyses as part of the steam generator action plan. Severe accident analyses performed as part of the state-of-the-art reactor consequence analyses, or SOARCA project, provide additional insights into the likelihood and impact of subsequent failure of the reactor hot leg shortly following a C-SGTR event.

Today we're going to hear about the research program proposed to address user need NRR-2010-005 support and development analytical bases and guidance for future risk assessments of consequential steam generator tube rupture events. This research program is being developed to assist risk-informed decision making related to C-SGTR. In particular, we'll hear about the staff's plan for evaluation of proposed modifications to existing requirements and in evaluating the risk significance of SG tube degradation. In addition, the staff will discuss the software that's being developed to estimate SG probabilities for given RCS and secondary side conditions.

As we hear the staff's presentation, I'd like for us to focus our comments and offering suggestions on the revised plans when it's in its initial stages so it can be more easily redirected if needed. In addition, to assist us in providing these comments, I'd like to ask staff to identify what issues will and won't be addressed by your proposed plan so that all of us agree on what is and isn't being addressed and that the outstanding items that will not be resolved by the proposed research program as appropriate.

We're now going to proceed with the meeting and I would like to call upon Dr. Raj Iyengar, lead project manager for this effort, to begin.

DR. IYENGAR: Thank you very much. Good afternoon. It's indeed a pleasure and privilege to be spending this afternoon with such highly accomplished and committed experts.

MEMBER POWERS: Oh, let's not -- too much here. It won't help.

DR. IYENGAR: I'll try again.

MEMBER CORRADINI: You get a do over. One.

DR. IYENGAR: I'm Raj Iyengar. I'm from Division of Engineering, Office of Research and I would be pleased to -- along with the team members, we would be presenting to you the project status, early status of the consequential steam generator tube rupture.

This project originated from a User Need that NRR had requested Office of Research to conduct. Because this required multi-divisional effort with the Office of Research due to its technical complexities, even though this is a small to medium level project, we decided that it was prudent for us to develop a proper plan, project plan in accordance with our office instructions of research so that we can have a seamless technical coordination and information exchange between the various teams within research, as well as NRR.

This project plan was developed and discussed with NRR staff last year. And subsequently we engaged early on through an informal meeting with Dr. Powers. Dr. Powers was very interested in hearing about this project and the details of how we are going to be executing this project. And he did encourage us to meet again with Dr. Rempe and Dr. Shack, which we did in early January. And that's how we ended up here.

And so actually it's pretty early in the project, so we would like to get your feedback so that the path we are traveling on is not perilous and if there are any roadblocks that you anticipate, perhaps you can give advice and some insight so that we end with the simplified risk assessment tool. The difficulty is that there's so much complexity, technical complexity in the project, but yet at the end of it the NRR requires a simplified assessment tool. That is a big challenge. So I think this early engagement would be very beneficial for us and we thank you for participating and helping us through this effort.

Now with that said, I did want to say to you that Dr. Powers was so enthusiastic when I met with him, he did mention that it was such a juicy problem many times and that he was jealous. And he also said that you should -- and you should let the ACRS members work for you.

MEMBER CORRADINI: Do you have a tape of that conversation?

MEMBER POWERS: Everybody except Corradini. Corradini will set you back a ways.

MEMBER CORRADINI: That's what was said earlier today, too.

MEMBER POWERS: And it's true.

DR. IYENGAR: And that said, I will turn it over to my colleague from NRR, Antonios Zoulis. He will be giving the details of the User Need.

MR. ZOULIS: Good afternoon. Thank you, Raj.

I'm Antonios Zoulis from NRR, Division of Risk Assessment and I'll go over a little bit of the background, the tasks associated with the user need and give you a little brief summary of what we discussed.

Basically the committee and staff understood that the need to continue to do future research on the topic of consequential steam generator tube rupture. And for simplicity I will be referring to it as C-SGTR.

I want to emphasize that my team members will be going over each of these topics in great detail later on in the presentation and to give you the opportunity to interrupt. And as Commissioner Apostolakis said, the enjoyment of interrupting that he now misses the Chairman.

MEMBER POWERS: Don't encourage him, Antonios. They need no encouragement.

MR. ZOULIS: Basically what we did was we -- we're grouping these items into three areas: One is TH analyses. The other one has to do with materials and structural analysis. And finally, the risk assessment piece. But these issues were the ones that came out of the -- that we felt would require further work going forward and again involves further TH analysis to understand the phenomenon with Combustion Engineering plants. We wanted to update the steam generator flaw distributions so that we can incorporate that information when developing the probabilities for our -- on the chance of having a conflict of consequential steam generator tube rupture.

We then wanted to develop a simplified method to use when either an application comes in or an SDP analysis is required to -- that involves steam generator tube rupture. We have guidance or tools similar to the simplified LERF method to use in assessing that.

And finally, out of this endeavor we want kind of like a knowledge management effort where we -- someone could go and find the history and all this stuff that was done in reference to C-SGTR.

MEMBER POWERS: There's no question that that last item is an item for the staff. I also point out that the problem that you have with the CE steam generator is a problem. I mean, the thermal hydraulic situation with the -- probably also arises in connection with the EPR where they have a similarly small plenum and small loop seal flat entry coming in a lower plenum and the steam generator. So it may have more --

MR. ZOULIS: More applications.

MEMBER POWERS: -- implications than just the CE plants.

MR. ZOULIS: Thank you. A little bit more background. The staff decided to pursue the further research items on a follow-on NRR User Need Memo. I have added the ML number for you. I'm sure you've all seen it, but for your convenience it's there. This approach was presented to the committee back in October of 2009 and it was found an acceptable way to resolve these ongoing research issues in the appropriate venue of the different offices and different organizations of the agency.

So again, we've broken down into three areas: The thermal hydraulic analysis is going to focus on updating the CFD codes and the models to address the issues of Combustion Engineering-designed plants. We also wanted to find out how incore instruments and the tube failure -- what impact they have on natural circulation for both Westinghouse and Combustion Engineering plants.

MEMBER RAY: Dana, does this apply also, for example, to AP1000, which basically uses a CE steam generator?

MEMBER POWERS: It depends on the depth of the lower plenum and how flat the entry is into it, and how much internal mixing you get there.

Now, I would suspect that before -- before I said anything about a particular plant, what you want them to do is develop this CFD code, then just go in and check for the amount of mixing that they get in those lower plena. And I mean, the nice thing about this CFD update is that once you have it it's pretty generic. I mean, it's just the boundary conditions that -- I mean, the boundary geometry that has to be changed.

MEMBER SIEBER: Yes, but all steam generators are subject to the configuration that determines how high the temperature gets.

MEMBER POWERS: That's right. That's right. Just how hot and how much Delta-T you get.

MEMBER SIEBER: Right. Yes, because it's a streaming effect.

MEMBER POWERS: Yes.

MR. ZOULIS: The next area was the materials and structural analysis. Again, as I mentioned before, one update, the steam generator flaw distributions for the current fleet incorporating the current operating history and improvements that industry has done over the last 10 or 20 years in steam generator chemistry and integrity.

The structural part deals with the RCS components and it's prediction to RCS piping failure. And I'm sure is all going to understand, you know, the surge line or what's going to happen in terms of -- and during a severe accident how those components are going to behave and the phenomenon that influences the C-SGTR.

CHAIR REMPE: Could you comment on how good you think the industry flaw distribution update will be? How good is that data, the quality, and give us a little insights on that?

DR. IYENGAR: Yes, Charlie?

MR. HARRIS: Hi, this is Charles Harris from the Office of Research; and I'll talk a little bit later in the slides on the flaw distributions, but your specific question, industry update, there is no industry update on flaw distribution. The information from the industry is contained in the in-service inspection reports. And here at NRC we'll go through that to update the information, but specifically from EPRI or any of the utilities there's no direct input on flaw distributions.

MR. ZOULIS: The third section involves the risk assessment portion. Here, when we get all the information, we want to be able to utilize it. As I mentioned earlier, in the applications that we do in NRR, specifically either an SDP or license amendment review -- and the whole purpose is to have efficient tools that allow the analyst to come with a best estimate answer that won't take up significant resources and time to do. And lastly, we said the summary report compiling the key insights and the state-of-knowledge.

So to summarize, what to understand the -- and further develop the steam generator tube rupture phenomenon and how it -- its implications to risk. Again, develop the efficient tools to be used by SRAs or risk analysts in either evaluating findings or risk-informed applications and any other future issues that we may not have foreseen. And again, document and develop the guidance to capture the information.

If there aren't any questions, I would like to allow Raj to continue on with his presentation. Thank you.

DR. IYENGAR: Thank you, Antonios. So as we saw that there were these three major components involved in developing this risk assessment tool, and so it just fell very nicely between the various divisions in RES, which of course as I mentioned earlier, requires continuous and intense coordination.

We did outline specific tasks involved in the process; 1.1 to 1.3. I don't want to go through this because it's a kind of a busy chart.

Just to let you know that we have identified other people who would be leading on the Office of Research side, as well as from the NRR. In essence, this project as it stands now has two external contracts from DRA and DSA and the Division of Engineering work. There are two elements to that. One is the updated flaw distributions for the steam generator tubes, which the corrosion and metallurgy branch will be leading. Charlie Harris will be leading that effort and he's trying to coordinate and work with the industry, too. And of course, as he said, looking at the in-service inspection to get all the information that's need. This is very critical information. Without that, any risk assessment took that you develop would not be accurate or appropriate.

And then there's another element of the work which involves the analysis and prediction of RCS other component failure, which will let us know whether the containment bypass has occurred or not. That would be done largely in house and at the DEE, which is the branch of component integrity branch of Al Csontos. And I've been penciled in to complete the analysis as in when we get the thermal hydraulic input from DSA.

Now, I did say that, you know, this is -- you know, the difficulty in this project is the coordination between the various divisions, but also we need information flowing from one side to another so that we can get all the analysis and the predictions done so that we can get a sound risk assessment tool.

Here what I show you is the simplified flow chart, if you will, which just tells you we define these accident scenarios. And in MELCOR will be used to develop, you know, the thermal hydraulic input that would be fed into the RCS component analysis to let us know when the RCS component will fail, which is then -- will be fed into a calculator, a risk assessment calculator, which is part of a separate project. And that calculator will also have the updated flaw distribution so that you would in essence get the, you know, appropriate risk assessment for C-SGTR.

And additionally, there's some LERF assessment that's required and was requested by NRR. That will be handled as well. And in the end what we envision is we envision a simplified useful tool that the NRR staff can use to assess the risk assessment. And of course we will also compile and summarize all the activities that have gone on in this project.

So, what it requires is we do have very periodic meetings with RES staff, informal as well as formal meeting, monthly meetings. And we do expect to provide updates, frequent updates to NRR.

And as I said, this is the start of our technical engagement with the ACRS and we hope to have one or two of them throughout the project as we go on.

The next slide is -- oh, it's deleted?

That's fine. It was too busy a chart. That's okay. Just I'll play the Vizio, MS Vizio. Yes, that's one. Just to tell you that, hey, we know how -- where the information has to come from, where it has to go and all of this end up in a final product.

Well, it was not part of a detailed discussion anyway, so I think, I don't know, whoever deleted it did me a favor.

CHAIR REMPE: Well actually; again I'll wait until Mr. Harris or Dr. Harris comes up and talks, but in that flow diagram that's where I got the impression that it had in here obtain flaw distribution from EPRI for CE and W plants. And so, I would like to at some point talk about that a little bit more and how that process is going to occur.

DR. IYENGAR: Most certainly.

CHAIR REMPE: Yes.

DR. IYENGAR: Charlie would talk to that.

CHAIR REMPE: Okay.

DR. IYENGAR: If there is any error, it's my fault in producing this chart here.

Now at the end of it, as I mentioned, the research products we envision are very simplified risk assessment tools. That's the key thing that NRR staff needs so that they can do their job appropriately and accurately.

MEMBER CORRADINI: What are they doing now without this? How are they accomplishing their tasks now because this is not here?

MR. ZOULIS: Fortunately, we haven't had issues that involve consequential steam generator tube rupture since I've been with the agency, which is about five years, and I think --

MEMBER CORRADINI: But you must be doing something.

MR. ZOULIS: Well, if an issue occurs, we have experts in research and as well as NRR, myself and others included, could assess the risk. It may take us a little longer than without this method, but we can still do it.

MEMBER CORRADINI: Well, I guess what I'm trying to get at is just -- let me just ask the question differently: The value added through this is more comprehensive with less uncertainly in what the staff is currently -- how the staff currently analyses these sorts of possibilities? I'm just trying to understand if today you're doing X and tomorrow you can do Y, the benefit between X and Y is what?

MR. ZOULIS: I think it's going to be a --

MEMBER CORRADINI: Faster, better, cheaper? What?

MR. ZOULIS: I think it's going to be a better understanding of the phenomenon of consequential steam generator tube rupture and its implication to risk.

MEMBER CORRADINI: Okay.

MR. ZOULIS: And that follows that is less uncertainty and more realistic numbers.

MEMBER CORRADINI: Thank you.

CHAIR REMPE: But there have been, years ago, analyses done with SCDAP/RELAP5 that again was based on limits with data and they would predict using structural-failure-type of correlations when a steam generator tube would fail. But I thought the benefit would be that you would (1) have better data, from what I've read; and you're going to try and have a simpler tool when to have to go through these detailed assessments. Is that not a correct understanding of the situation?

MR. ZOULIS: That's correct.

MR. WONG: Can I make a comment?

CHAIR REMPE: Sure. Yes.

MR. WONG: I'm See Meng Wong and I'm the senior risk analyst in the NRR Division of Risk Assessment.

In response to Dr. Corradini, it is a question. Yes, we have developed guidance, but the guidance we have used; and as Antonios stated, we did not have with the last few years issues related to steam generator tube integrity, issues that we have to analyze extensively. But there was guidance developed before.

So, this project would I think -- will have to improve, you know, the tools that we have in existence. And so, that's why we are proposing this point.

MEMBER POWERS: So, let me see if I can offer some perspective here. The challenge we have faced since entering into the risk-informed world is understanding what happens in accidents that are not an initiated by pipe rupture, but they're initiated by transient and station blackout events. And what we find is that eventually, sooner or later the reactor coolant system ruptures itself and we get a depressurization. If it ruptures itself in general locations, we get venting into the containment that looks indifferent from a pipe rupture.

Unfortunately, we can also rupture in a steam generator tube, which gives us a containment bypass. That has dramatically different consequences. So you would like to know for sure where you rupture in these accidents, especially as we find that the classic rupture-initiated accidents decline in probability in station blackouts and other transient events become the more dominant feature.

When we try to apply mechanistic models, accident analysis models. We find that the answer always comes back, well, it's a horse race. They in fact predict various locations depending on how they configure the analyses. But if they artificially arrest that location, it promptly fails at another location a few seconds, tens, maybe a 100 seconds later. so small in difference that you call into question how well do you know this sort of thing, how well do you know the piping system and where the failure will occur? Because it makes a huge difference to us where it occurs.

So, but what these gentlemen are trying to do is -- and focusing appropriately is the one that makes a difference is failing at the steam generator, too, because that has big implications and it has implications across the board; emergency planning implications, accident management implications, all kinds of things come in there.

So they're trying to say, gee, I don't really care whether it fails at a surge line or a nozzle. Either of those is about the same to me. What really makes a difference is for me to understand well that if it will fail at steam generator to give me a containment bypass. And quite frankly, our existing models you can -- well, calculate all these things out to six significant figures and what not, but the physical understanding there is poverty-stricken. The research has done enough work in the CFD area to say, well, we can inform these accident analysis codes about these things.

Some of these flow things and some of the heat transfer things, we really don't have that comprehensive understanding that allows us to make confident predictions on these things. And it's a confidence and it's a classic risk analysis where risk is the product of probabilities times consequences. It happens that this one -- doesn't matter what the probability is. The consequences are so large that it over weighs everything else.

So I would say that's what they're -- they're trying to get enough put into the accident analysis models that people will come back and not say it's a horse race. They'll say I can confidently say it will not fail at a steam generator tube, because that's the one that makes a difference. It fails at a surge line or a nozzle. Those are about the same.

MR. CSONTOS: And let me just add one thing; this is Al Csontos from Office of Research.

You know, that's where we're updating -- the flaw distributions is one area that we're updating information. But another one that we're looking at; and I think Raj will talk about later, is we've done a lot of activities to mitigate against cracking, okay, on surge nozzles, hot leg nozzles, things like that, or we've done overlays, for example. And so, places where we thought we were helping to stop, okay, may be actually causing us other issues down the line, unintended consequences. And that's some of the things that we're going to be also looking at as well.

MEMBER POWERS: Very good point. Very, very good point.

MEMBER CORRADINI: That helps a lot. So just to make sure I understand; so the assumptions going into this are I'm not going to have the ability nor do I count on any sort of operator action to depressurize? I am staying at high pressure and cooking the system and looking for -- or are you going to look for operator actions also as mitigating effects in all this?

MR. CSONTOS: I'm sure the latter.

MEMBER CORRADINI: The latter? And then the second part is; I guess maybe you're going to get to this, what experiments are you going to do so I trust the CFD?

MR. CSONTOS: That would be a multimillion dollar question.

DR. IYENGAR: Conveniently, our CFD expert is out of town, Chris Boyd, but --

MEMBER CORRADINI: Where did you send him?

MEMBER POWERS: Well, I mean, it's an

issue that we're going to have to explore. They're -- fortunately these are single-phase analyses and they're not involving condensation phenomena. So, CFD doesn't face formidable challenges there, but I'm sure the issue will come down to -- at some point you're going to have to think about, okay, if it turns out that the thermal hydraulic issues are of paramount importance here, they're not the flaw size distribution. Everybody knows the flaw size distribution is the most important thing; just ask Dr. Shack.

MEMBER SHACK: Best case thermal hydraulic --

MEMBER POWERS: Well, thermal hydraulics is the dominant thing. You'll want to have a fair amount of confidence in those calculations. Like I said, it's single phase, it doesn't involve condensation, doesn't involve a lot of the problems where CFD becomes more questionable. So it may be in fairly good shape.

MEMBER SHACK: Or you have the one-seventh scale test, too, for one geometry which --

MEMBER POWERS: Well, I think the one-seventh scale test is at least part of the problem in that that test did not extend out to the parts that we're interested in. And what you find in these calculations is the knee bone is connected to the thigh bone and it does make a difference out there.

And so, clearly one of the things that you all have to think about in going along here, should we redo the one-seventh scale and get rid of that problem that they had on the outlet nozzles? That boundary condition is just the wrong boundary condition for these calculations.

MEMBER BLEY: I don't know, I just have to toss something in here.

MEMBER POWERS: Yes, because the risk guys can't leave this alone, right?

MEMBER BLEY: If the situation develops that this becomes important, it's certainly a lot more than a $1 million calculation. If we ever get to the point that we have such confidence in one failure beating another to save the day, I think we're in a relatively indefensible position. So somewhere out of this has to come something more than that that provides assurance or provides a way for operators to confidently do something to avoid getting into the place that we're relying on a horse race between failure modes. That just troubles me as a -- it's not good engineering practice to rely on these failure modes occur in the right sequence.

MEMBER CORRADINI: I'm taking away from the Dana explained this, which I think I get it, is in some essence you're trying to better inform what was done years ago and expand the calculational database to understand where the uncertainties are and which one's dominant. To me that's important because all I do remember is the EPR and NRC stuff from I don't know how many years ago. Twenty pops in my head, but longer, right? So that to me is a useful thing to do. I'm guess I'm kind of curious about the context in which you'd do it.

MEMBER POWERS: You remembering back when you were in grade school?

MEMBER CORRADINI: God bless you.

MEMBER ABDEL-KHALIK: I guess relative to this timing issue, I'm just wondering about reactor coolant pump seal failure. Where does the timing for that come in? I mean, that must come very early in this process.

MEMBER POWERS: And sometimes is a dominant sequence. But remember, the Licensees have gone to substantial effort to upgrade those seals.

PARTICIPANTS: Depends on the seal.

MEMBER POWERS: And that's what creates -- used to be that you always got out of it because you blew the seals.

MEMBER ABDEL-KHALIK: Right.

MEMBER POWERS: And now you don't.

MEMBER SHACK: What you want is a seal that hangs in there until you've melted the core and then you want --

MEMBER POWERS: And it goes away, yes.

MEMBER BLEY: Yes, but if you go back to the original work on -- the seals, I mean, the position that was -- came out of the disputes between industry and NRC, and the tests that were done up in Canada led to what I would call a conservative agreement that leaned toward early failure of the seals. There's a -- at least to me, when you look through the data, there was great uncertainty about when those seals would actually let go. Was it 20 minutes or 5 hours? And it wasn't as clear as it began to be assumed after there was a negotiated position. And that's what it was, it was a negotiated position, not a real scientific analysis including all the uncertainties that came up with that. So, and we never knew for sure when those seals were going to go.

MEMBER ABDEL-KHALIK: And I'm not sure we know for sure now. Well, we don't.

MEMBER BLEY: As to when the seals will actually --

MEMBER ABDEL-KHALIK: We know they're going to last longer, but they're less likely to get challenged.

MEMBER POWERS: Yes.

MEMBER ABDEL-KHALIK: And the ones we have are better than the ones we had then.

MEMBER STETKAR: And there are manufacturers now who claim their seals will not fail. You know, there are manufacturers and have run -- you know, believe 24-hour endurance tests that temperature and pressure with essentially no leakage. So a lot of the new plants that you see coming down the line are indeed, you know, making those claims and there are manufacturers that do make those claims with, you know, some test-based justification.

MEMBER SHACK: So once you're into the severe accident, that's not so good news. You know, just thinking about this, I mean, there's the insight and the actions that you take. If you think about it from the regulatory basis, it's not always clear to me what you'd do. I mean, we by and large regulate on a kind of design basis accident basis, not a severe accident basis. One regulatory decision that I know was sort of made on this basis was the electrosleeve repair, which looked wonderful in a design basis situation, but was in fact bad news in the severe accident. I'm not sure, you know, it will help you perhaps understand actions that you should take in SBO situations, but you know, will it change the way you regulate SBOs? It's harder to see.

DR. IYENGAR: Yes, we will be --

MEMBER CORRADINI: We're just talking to each other.

DR. IYENGAR: No, no, we will be revisiting the thermal hydraulic uncertainties when Dr. Richard Lee will be talking about it little bit later. We had some not difficulty -- some difficulty with our team members. One of them is now in Japan who probably would have chimed in little bit more on this; Mike Salay.

Anyway, so that's most important key; deliverability. In addition, we do have -- NRR has requested some kind of regulatory guidance, which we will be undertaking. And the other thing we have done is we have compiled and collected all the publicly available C-SGTR, SGTR-related information in a repository in our SharePoint, in the inter SharePoint for our team members to have access to all the needed documents. Once we are done with this project, that probably will be available, the portal will be available for public as well. So we will have, you know, 20 or 30 years of research products and developmental activities in this area.

With that, I will turn over to Richard Lee who will talk about the steam phenomenological aspects of C-SGTR so that this will be a very nice overview that he plans to present.

MR. LEE: Okay. I'm Richard Lee from the Office of Research. Too bad Mike cannot be here because we send him over there to collect samples in Japan. And first thing he did, he send me his viewgraphs. First thing I did I delete half of his viewgraphs because it was too long.

I was involved with the steam generator tube rupture analysis that Dr. Rempe mentioned back in late nineties using SCDAP/RELAP5 and I thought the problem went away, but it didn't. So I'm asked to just talk about the phenomenological aspect of it.

The steam generator tube rupture is a design basis event. Those are the single tube or a few. And as far as in U.S., like we have been able to cope with it so far. But the one that we're talking about is something that more severe that you go from design base to a much more severe conditions. And this was -- the one that we're talking about is a severe incident induced steam generator tubes rupture. Basically you have much more events that happens beyond the design base.

And you look at the risk assessment. As we said, it is -- as Dana mentioned, that it's a low probability, but if it happens it's bypassing containment because that's a direct path that go out into the environment when the core start to release fission products and so forth.

Recently, when we were at training for the severe accident management guidelines by Westinghouse, actually they mention that they were supposed to recover water at a certain later time. Instead of putting in the core, they decided they going to put some of them back in the steam generator. So, this is one thing we should keep in mind.

The second thing is the -- as Dana

mentioned, that the failure at the time that we talk about failure of the primary system that include overhead. Those overhead cases are usually the traditional accident analysis that you don't do the bypass. If that fail, you relocate materials into the cavity and you have the other events like the molten core concrete and the actions like fuel cooling action. Those are thing you deal with.

And then for the steam generator tube rupture, there are three things that we look at previously is the hot leg rupture, the surge line failure versus the steam in the tube. The other two are inside the containment. The steam in the tube is of course a bypass event.

When the core to uncover, you have is -- the case that we analyze is a station blackout event. Loss of all AC power. Loss of all feedwater. There's no recovery. No operator actions. And as the core boil down, you can see that as it's uncovered, the hot gas flow from the core up into the hot legs. And then especially when there's a loop seal there, so there's -- you cannot have a -- how do you call it -- complete circulation of the steam that go through the entire loop going back to the core and heat up and then go to steam generator. So you have a loop that go -- a tube carrying hot gas up and come back down some of the tube return flow. So you have a mixing of cooler fluid mixing with the hotter fluid. So there are -- they are counter fluid in the hot leg.

And so you eventually have three circulation loop. One is the mixing from the core coming back, flow, going back out from the upper plenum, the hot legs one and then the mixing in the steam generators in that plant.

At that time we look at the Surry plant and also the ANO2 plant, which is a CE plant. They are different types of -- one is a Westinghouse 3-loop plant. They have different loop seal conflagration. The power density is different. The secondary site stimulator water inventories are also different. So we look at those type of variations.

The case that -- when you challenge the tube, has to fulfill three conditions. It's that you have a very high -- the primary pressure should be high. So in other words, the RCS doesn't have much significant leakage. Of course we take into account for example the seal leakage for 21 gallons at the beginning when you lose the loop seal cooling, but later when you can continue to heat up higher temperature, the loop seal fail and then you go to -- like for the Westinghouse plant is like 250 gallons per minute. But I believe that the newer seal may be better, so they may have less.

I believe that we did some more work on looking at the loop seal for the SOARCA project, but I don't know what those numbers are. So I probably -- for this project they're going to bring in some of the knowledge for this, latest knowledge about these loop seal leakage.

Then of course you have to have a steam generator secondary side dry. That's mean you don't have any aux feed and also basically the other side should stuck open, so you really have a depressurized steam generator and dry condition. So you have a low pressure and no water.

MEMBER CORRADINI: When you get into this -- I guess I don't remember any of this other than just the net result that you explained in terms of phenomenon. Do you get into this situation that by procedures that you would not have a main steam isolation issue, or you wouldn't have main steam isolation, you'd be having essentially an open path to bypass containment through the main steam? Or even if they were closed, the leakage is such that it doesn't really matter from a dose standpoint? You know what I'm asking?

MR. LEE: No.

MEMBER CORRADINI: Okay. So are the main steam line valves closed at this point in time so you would have it simply from a leakage through them to create a dose problem if -- you would have radiologically? I'm trying to understand the path.

MR. LEE: You're talking about the bypass sequence?

MEMBER CORRADINI: Yes.

MR. LEE: It goes right outside.

MEMBER CORRADINI: So it goes to the safety release valves as --

MR. ZOULIS: Right, they're stuck open. They're -- or they're -- the high pressure's -- then that's the direct pathway to the atmosphere.

MR. LEE: Yes, because the thing is stuck open, too. That's why.

MEMBER CORRADINI: Oh, it is?

MR. LEE: Yes. Right.

MEMBER CORRADINI: Excuse me. Okay.

MEMBER POWERS: Typically when your safeties pop on the secondary side they just don't close. And if they do --

MEMBER CORRADINI: Okay. I didn't realize.

MR. LEE: Can recycle --

MEMBER POWERS: Even if they do start cycling, the gas is hot enough that you erode the -- and they leak like sieves.

MEMBER CORRADINI: Okay.

MEMBER POWERS: Yes.

MEMBER CORRADINI: Right. Thanks.

MEMBER POWERS: Leakage pathways are huge compared to the aerosols, so it's like they're not there.

MEMBER CORRADINI: Okay. Thank you.

MEMBER POWERS: Gets us into some serious trouble because it's a high-pressure leakage and so you're decontamination efficiency in the aux building goes to zero.

MEMBER CORRADINI: Right. Okay.

MEMBER POWERS: I mean, it goes to what? You don't get any.

MEMBER ABDEL-KHALIK: If you have total loss of feedwater, you don't have aux feed and one of the safeties pops open and you get a puff of release when the steam generator is dry, wouldn't the steam generator pressure drop down to atmospheric and stay down there because you don't have any water?

MR. LEE: Right, That's what we have now, is the secondary became very low pressure. So the steam generator tube failure is due because of the high-Delta P across the tube.

MEMBER ABDEL-KHALIK: Across the steam generator tube?

MR. LEE: That's the reason of it. Is primary to secondary Delta P is very large.

MEMBER ABDEL-KHALIK: Okay.

MR. LEE: But if you don't have it -- because the failure of the steam generator tube is due to two things; is the Delta P and the temperature.

MEMBER POWERS: Right.

MR. LEE: So those are the two criteria we used. At the time of the SCDAP/RELAP5 analysis we used adopted criteria for the tube rupture calculation for the so-called index of failure and so forth. That's what we used.

MEMBER ABDEL-KHALIK: Okay.

MR. LEE: What's shown on this figure is all the variation that have been study between the late nineties and now on what are the different things that they look at. Is the loop seal clearing? If the loop seal clear, then it depends on the depth. What is the volume and the location and so forth? And how you model is because we have found differences between the MAAP modeling versus our SCDAP/RELAP5 modeling. So there always be questions arise about how do you model the loop seal clearing. Because if you clear the loop seal, the flow will became one way and then you will -- the flow will go through the core and then you essentially -- the steam will transcend to the steam generator tube even hotter than when you don't have the loop seal clear. So those are the things that we look at. That's why the loop seal clearing is important.

The pump seal leakage is going from 21 to whatever the values that we use for different pump seal. The CE pumps are different than the Westinghouse pump. And we also look at the core nodalization inside the core. I remember for the Zion and the Surry plant, there are certain difference between the downcomer. There is a leakage path there. So when the flow come in, they can bypass each other. So the downcomer mixing also affects how the loop seal clearing occur. And of course all the oxidation, how you assume in the core will determine the melt progressions.

CHAIR REMPE: Richard, did you say the difference between MAAP and SCDAP --

MR. LEE: MAAP and always big discussion between -- because the -- if you clear the loop seal, then you will have higher -- hotter temperature going to steam generator tube, so you will fail the tube --

CHAIR REMPE: Okay.

MR. LEE: -- because of the temperature. Giving that the high-Delta P. So there is always discussion about those issues between the industry calculation versus our calculation. I'm telling you just these are the issues that we deal with when we do our analysis.

The surge line orientation is also important because the CE will connect it up. So basically the hot flow on the upside so you will be sucking it up, so the surge line may fail first. But if you go to the Westinghouse connecting on the side. So you tend to pull the colder fluid into the surge line, so into the pressurizer. So that change also the sequence of calculation whether you have a hot leg rupture first or the surge line fail first or the steam generator tube fail. And then of course the big thing is to do the one-seventh scale that gave us the benchmarking for the mixing in the inner plenum. And that always a big discussion.

CHAIR REMPE: So my memory's not so good. Wasn't water chemistry also an effect that they thought could impact steam generator tube ruptures? And what about like -- you have here like the hot tube fraction, but there were a lot of things I thought they considered back then. And is that something that they thought was or wasn't an important parameter?

MR. LEE: Water chemistry may have to do with the -- how -- what effects it has on the pre-existing --

CHAIR REMPE: Tubes?

MR. LEE: -- tube structure itself.

CHAIR REMPE: Yes. Right. Okay.

MR. LEE: Okay. But not during the transient. Water chemistry doesn't come.

CHAIR REMPE: That's right.

MR. LEE: We also look at the -- for example, the hot leg, we also did some calculation by deposit fission products on it. Does the decay heat make any difference?

CHAIR REMPE: Okay.

MR. LEE: As you remember, in the SCDAP/RELAP5 calculation we split the hot leg into two. One, because it was not a multi-dimensions or is one dimensional. So we have the hot one going up, the cold one coming down. They don't communicate.

CHAIR REMPE: Yes.

MR. LEE: So we also did some re-coupling of those two. We also look at radiation heat transfer in those pipe because it is very hot. So we like to look at the heat loss.

Heat transfer coefficient variation, we look at that, too, but that doesn't make that much difference.

Then we also do a lot of nodalization near -- we're talking about the SCDAP/RELAP5 system level

CHAIR REMPE: Yes.

MR. LEE: At that time we didn't use too much of CFD, but since then there's a lot of CFD analysis. So that gave us a more informed analysis, how should you do -- with SCDAP/RELAP5 or MELCOR, for example, how will you do those type of analysis? Give you some guidance on how you do the mixing. So these are the variation that has been conducted.

Now, this is a CFD calculation that Chris Boyd gave me. And you can see this is one of the -- this is not a CE plant. And you can note that the surge line connection is on the side, is pulling relatively cold water from the lower stream into the pressurizer. If it is a CE plant, it will be pulling hotter gas from the upper part. So the surge line will have a higher propensity of failure. And the flow stream going into the plenum of the Westinghouse-type connection, which is connected very further down and you see the jet going into the -- this is a CFD simulation. I don't have the -- how do you call it -

MEMBER ABDEL-KHALIK: What causes the surge line failure? Is it the high temperature in and of itself, or the high temperature gradients?

MR. LEE: It fail at the connection right there.

MEMBER ABDEL-KHALIK: But is it caused really by temperature gradients?

(Simultaneous speaking.)

MEMBER SHACK: Right, you know, it's the pressure stresses and the weakening from the --

MEMBER ABDEL-KHALIK: Oh, as a result of

the elevated temperature?

MR. LEE: It actually has two points that -- we calculate the failure over here, the failure over here, or you have failure over -- inside here.

MEMBER SHACK: But that news that the pressurizer or the surge line gets hot in the CE plant is the best news I've heard in a while.

MR. LEE: This is a Westinghouse --

MEMBER SHACK: Well, it gives you a chance to fail something.

MR. LEE: These are pictorial comparison between the two type of simulator. This is a Westinghouse connection. You see it coming very deep. This one come in very shallow on the top close to here. So when you have a flow coming in, it will tends to go up into -- there's a jet of stream going up to some of these tubes. Okay? So what Chris did is that if you plug a normalize fraction between temperature, the Westinghouse index is about here, the CE index is about here.

Another thing you need to know is that some of the replacement steam generator for Westinghouse went to this type of steam generator. So when you go to a Westinghouse plant, is not necessary having a steam generator of this type anymore. Because when they replace the steam generator, it could be a different manufacturer and the connection is at this fashion. So these are the type of analysis that CFD can perform and tell you that what type of risk that steam generator tube can face.

This is a qualitative explanation about what can happen looking at just two parameters and mapping out. Actually this is multi-dimension mapping of a potential containment bypass. So the first one you look at the seal leakage. When you have small leakage and you have very large leakage on the other side, that's mean you can induce a very large Delta P across. So you have a lot of potential failing and bypass. So but this path here is that you do not -- basically it's a match with Delta P and the temperature.

Now, on this one here is, when you have a very large leakage in a seal you can clear the loop seal so you essentially will fail. Now you have much hotter gas coming into the steam generator. So this is sort of a so-called MAAP.

MEMBER ABDEL-KHALIK: But the RCS pressure is going to be very low if that is the case. Would it?

MR. LEE: It can be low, but the thing is that it's still very hot, because the -- your flow is going through the core and circulating and picking up the heat from the accident core. So and transferring very high temperature into the steam generator tubes, because is a Delta P and the temperature both. Either one will get you in trouble.

MEMBER SHACK: It's still a horse race. I mean, it's the P going down and the T going up and --

MR. LEE: So you have something of a MAAP like this, but don't take this is a quantitative MAAP. This is just give you some idea what the variation of two parameters would look like, but there are other parameters.

MEMBER CORRADINI: What -- okay. Fine.

MR. LEE: Don't ask anything.

CHAIR REMPE: Did you have a question?

MEMBER CORRADINI: No, I've stored that one way. That's one for him.

MR. LEE: I brought this up because at the time of the steam generator tube rupture analysis going on the Paul Schermer Institute in

Switzerland launch a so-called ARTIST project. And they were studying the behavior of aerosol transport in the secondary side of the pressurizer and they were doing flooded pressurizer, but we are interested in the dry case, which is a completely dry aerosol transport in the secondary side. And we were hoping that even you have a -- let's say you have a break in the steam generator and it's transferring through the forest of these pipes of tubes and plates, because it depends on the -- where the location of the break. It has to go through many levels.

So we was thinking do you have any attenuation or decontamination factor that ones can get from aerosol transport in the second side even you have a steam generator tube rupture? Back in NUREG-1150 time, the DF factor, it was around five. Okay? So we said perhaps maybe from this experiment we can get a larger number, but it didn't turn out that way. What happened is that these aerosol get transport. First it come up from the break. It could be big size, but what happened is it get hit on these tubes and it breaks unto smaller part and it get transported with the flow stream. So the overall decontamination factor we get is around five.

MEMBER BLEY: Rather than having more surface area where --

MR. LEE: Right.

MEMBER BLEY: -- it actually makes it worse?

MR. LEE: Yes, it didn't do anything and so we didn't get anything out of this. But that was not something we count on. We thought we may get some more DF that are different than the time of NUREG-1150, but it didn't turn out that way.

MEMBER BLEY: And these tests, they included some mock-up of this, steam separators and all that stuff?

MR. LEE: They have all those thing in there.

MEMBER BLEY: Yes.

MEMBER ABDEL-KHALIK: How about the tube support plates?

MR. LEE: They have all the tube support plate, too. Because it is a simulation thing, I forgot what the size of this was. It's a full --

MEMBER POWERS: It's about a third of the full height and about a twentieth of the diameter. It was chosen so that the jet would lose its horizontal component of momentum before it got to the walls of the experimental apparatus. And it used a broached-hole tub support plates which are of the more modern design than the others. The steam separators and steam dryers were full size. I mean, they took them out of a steam generator and put them up. They just don't have as many as a steam generator. They have one. You have to understand the separators and dryers are meant for separating water droplets which are around 50 microns. These aerosol particles are around a micron. And so it's like driving through the Grand Canyon. You know, they don't even see the steam separators and dryers.

We expected to get a lot of deposition. And a little white powder on stainless steel looks like you get a lot of deposition, but in truth the DFs were 1.1, 1.2. And they get them for -- DFs for each of the tube support plates and the spans and whatnot. So you can just hypothesize where a leak goes, because we have a fairly continuous distribution of where leaks will occur in tubes, you know, based on historical evidence. And so you can just multiply it together to get the DF and they're like five.

MR. LEE: And actually some of those are

so-called break openings and you did some of those openings for them at Argonne, busted some of the tubes that we sent over there.

MEMBER SHACK: Yes, we made the fish-mouth --

MR. LEE: Fish-mouth.

MEMBER POWERS: Yes, you made a fish-mouth.

MEMBER SHACK -- ruptures. So I mean, these things sort of look relatively realistic as far as the exit goes.

MR. LEE: Another thing that Chris Boyd told me is that the problem with the one-seventh scale tests, he went back and look at the geometry, the way the scaling look and see how the connections come in. Is actually the one-seventh scale have certain distortion that gave these mixing coefficients that may not be correct.

MEMBER CORRADINI: You mean geometrical distortions? How things are connected?

MR. LEE: That's correct, how they were connected. You scale it back just by volume. You see that the connections as slightly distorted.

MEMBER CORRADINI: And that means they don't correspond to anything?

MR. LEE: No, they correspond to something, but it's distorted. So when you get these mixing parameters, like the hot flow mixing in the plenum, those three mixing parameters that we use that were derived from the Westinghouse.

MEMBER CORRADINI: Right. I understand. But then to get back to Bill's question originally when you and Dana were talking, even though they're distorted if a single phase super-heated gas calculation can benchmark against it and then you can do slight parametric variations off of that, that leaves you some experimental confidence. Okay.

MR. LEE: Chris can do those things, because --

MEMBER CORRADINI: Well, it's --

MR. LEE: -- this is a 1D-type flow, so you can see if you can sort out some of those.

MEMBER POWERS: Yes, I mean, in defense of the people that did the test, they set up the test when the debate was one area. By the time they ran the experiment the debate had moved down the piping system. And so they're connecting positions. Where they stopped their experiment is where the debate wanted the answer. And so it gives you -- it is better suited for looking at the flows within the vessel and not in the piping system. So you get some confidence always when you're matching anybody's experiment for anything.

The critical question that you'd like to have when you say get some validation of -- maybe it isn't addressed by the one-seventh scale. And so I think this program is the one that's going to help us define where out of all this should we ever do the next experiment.

MEMBER CORRADINI: Where you need it, yes.

MEMBER POWERS: Yes, quite frankly, at the time the debate was going fast and furious and people were cobbling things together as fast as they could. Now we have a chance to go back and kind of look at it in a very definitive fashion and say, okay, now we've looked at it. Here's where the crucial experiment is and do this one. And then we come away with the warm fuzzy inside and can wrap a bow around this experiment, around this technical issue. Which I mean, this DF plot says it all to you. You ain't getting any.

MEMBER ABDEL-KHALIK: Well, back to the tube support question, in this scaled facility did they keep the spacing of the tube supports the same, or were simply a number of tube supports the same?

MEMBER POWERS: They kept the spacing the same.

MR. LEE: The spacing the same only because they could not afford the entire height.

MEMBER ABDEL-KHALIK: I understand. That's why I'm asking the question. Doesn't the attenuation depend on the number of tube supports?

MEMBER POWERS: It does.

MR. LEE: It does.

MEMBER POWERS: And so you --

MEMBER ABDEL-KHALIK: And how do they account for that?

MEMBER POWERS: Well, you get the DF per plate, so just count plates. And the DF is like 20 percent per plate, so you can even just -- it's really easy, so you don't even distort the distribution.

MEMBER ABDEL-KHALIK: So it's just assumed logarithmic attenuation essentially by doing that, by assuming the same --

MEMBER SHACK: He's got multiple plates to begin with, so he has to check on --

MEMBER POWERS: Yes you can have three --

MEMBER SHACK: -- what the approximation is.

MEMBER POWERS: -- and the DF is so small per plate that linearizing the logarithm is a pretty darn good approximation. It's a very good approximation. In fact, when you do it -- they do it both -- they can do it both ways. And so you get an internal check on that, adding things together, or multiplying probabilities. And so you get a very accurate indication that the DF is really low.

MEMBER ARMIJO: I had a question on the previous slide. Looking at the tubes, 26, those tubes are bright and shiny in this test. Does it make any difference whether they're oxidized steam generator tubes? Does decontamination surface?

MR. LEE: They start off with the stainless steel tube bright and shiny. And all those white stuff are the deposit that they --

MEMBER ARMIJO: Yes, I understand, but if in a real case you --

MEMBER SHACK: He wants to put a corrosion film on the thing.

MEMBER ARMIJO: Yes, would it make any difference, or do these aerosols bounce off of that just as well?

MEMBER POWERS: Yes, they did some separate effects tests looking explicitly at that. They roughed them up, they had bashed them and things like that. Understand that outlet is sonic. It doesn't even notice.

MEMBER ARMIJO: Just another surface.

MEMBER POWERS: Yes, it's just -- in fact, typically the particles don't even actually touch the surface. They're just following the stream lines around it.

MEMBER ARMIJO: Right.

MR. LEE: Because they're so small there's no reason for the particle to get out of the stream line, do more work and deposit itself on the surfaces.

MEMBER ARMIJO: Okay. So that's --

MR. LEE: So it just go over the stream line.

MEMBER ARMIJO: Okay.

MEMBER SIEBER: Now, the non-fresh tube support plates actually have flow holes drilled in them that don't have tubes in them, right?

So you still get the same relative flow.

MR. LEE: Yes, we were also informed recently that the Paul Schermer Institute want to launch a program to look at the steam generator in that scale, seven scale type, so we are looking into whether we should participate on that.

MEMBER SIEBER: Okay.

MEMBER POWERS: Yes, this isn't -- if you want to see stainless steel, this Paul Schermer facility. I think they've got the market cornered in stainless steel.

MEMBER CORRADINI: You're talking the -- I'm trying to think what it's called now -- the PANDA facility?

MEMBER POWERS: Well, that's another facility made out of stainless steel. This is even a second one. This is a different facility.

MEMBER SHACK: Well, it's a lot cheaper than making it out of 690.

MEMBER POWERS: Well, the tubes are.

MEMBER SHACK: Oh, the --

MEMBER POWERS: Yes, the tubes are real tubes. I mean, they just -- one of the utilities gave them a steam generator to tear apart and put this thing together with -- because the guy that runs the program went in and pretty much sold it as he was going to show them the DF was 10,000.

MEMBER SHACK: Yes.

MEMBER POWERS: And it's 10,000 -- I think he was looking for a DF on the order of 100 or 200 and that got some enthusiasm for the program and leads to some amusing mathematics, because 1.2, that's close enough to 2, so he called it 2. And 10 times 2 is 4, but that's really 10 in log space, so --

MR. LEE: So he estimate about 100.

But if you look at the data, it didn't show that, so it's around five.

So what do you want me to do now?

CHAIR REMPE: Actually, I think we're scheduled for a break that was supposed to start at 2:45, and we're five minutes ahead for a change. So should we take -- come back at five to 3:00 then?

(Whereupon, at 2:40 a.m. the above-entitled matter went off the record and resumed at 1:54 a.m.)

CHAIR REMPE: Okay. Shall we go back in session? Are you going to start, Richard?

MR. LEE: I guess so. I'm going to go to the next three viewgraphs that Mike prepare. Actually I have look at it carefully trying to find out what the heck he's talking about, so we just look.

The TH analysis, it has to do with the CFD and the MELCOR I believe that we're going to be using for the analysis and focus on the CE plant.

The next bullet say un-fail thermal hydraulic behavior. What I believe has to do with even though you calculate when a component is supposed to fail, you don't fail it. You continue the calculation. So you can see the timing between the hot leg failure, surge line and steam generator tubes just looking at the Delta T between -- I mean Delta time between each of these components.

The next type of calculation you can do is let it fail and then you can calculate what type of fission products get transport out to the -- especially the one if it go to a steam generator tube. But I have to say that all these analyses are still up to discussion among the groups. Right?

DR. IYENGAR: Yes.

MEMBER ABDEL-KHALIK: The thermal hydraulic calculation and the stress analysis calculation are run sort of sequentially or are they run simultaneously or --

MEMBER ARMIJO: Sure, should be iterating.

MR. LEE: It would be iterating. For

example, the steam generator tube flaw distribution can be fed into -- as a preexistent flaw. You can use those to start with. You can have pristine tube. You can have distribution of flaw already there. And depending --

MEMBER ABDEL-KHALIK: No, I'm talking about the failures of -- you know, like the surge line, for example.

MR. LEE: Yes.

MEMBER ABDEL-KHALIK: Would you do that simultaneously with a thermal hydraulic calculation?

MR. LEE: Well, I think we going to give the boundary conditions so they can do more detail analysis. For example, the hot leg, you give the pressure and temperature and whatever the condition they need for the more detail analysis of the --

MEMBER ABDEL-KHALIK: So would they have done sequentially --

MR. LEE: It would be sequentially, yes.

MEMBER ABDEL-KHALIK: -- rather than simultaneously?

MR. LEE: No, it's not.

(Simultaneous speaking.)

MEMBER ABDEL-KHALIK: Yes.

MR. LEE: That's how we typically do.

MR. CSONTOS: This is Al Csontos from Research. Yes, what we're doing is we're getting the thermal hydraulics data from Chris Boyd and then we put that into -- we have models that we develop for hot legs, cold lets at different areas, different locations, different fabrication techniques, different conditions that we either degraded; like for example, some plants may not -- if they have superficial cracking, they may just leave that in service. If they have deeper than certain amount, then they'll put a different type of mitigation on. Some plants may have cracks that go to leaking and they put an overlay on. Like Davis Besse had that on a drain line, okay, for example.

So, we have all these things that we're trying to place together and put into some sort of -- and that's what Raj will talk about is he's trying to create a nice kind of database or a finite element modeling repository of all these different locations and conditions. And then what we'll get is we'll get Chris Boyd's results from the thermal hydraulics information and we'll feed it into the analysis that Raj is doing. So it sort of is a sequential effort, but there's a lot of conditions that we're looking at.

And then that's where Charlie's flaw distributions come into play, but that's where we place in close to the steam generators.

CHAIR REMPE: So is this an ABAQUS model for the structural behavior, or is it a simpler tool like they used years ago with --

MR. CSONTOS: Oh, no, it's -- yes, that's not what we're -- not the simplified tool. That's what we saw before.

CHAIR REMPE: Right. So you're doing this like ABAQUS or something?

MR. CSONTOS: And we're going way beyond that. Yes, we're -- Raj can talk to -- a little bit more on that.

MR. LEE: And from Chris Boyd, he can nodalize those thing up to whatever details they need it. There's no problem for the CFD.

And then from there you can give some guidance to how do you average these temperature for MELCOR nodalization.

And at this time now we are developing the CE Calvert Cliffs plant models at Sandia. We ask them to take the Calvert Cliffs stack and update it. Of course now we are up to the ears with this Fukushima thing, so everything is secondary now.

What impacts it on the schedule, we don't know at this time.

We're not going to start from scratch because we have a SCDAP/RELAP MELDOR deck. We're going to start from whatever we have and try to build upon what we have learn. As I mention to you, we have extensive analysis done with SCDAP/RELAP5. We're going to go back and look at what has been done through that. And we'll work very close with Chris Boyd on how to do the parameters -- I mean, for the so-called system level analysis. The reason you do the -- because all the fission products and melt progressions are in the MELCOR decks. Is not in the CFD. So we have to iterate between the two closely.

MEMBER SIEBER: When you talk about instrument tube failures, what instrument tubes are you talking about?

MR. LEE: Ah, that's -- what happened is that last year or so Bob Henry brought up from the TMI.

MEMBER SIEBER: Okay.

MR. LEE: And during the accident, they noted that there was instrumentation failure, tube failure was evident, because if you look at the instrument tube, it goes up to a seal table. There was a -- radiation detection went up. So Bob Henry brought up that during this accident instrumentation tube failure, it is a possibility.

MEMBER SIEBER: You're talking about incore instrumentation?

MR. LEE: Incore instrumentation, right.

MEMBER SIEBER: Now that is always filled with water and it's outside the hot flow path, right?

MR. LEE: Yes, but the thing is that the melt are relocating into the lower plenum. So there can be a --

MEMBER SIEBER: So you're assuming there is core melt going on?

MR. LEE: We look at that one with the -- for the TMI case --

MEMBER SIEBER: Okay.

MR. LEE: -- with melt core. What it did is that it did not make the problem goes away. All it does it delay the severe accident progression.

MEMBER SIEBER: Well, they aren't that big.

MR. LEE: That's right.

MEMBER SIEBER: And they plug --

MR. LEE: Yes.

MEMBER SIEBER: -- with molten material. And all kind of debris --

MR. LEE: Yes.

MEMBER SIEBER: -- is coming down.

MR. LEE: Correct. We look at that.

MEMBER SIEBER: And it's not that hot that it will -- you know, instruments will melt.

MR. LEE: But we're going to go back and look at that, what impacts that one has, because that was -- instrumentation tube is not one thing we have considered the analysis.

MEMBER ABDEL-KHALIK: Let me just try to understand this, because somewhere earlier you say the impact of instrument tube failure on natural circulation.

MR. LEE: What happened is that --

MEMBER ABDEL-KHALIK: There's a hole in the center of the lower plenum and that sort of somehow disrupts the vertical part of natural circulation, or what --

MR. LEE: Will depressurize the system, so if the instrument tube fail, then you are failing inside the containment. So you will not --

MEMBER ABDEL-KHALIK: Right.

MR. LEE: It will be less risky to assume -

MEMBER SIEBER: The motive force goes down.

MEMBER ABDEL-KHALIK: Depending on the size, the neat break might be less than the 400 gpm that you were talking about in your diagram.

MR. LEE: It's a race between all these leak gauges we have; the seal leak gauge, the -- and Ed?

MR. FULLER: Is this on?

MR. LEE: Think so. Yes.

MR. FULLER: It is? Ed Fuller in the Office of New Reactors.

One of the things that we've noticed in the process of doing our reviews for new reactors is in a confirmatory assessment activity that what -- it looks like the instrument tubes would probably fail just when all the other action is going on from the Zircaloy oxidation. And the problem is that the inside of the tubes is at the reactor containment pressure. So the instrument tubes become part of the RPV boundary.

For traditional PWRs where the

instrument tubes come out the bottom, the flow of gases and fission products from the core would go down the tubes, up the seal table and into the containment. For PWRs of the new designs with clean bottom heads, the instrument tubes come in from the top, so the gases and radioactive materials would go out that way.

The difference between going up and going down is in an accident scenario, severe accident scenario, as core melt progression proceeds, you can eventually block off those pathways with molten re-solidified debris. And that's why in TMI it's postulated that these flows stopped after awhile. One would not expect that if the flows were going to go upward as in new reactors.

We haven't really examined that for the BWRs yet, but in principle one could have the same issue.

CHAIR REMPE: Richard, just to be clear, when you're talking about an instrument tube failure, you're talking about away from the lower head, not anywhere near where the nozzles attach to the lower head? He's talking about that it was up higher and there was some sort of radiation coming down?

MR. LEE: No, what happened is that there is a -- the evidence is that it was fail in the lower part. So the gas got transfer up to the seal table. So the detectors detect a high radiation level for awhile, but that went away after awhile. So we did the analysis. As Ed mentioned, even though you may have open the path earlier, but the melt relocated, got solidified and blocked the thing so there is not more transport of anything that go. For example, the noble gas or whatever down there transport out to the -- into the containment.

CHAIR REMPE: I'm aware of the fact that radiation leaked --

MR. LEE: Yes.

CHAIR REMPE: -- and I can remember from looking at the data years ago that we could see when they removed the nozzle above the lower head that there might be a few piece of melt that had come down, but I don't believe that anybody ever had enough evidence to really say that the melt actually traveled below the lower head.

MR. LEE: The reason that point was brought up is that in case if you really have a instrument tube failure, then the steam generator tube rupture problem goes away.

CHAIR REMPE: Yes.

MR. LEE: So we went and look at it.

CHAIR REMPE: Okay.

MR. LEE: And it didn't go away.

CHAIR REMPE: Okay.

MR. LEE: It didn't go away. That's the bottom line.

MEMBER SIEBER: So it's conservative what you're doing?

MR. LEE: Yes. Okay. Since someone brought it up, we have to look at it.

CHAIR REMPE: Sure.

MR. LEE: And we did.

MEMBER SIEBER: Okay.

MR. LEE: And it did not go away. The uncertainties analysis are base on these parameters as that's what we plan to investigate.

Raj, is there more than these parameters? I don't know, are these agree upon?

DR. IYENGAR: No, this is -- yes, after this Charlie had -- if you have any questions for Richard --

MR. LEE: Okay. So this is only for the

TH part of it.

DR. IYENGAR: Yes.

MR. LEE: And there are more other uncertainty, but in terms of the tubes and all the other components will be discussed afterwards.

Any questions?

MEMBER ABDEL-KHALIK: Turbine-driven aux feedwater availability, I mean, if you have turbine-drive aux feedwater would you ever get into this kind of scenario?

MR. LEE: But I think after awhile it doesn't exist anymore because basically there's no more steam supply, so that's the end of it.

MEMBER RAY: You get into it in the -- if you've lost cooling to the shaft seals because you can naturally circulate and remove steam from the steam generators using the turbine-drive aux feed pump, which is probably what you're talking about. But pretty quickly the reactor coolant pump seals will fail and you'll have a loss of coolant accident and the turbine-drive aux feed pump's useless then. You need to get the pressure down and that's not easy.

MR. LEE: So they're looking at those type of sensitive -- whatever the case is. So that is one of parameters that they've been looking.

Okay. All yours.

DR. IYENGAR: Charlie?

MR. HARRIS: Okay. My name's Charles Harris from the Office of Nuclear Regulatory Research and I was asked to provide information for this project regarding the current condition of the tubes in the current steam generator fleet.

If you have questions, you should have them ready, because I only have two slides.

As I said, we want to represent the current fleet and that would include getting the condition of CE plants, Westinghouse and Babcock & Wilcox once-through steam generators.

The flaws. To describe the flaws, we would want to know the number of flaws, the size of each, what type of flaw it is and where they're located to get a total leak area to do all the probability calculations. Work had been done in the past on steam generator flaw distributions in the early nineties, early to mid-nineties, but previous work was done with Alloy 600 material. Of course most of the Alloy 600 is now either replaced or being replaced. So information that I'm providing is on still some Alloy 600 thermally-treated materials. The Alloy 600 in the past of course was the mill-annealed. So there's still Alloy 600 thermally-treated, and of course the newer replacements in the U.S. are Alloy 690.

MEMBER SHACK: You do plan to update the distributions for the Alloy 600 plants that are left though, right?

PARTICIPANT: Yes, they're not all --

MR. HARRIS: Let me start on the next slide. The work that was done in the past was done by Gorman and others from Dominion Engineering in Oregon and there was a NUREG contractor report 6521, which was published in 1998.

So as far as describing the distributions, the sizes and the numbers of the flaws, that report we feel is still valid as far as the statistics go, but as I just said, this was done on -- with information, you know, only up to that point on the existing fleet and it was done on 600 mill-annealed tubes. So to update that information we want to use information on flaws in -- that aren't thermally-treated and 690.

Emmitt Murphy is here. Did we decide on the significance of 600 mill-annealed? How many -- or will they soon be replaced anyway? I'm not sure.

MR. MURPHY: This is Emmitt Murphy from NRR, DCI. There are a handful; five, six, seven PWRs with steam generators with Alloy 600 mill-annealed material and most of these will run a few more years. I didn't come prepared with the actual end dates on these plants, but for the next few years we're going to have a handful of such plants, and certainly we could develop a flaw distribution -- a representative flaw distribution for the remaining plants. That's certainly doable.

Just maybe one piece or clarification with respect to what you were talking about. Our thinking, our current thinking that the statistics from the Gorman report were still valid, we're talking about the probability density functions that were published for each of the flaw mechanisms.

For the generators that are out there right now, with the mill-annealed to the thermally-treated 600 to 690, to the extent that you have a degradation mechanism, you're probably dealing, at least with the stress corrosion, a smaller number of such flaws than you had back in the nineties. So you would be interrogating the probability density functions with a smaller number of flaws.

MEMBER SHACK: But for the new plants

these flaws would be mostly fretting-type things rather than cracks, right?

MR. MURPHY: For the 690 it's the fretting associated with the support structure and loose parts. Loose parts will continue to be a key player.

MR. HARRIS: All right. Of course, in the past the major problem was cracking and Alloy 690 has more chrome to prevent the cracking. So as Dr. Shack was saying, where is more of a problem that we're looking at now with the Alloy 690? And where NRC is coming up with the information is from in-service inspection reports on history, of course the past history and the newer replacement steam generators since the early nineties, taking from the ISI data to get the updated flaw information.

Okay. That's all I had.

MEMBER ARMIJO: These materials, the new materials, you have a perfect un-flawed Alloy 690 tube compared to something with a realistic flaw, whether by fretting or whatever. How much difference does it make in the life at these temperatures, which are really very high? I mean, you know, is it a big difference?

MEMBER SIEBER: Ten minutes.

MEMBER ARMIJO: Seconds? Well, it is -- you know, I'm just trying to get a feel for how --

MR. HARRIS: I'm not the thermal hydraulics person, but --

MEMBER ARMIJO: Well, you know --

MR. HARRIS: -- it is possible to do calculations on a pristine tube, that pristine tubes can fail in certain plants.

MEMBER ARMIJO: Yes, that's what I would expect.

MR. HARRIS: And flaws in the tubes only make it worse.

MEMBER ARMIJO: I'm just trying to get a feel for how much worse.

MR. HARRIS: Weld overlays can possibly even make it worse.

MEMBER SHACK: Well, think of something like, you know, failure at 850 C versus failure at 750 C.

MEMBER ARMIJO: Okay. That's good.

MEMBER SHACK: And then you sort of figure out how long it takes you to --

MEMBER ARMIJO: Go from 750 to 850.

MEMBER SHACK: Eighty-fifty.

MEMBER ARMIJO: Yes. Okay.

CHAIR REMPE: When they did the calculations a long time ago with SCDAP, I thought that it did make a big difference if they assumed -- and they only had one plant that they'd inspected and all that. But it made a difference in the likelihood of steam generator tube rupture. Is that not a correct statement?

MEMBER SHACK: Oh, yes. I mean, that temperature difference is important. I mean, you know, don't expect it to go -- it doesn't process hours though, or days.

CHAIR REMPE: Yes.

MEMBER SHACK: When these rates are fairly steep, you know, things just sort of happen and you may not know exactly when this thing is going to go steep, but once it decides it's really going to light up, things are going to happen fairly quickly.

CHAIR REMPE: Today I heard that we were going to use some of the results from this activity to determine tube repair criteria. And respect to the design basis and severe accident conditions, is the database that we're getting appropriate for making such decisions, or are there any suggestions that it should be expanded upon or anything? Are you -- this is -- what we're doing is the appropriate way to go?

MR. HARRIS: Yes. We're looking at design basis accidents also, yes.

MEMBER SHACK: No, what I was looking at was the regulatory impact of this work. And by and large the regulations governing the flaws that you're allowed to have in the steam generator tube are primarily based on design basis accidents. Sometimes when reflect on this, it makes decisions though. You know, when they've done it, they -- as I mentioned, the one that comes to mind is the electrosleeve repair which did meet all the requirements for the design basis accidents, but because it looked so bad in the severe accidents, its use was discouraged.

And, you know, I was just trying to think of how this impacts regulatory decisions and, you know, since they're primarily based on design basis accidents, sometimes it's fairly indirect. As I say, I keep thinking that most of the impact will be in deciding how you perhaps do operator actions in certain classes of accidents and would give different perspectives on that. But the insights are useful.

CHAIR REMPE: Yes. I just was wondering if what we're getting from the data for the flaw distribution is appropriate, there's nothing else you can do. And is it less important than the thermal data that could -- the thermal hydraulic data that could be obtained is why I'm kind of pushing the issue.

MR. HARRIS: Oh, it's not less important. If you have a lot of flaws in the tubes, that's important.

CHAIR REMPE: Sure. Yes.

MEMBER SHACK: Maybe less important is the steam generator gets in better and better condition I guess is -- you know, I --

CHAIR REMPE: Okay.

MEMBER SHACK: We had sort of multi-level distributions in the old NUREG and I think most of the ones at the bad end of that are history.

CHAIR REMPE: Okay.

MEMBER SHACK: Those are steam generators that are gone. So, you know, I think we've skewed the statistics that you've developed from 6521 just because more modern inspection treatments and that don't let them get in that conditions, but --

MR. HARRIS: Never.

CHAIR REMPE: Okay.

MR. HARRIS: Anything else?

No? Okay. Thank you.

MEMBER SHACK: The good news is we're much better at characterizing fretting that we are cracks.

MEMBER POWERS: Well, it's easier to see frets than a crack.

DR. IYENGAR: The next step of analysis that we would be undertaking, it would be the failure of RCS components. We've talked about it at length as well in the past. The main tasks are to identify and characterize, and model of course, the RCS nozzles, as well as other potential weak areas to see when they would fail in terms of time so that that could be fed into the calculator to make the assessment of containment bypass or not.

So what we have to do is we will get the thermal hydraulic input from MELCOR, as earlier indicated. We will feed that into a finite element model of the RCS components with the properly-bounded conditions for both the Westinghouse side and the CE plants.

The challenge here I -- well, we're not

doing this from scratch at this moment, because we have some work with the past ANL which we will rely upon. Some nice analysis have been done by Dr. Majumdar on this. What they had done was done for one Westinghouse-type plant. But now we have a little bit more of a challenge here in that we are -- in order to become consistent with the steam tubes -- steam generator tubes, we are hoping to develop some kind of a failure model for our critical RCS component; perhaps what comes to mind is a hot leg nozzle; that seems to be the most critical based on many studies that Dr. Majumdar had done, which would not be specific to one particular geometry in one particular plant.

Can we develop a model that's creep rupture or tensile rupture depending on -- which would involve, you know, some geometry changes. If you have -- from plant-to-plant, you know, the diameter or the thickness changes. Can we have the appropriate model? That is a little bit of a challenging task. And if that's not much of a challenge, as my boss had indicated, we want to do some weld overlay, which is going to complicate matters as well. So these are some of the challenges that we are, you know, trying to address right now. And if you have any advice or input on that, we certainly would welcome that.

MEMBER ABDEL-KHALIK: How big a sub-component or a sub-part of the system would you have to model --

DR. IYENGAR: Well, yes.

MEMBER ABDEL-KHALIK: -- to capture the behavior of this particular component?

DR. IYENGAR: Yes, there are two issues. Now that's what we do for component integrity. We do the sub-model. Here you have, in the severe accident condition you have very high temperatures. So you have substantial thermal stresses which will -- much more than the design basis. And then over that you have primary stresses.

Now, if your primary stresses are changing substantially, those are things we do not know yet. The ANL work had not addressed that because that was only one plant and the sub-model. That's what we are trying to see in this. We are trying to see if we can take the weakest link; for example, hot leg and do a sub-model of that. Would that capture all the important essence of doing a full-fledged model? That we haven't done yet. And if that were possible, that will help us a lot, tremendously in terms of addressing weld overlay and the different thicknesses.

MEMBER ABDEL-KHALIK: Would you have to do a transient three-dimensional model for each component covering the entire history of the --

DR. IYENGAR: Well, what we have to do is we have to take the first full line. We do the transient analysis of the critical ones. And then we take a sub-model of that and just do -- put the -- apply the thermal hydraulic boundary only to the sub-model and see if you get, you know, fairly close results. That's one way to approach. If you do, then, you know, probably you want to try for other transients. And then once we have that confidence, and you can take the sub-model and do different geometries, different weld overlay thickness. That's one approach.

The other approach is you -- I mean, while the other approach is in the finite element context, you can do the shell model of the entire structure, which is, you know, a little bit less expensive. And then take the sub-domain that you're interested in and do a three-dimensional analysis of the sub-domain. But that still doesn't tell us whether you can just do the sub-components for your analysis with different geometries. So, these are the two things that we would try.

MEMBER ABDEL-KHALIK: Well, I'm trying to even find out whether you need to do transient analyses for the sub-components or a sequence of steady state calculations with different pressures and temperatures.

DR. IYENGAR: We do need to do the transient because the temperature changes during these accident scenarios. The rate is extremely high. And I do not know if without doing transient analysis you would be able to capture the thermal stress changes and if any primary stress change effects.

Dr. Shack?

MEMBER SHACK: Yes, I mean, I think you'd have to do that in that hot -- you know, the nozzle reach in which -- again, the reason we did such a detailed calculation was we weren't sure where the thing was going to be and in fact it shifted around. As the CFD went through its analysis, they had sort of underestimated some of those entrance effects. And as the CFD analysis became refined, the location of the likely failures had changed. And I think everybody sort of now agrees it probably is the hot leg.

DR. IYENGAR: Okay.

MEMBER SHACK: Whether that will change when you go to a CE plant is, you know, perhaps another question, but -- for these plants and so -- but at least in that region you would still be doing the transient because again the walls are thick enough and the prime temperatures are changing fast enough that you really can't do --

MEMBER ABDEL-KHALIK: A sequence of steady state calculations.

MEMBER SHACK: -- a sequence of steady state calculations.

DR. IYENGAR: Yes, if you did -- actually there is. For a creep rupture at least, if we could do the steady state analysis, we have equations that would give some kind of estimate for timed rupture for -- you know, given pipe geometry. We could use that and we don't have to do all these things, but --

MEMBER ABDEL-KHALIK: Yes, that's why I was asking.

DR. IYENGAR: Yes, we have textbook solutions for that. That would be easy on me.

MEMBER POWERS: Dr. Shack, I'm slow.

Earlier we discussed flaw size distribution. We didn't discuss shape and we certainly in connection with overlay analysis and things like that we found that shape made a difference. Should we consider in this program flaw shape?

MEMBER SHACK: Well, we haven't gotten to the tube models yet where the flaw shapes will presumably be important if you want to do a realistic-type analysis.

MEMBER POWERS: Yes.

MEMBER SHACK: I don't know what the plans are to refine that. Because we dealt with flaw shapes for ductile failures, we really did the -- at least the experimental confirmation of the creep models basically for rectangular cracks. And the way that we treat multi-shaped cracks in the ductile model gives you a guide for the way you might attack the problem for the creep problem, but I'm not sure you'd -- you know, you'd presumably want some experimental verification of that and I don't know whether that's included in the plan or not.

MEMBER POWERS: Well, it seems to me this general issue of shape out to be at least considered, as the revered Dr. Rempe pointed out at the beginning of the program, so we can make adjustments, or so she tells me.

MEMBER SHACK: I'm assuming if they have any significant flaw, this thing is going to be overlayed and then so they'll be looking at the overlay configuration, which will make the flaw much less important.

MR. CSONTOS: Yes, different components have different types of mitigation strategies. For a hot leg and cold leg the sizes are so large it would take on the order of three weeks to four weeks and maybe more to do a full structural weld overlay.

So since plants had that problem with having an extended outage for doing a full-structure weld overlay, many of these locations went to MSIP, mechanical stress improvement, squeezing or there's a new approach that industry is looking at with doing flaw evaluations in lieu of doing mitigations and doing inspections every four years. And if they do find a flaw, can they go on for another one or two cycles type of thing? And it's an individual case-by-case evaluation plant-by-plant.

Another thing is that they've also looked at --

MEMBER POWERS: It's had a pretty poor

track record, too.

MR. CSONTOS: And the other part to this is optimized weld overlays. And optimized weld overlays is basically I wouldn't say a full -- it's in between doing nothing at a full structure weld overlay. It's about half of a full structure weld overlay. And it's specifically designed for the pressure temperature and the situation of the crack or a potential crack that would be there.

And so there are different types of mitigations and these are the types of things that do you analyze a situation for a creep or other type of failures modes, you know, with a crack, without a crack? Do you have it with MSIP? Do you have it with an optimize weld overlay? Do you have it with a full structural weld overlay? And then what kind of size cracks? What shape are the cracks? Are there multiple cracks? These are questions that, you know, it just goes into the level of complexity into the details of what's really out there in plants right now.

And so that's some of the discussions of what level of detail do we go down? Do we start off from the generic pipe analysis, you know, just a general pipe stressed analysis or do you go all the way down to a degraded condition with different types of mitigations? Does that --

MEMBER POWERS: Well, I think you make my point that we need to look at some of these real plant issues and say are they important or not important? And if they look like they're important, the overall goal is to put into hands of the line organizations tools for making those tough decisions on --

MR. CSONTOS: Right.

MEMBER POWERS: And it is explicitly can I go another outage before I do anything because it's going to take me some time to set up to do something and I'd just as soon do that while I'm generating kilowatts rather than twiddling my thumbs. And that's a tough decision to make because the consequences of being wrong are really, really bad.

MEMBER SIEBER: I think the problem though that seems to be coming out is if you repair your plant, then you move the vulnerability point back to the steam generator, which is the cause of the bypass. And, you know, it seems like there's a horse race amongst a lot of different candidates for the failure point, some of which are not as bad as others. And I suspect that there are a lot of plants that are unique out there as far as strength at various points. And I think it's very difficult. You almost have to do an assessment of every plant in order to figure out what's going to fail first.

MEMBER BLEY: Let me ask you a question. What's industry doing in this area? Are they participating with you at all? Are they following it? And do you know what the SAMGs say about this kind of event?

MEMBER SIEBER: Put your respirator on.

MEMBER BLEY: It says more than that actually. I've seen the European ones and they do have some aimed at address this very scenario, but I don't know about the ones here.

DR. IYENGAR: Well, as far as industry goes, I think we have been in contact regarding this project. They are aware of this project. I do not know if they are developing methodology on their own or not. That I do not know.

But, Al, do you have any --

MR. CSONTOS: Can you repeat the question about the Europeans?

MEMBER BLEY: Well, the question had nothing to do with the Europeans.

MR. CSONTOS: Okay.

MEMBER BLEY: That was an example. The question had three parts: What's industry doing with respect to this creep rupture possibility for the steam generators? Are they involved with you at all? And do you know what they've already done within the context of the severe accident management guidelines aimed at this particular possible failure mode?

MR. CSONTOS: Well, I know my group has not been that involved working with industry on this, to be perfectly blunt. But that's my group.

MEMBER BLEY: Come back, Ed.

MR. FULLER: This is Ed Fuller again from the Office of New Reactors. In my previous incarnation in the industry, EPRI developed a steam generator tube integrity risk assessment methodology which utilized pretty much all of the concepts that you're hearing today, although things are maturing much, much more now than they were then. These documents were provided to the various utilities in the industry and they use them to varying degrees. Since I've been at the NRC nearly five years now, I've lost track of what they might be doing in this area. Regarding accident management, yes, in particular the Westinghouse SAMGs do address the possibility of induced tube rupture and --

MEMBER BLEY: Do they try to act before the event or is it following up after?

MR. FULLER: Well, generally speaking they try to keep track of the core exit temperature and when it gets up to around 1,200 degrees Fahrenheit, if they can depressurize they will try. Otherwise, they'll try other techniques to minimize the probability that a tube would fail before some other point.

MEMBER BLEY: Okay. Thanks.

MR. FULLER: And for the new reactors they all come with depressurization systems designed to prevent just this.

MEMBER BLEY: Thanks very much. And I know you've got some slides on PRA, so I hope when you get there you'll talk about what you're thinking about from the standpoint of the operators' involvement in this.

DR. IYENGAR: Sure, Selim would gladly address that.

MR. LEE: This is Richard Lee. As I mentioned to you earlier, a few weeks ago when we went to a SAMG training given by Westinghouse.

My staff went; I didn't go. They told us that they're going to put water back into a steam generator, which surprised us, because most of the time when recover you put in a core. So perhaps we should revisit. It may be the case that they just say the core is gone so you might want to put it into the steam generator because that -- if the path open up there, there will be a direct out.

MEMBER BLEY: Yes. Okay.

MR. LEE: So we need to really look at that one again, see what it is.

MR. ZOULIS: I had the opportunity to be a severe accident management implementer at Indiana Point, my previous incarnation. And one of the strategies is to keep the steam generators covered. And the emphasis of the SAMGs that you're aware of is not core damage anymore. It's containment and release challenges. So the whole emphasis; and that was part of the training to the operations, was to refocus them on that issue. Forget the core. It's releases and containment. The core is already melted. You know, you're above 400 degrees according to thermal temperatures; you need to focus on that. And one of the main strategies was to keep the core -- the steam generator tubes covered to prevent a steam generator-induced rupture.

MEMBER SIEBER: Let me ask a question that's a little bit off the subject. So far this afternoon we've talked almost exclusively about Combustion Engineering and Westinghouse reactors. What about B&W reactors? Where do they fit into all of this?

MR. LEE: At the time of the B&W reactor, because it's a once-through steam generator with a very large hot leg going up --

MEMBER SIEBER: Right.

MR. LEE: -- and the --

MEMBER SIEBER: And it comes out the top.

MR. LEE: -- we didn't do that analysis back in the late nineties because they said the super heated steam really don't go up there with the circulation coming -- hitting back like the new tube seal behavior like this type.

MEMBER SIEBER: Okay. So the vulnerability --

MR. LEE: So we didn't look at the -

MEMBER SIEBER: Okay. The vulnerability is not there?

MR. LEE: Correct.

MEMBER SIEBER: All right.

MR. LEE: And also the steam generator tubes history in terms of flow and all those, they perform better than the Westinghouse U-tube steam generator. That's what I remember.

MEMBER SIEBER: Okay. Thank you.

CHAIR REMPE: I guess I'm a little confused because when we were looking at the user need background information that Christopher sent to us, wasn't there a request that came back from NRR saying that RES should modify the assessment method to include consideration or tube failure in once-through steam generators? Am I misunderstanding some of this information?

DR. IYENGAR: Yes, there is a task for once-through steam generator, which Charlie Harris was going to get some data.

Emmitt, do you work with Charlie on that, the once-through steam generator information or update?

MR. MURPHY: As memory serves me, that request was not related to severe accident-type analyses. We were interested in looking for tools to allow us to predict tube severance in once-through steam generators, circumferential failure under extreme differential thermal conditions that one might get outside of severe accident space like when you put a lot of cold water in with hot tubes.

CHAIR REMPE: Okay.

DR. IYENGAR: Thank you. We'll provide additional clarification --

CHAIR REMPE: Yes, it's not --

MEMBER POWERS: Raj, your job's not getting smaller is it?

DR. IYENGAR: I know we are all interested in the role of uncertainties in these predictions, and of course these are all analytical or numerical kind of predictions, and so we have to feed in a lot of information and information that we get will have more uncertainties. So certainly one of the most critical -- some of this work in terms of finding sensitivity with the respective material properties was done at ANL. Dr. Majumdar with respect to the hot leg failure.

We do have data available for the creep regime as well as the tensile properties of these -- I mean, temperatures for the carbon steel and stainless steel material that we are interested in. So that's a little bit comforting. At least we have properties which are available, so that might reduce some of the uncertainties involved in that. And geometry uncertainties will be there in terms of geometric dimensions, as well as weld overlay in terms of the defect.

Now, here is what I want to caution though. In terms of normal component integrity analysis that we do, we do idealize the different geometry of the dimensions such that the resulting analysis prediction will be somewhat conservative in terms of component integrity. But that's not what we can do here, because here conservative in one side implies non-conservative. Because what we are trying to do is to see if these would fail before the steam generators. And if you try to put in largely conservative geometry and conservative defects, then you will not have -- you'll have a non-conservative prediction. So we have to be -- you're flirting on the -- little bit of difficulty there. We have to be careful what we input in terms of distribution there.

And we do have -- we will be using both the creep rupture and the tensile kind of models, and that has been addressed in terms of how the property and certainly it will influence the results to some extent by Dr. Majumdar. So we rely on that, but we will do our somewhat sensitivity studies on that as well.

Now, as far as thermal properties, the ANL studies have shown that the thermal property, the thermal expansion coefficient variation is not that significant in terms of effected the results. The conductivity, little bit more than that, but still not as much as the creep properties. So these are things that we will address as we travel along the project.

MEMBER ABDEL-KHALIK: Before you go onto the next topic, there are many plants who test their aux feedwater pumps by injecting directly into the steam generators either immediately before they go into an outage or immediately before they get back out of an outage. And the question is whether this is a good practice or something that may have an impact on this particular issue. And if it does, would you recommend that people sort of install recirculation lines so that they can test their aux feedwater pumps without injecting into the steam generators while they're hot?

DR. IYENGAR: I don't have enough expertise to provide any answer on that, but I'm going to have Kevin Coyne or Antonios or Richard to chime in. If not, we will have to take this back and try to find, you know, if there's any information available that would be helpful to answer this question and we will get back to you.

MR. COYNE: Raj, this is Kevin Coyne from the Office of Research, Division of Risk Assessment.

That question, we really don't have the right people here and it's really beyond the scope of this particular project to answer that.

MEMBER ABDEL-KHALIK: But it may. I mean, if the periodic conduct of these experiments impacts the flaw size distribution that you ultimately accumulate in the steam generator tubes, then it does have a direct impact on what you're doing.

MEMBER STETKAR: I think you also have --

MEMBER ABDEL-KHALIK: And -

MEMBER STETKAR: Well, let me chime in here --

MEMBER ABDEL-KHALIK: I don't know whether --

MEMBER STETKAR: -- that there's --

MEMBER ABDEL-KHALIK: -- it does or it

doesn't.

MR. COYNE: In this case we're getting the flaw distributions from recent operating experience from the steam generator tube inspections, so it would reflect the current state of the operating fleet.

MEMBER ABDEL-KHALIK: But if it is a bad practice --

MEMBER STETKAR: Before you get too myopic on one issue, there's also a benefit to be obtained to know that indeed the lines that deliver the flow to the steam generators are indeed open, that, for example, valves in those lines are not somehow miraculously closed. And without doing an integrative flow test you don't know that. So there's benefits to actually putting water from point A to point B through a line to verify that the pipe is indeed open, that you have to trade off. We're talking about risk assessment here and one shouldn't get too focused one particular issue and imply that there are things that one should do to make that issue better, that could indeed make other issues much, much worse.

MEMBER ABDEL-KHALIK: In fact issues that might be likely to occur.

MEMBER STETKAR: In fact make issues that risk assessments have shown have been bad for people who do indeed just do recirc of their aux feedwater and never verify flow to the steam generators. They really don't know the internal status of valves in those lines without actually putting flow through them.

MEMBER ABDEL-KHALIK: I was just looking at it from a mechanistic standpoint --

MEMBER STETKAR: Yes.

MEMBER ABDEL-KHALIK: -- how this practice actually may impact --

MEMBER STETKAR: But I think that's part of what the risk assessment people are talking about.

MEMBER BLEY: Those kind of tests have actually caused some damages in the feed rings, but you know, you got to come then through -- well, on a Westinghouse generator you got to come down through the downcomer or there's going to be mixing because this is a lower level of flow and you don't run it forever. So there's a lot of trade-offs there. I'd be real hesitant to leave this meeting with a suggestion that that's a -- you know, not that you shouldn't look at it, but it's --

MEMBER STETKAR: Something should look at it, but I think the message is in an integrated risk sense to see what is the downside of putting potentially cold water in there versus the benefit that you get in terms of verifying --

MEMBER ABDEL-KHALIK: That the lines are --

MEMBER STETKAR: -- in an integrated risk assessment sense that the fact you have higher confidence that you can actually deliver flow under most of the conditions when you really want to get it in there.

MEMBER ABDEL-KHALIK: By just verifying that the valve's open when you're running the tests?

MEMBER STETKAR: Simply, an open indication on a valve doesn't mean that it's open. There have been events where people have believed valves were open when indeed the internals believed otherwise. Without actually putting flow through that line, you just don't know the internal status of the valve. It's a rare event, but you know --

MEMBER BLEY: Well, it's not as rare as -

MEMBER STETKAR: So it's -- that's right. Well, the question is is it -

(Simultaneous speaking.)

MEMBER BLEY: Vis-a-vis those events?

MEMBER STETKAR: That's right. They have happened.

DR. IYENGAR: Thank you. If you don't have any questions on the RCS component analysis, we will move onto PRA-related activities. Selim Sancaktar would be presenting that.

MR. SANCAKTAR: My name is Selim Sancaktar from Research, PRA.

I have a few slides basically concentrating on project-related stuff, although this is under technical section-wise presentation, technical -- it says technical. I really don't have any technical details, as you can see, for the simple reason that we have started relatively recently and we do not have any detailed information to present to you yet.

The first slide I have, this information is take from the User Need, and you already saw it at the beginning of the whole presentation. Antonios has a slide that's pretty much the same. These are the titles of the PRA-related tasks and we are concentrating on the first two. These two would be like a second phase after we figure out what works in here in the first two pieces, 3.A and 3.B. So to start the project we are addressing 3.A and 3.B.

So we have two PRA-related projects that are underway. First, after a lengthy effort we managed to place a commercial contract in place for creation of a PRA report as a deliverable to address task 3.A, which would document an acceptable PRA model acceptable to the NRR, and also to RES of course, and also other offices that have interest in this subject. And we are making progress in that, but we just placed it in the last few months so there isn't much done yet.

And we have a parallel contract, small contract, relatively small effort to create a consequential steam generator calculator for the specific task of estimating steam generator tube leakage probabilities under different conditions and for different designs and that said no more than that. It's not very smart. It's a calculator. So different people may have different expectations even in RES about it. And it's not that smart. It's not like a T&H code. It just tries to do mini calculations repeatedly without exhausting any resources trying to calculate some probabilities.

So that will support task 1 at some point.

MEMBER SHACK: But what does this thing start with?

MR. SANCAKTAR: Which one?

MEMBER SHACK: The calculator. I mean, what's the --

MR. SANCAKTAR: What it accepts as inputs, it accepts from T&H analyses a scenario, temperature and pressure that the tubes see as a function of time. So it's like a vector of numbers with Delta time increments of seconds or minutes or 10 minutes, whatever is appropriate. So that comes from T&H.

From the steam generator tube flow information comes flow type, circumferential or axial flow depth. And then flow length, flow depth and type of flow and how many of each, or something like that. And then of course there are supporting little libraries that give you material properties and constants and this and that. And the equations used are not really probabilistic. I mean, the equations we have are -- if you meet certain conditions, you can exactly say that it's going to fail at this temperature and this pressure, a given flaw. So what makes this probabilistic is the uncertainties assigned to various parameters that come into the calculators that are assigned by the users. That's what makes it probabilistic. Otherwise, it just calculates. Basically for each calculation it gives you the deterministic number. Does that answer your question?

MEMBER SHACK: Yes.

CHAIR REMPE: And what are you going to use it for? Are you going to take it and put it into MELCOR?

MR. SANCAKTAR: Oh, no.

CHAIR REMPE: Are you going to use it at the plant?

MR. SANCAKTAR: Yes, good question. Let me -- this is counter-intuitive for some reason. I'm going the other way. If you go back, it's going to address this. Basically, if you go back to the NUREG-1570 and so on, there are tables that said if you have this scenario on the risk conditions, the probability of certain well-defined steam -- whatever steam generator tube rupture is defined as whatever integrated opening area is, it's a probability 0.005. Change of scenario is 0.007. This is going to give you equivalent numbers to fill that table so somebody can read if I have this scenario, I have this. Or they can go back, change the flaw distribution for a given plant and calculate a different number. Change the scenario parameters and calculate a different number.

So we will prepare relatively limited set of scenarios with a small table for people to just pick up numbers for typical scenarios and then let the users who exercise it to change flaw sizes, flaw distributions and we are -- we defined this -- requirements for this calculator so that you can just put it on your computer and it works. You don't have to call your IT. That's very important. Otherwise, it won't work. Every time you have to call your IT to install it.

And we are pushing hard for people to use it actually and we are inviting people, too, from NRR and RES to come and exercise it. And we offer them opportunities to come out to their room and show it to them. So we are hoping that people will actually use this. Whether it will be used or not, I don't know, but we'll give it a try.

These are some words directly taken from the User Need. Just want to show you some of the words, you know, so you see what's -- how they're stated. It's a simplified method. Methods should be based on standard PRA techniques.

MEMBER STETKAR: Selim, let me ask you something about the words, because there are several words that give me pause for thought, words like "efficient," "simplified," "very simple," "standard PRA techniques." You said that you've just recently issued a contract for the PRA-related work. Does the scope of work for that contract examine fundamental changes to Level 1 PRA models such that they are capable indeed of identifying and quantifying the scenarios that could leave you vulnerable to consequential tube ruptures? Because I submit that the vast majority of existing Level 1 PRA models, with the exception of steam line breaks, do not because the vast majority do not look at excessive cooling. They do not look at openings of secondary relief valves. They do not look at turbine bypass valves and you should not get myopic about station blackout is the only thing that could lead to core damage.

And I've thought about this quite a bit over the last couple of years as I've learned more about this issue thinking about how I would restructure a Level 1 PRA model to capture the scenarios which would leave you vulnerable to this.

And it's a fundamental restructuring because the analyst must think now of what events can leave me vulnerable to depressurizing the secondary side of steam generators, which is generally considered to be a good thing. More steam relief is generally a really good thing in the world of Level 1 PRA.

But if you have that, people tend not to look at, well, okay, I opened up all the relief valves in the world and, darn it, I couldn't get any feedwater. And they tend to think that that issue is not tracked. That is not a scenario that's tracked. It's simply that I didn't have enough feedwater. You don't know the status of the relief valve.

So is part of your contract to give people sensitivity to the fact that this is -- you know, if you're just identifying scenarios from existing PRAs that may be vulnerable to this condition, you're probably only identifying a fairly small subset of the real scenarios, especially if the operators are given guidance, for example, on loss of main feedwater and auxiliary feedwater to rapidly depressurize the secondary side of the plant to maybe try to get condensate in there. Those scenarios aren't looked at.

MR. SANCAKTAR: Well, although everything is written in simple English and it's in black and white, things are -- what they mean like is when it says design basis accidents. I mean, that's like a -- that's going to be a huge area and just like you mentioned. And also the factor of when you finish this product, who's the cognizant receiving-end champion who is going to evaluate, make the scope one way or the other? I mean, we cannot estimate the scope by purely reading these. So we have a task one which says interact with NRR cognizant engineers, RES supporting technical cognizant engineers and assess the situation. Figure out what are you going to do with this? What is this product going to be used?

In fact, we have meetings and we ask the question. And we ask the question to the current cognizant engineer, not the previous cognizant engineer who wrote this and retired, or whatever, gone. And by the time we are finished probably there will be a new cognizant engineer who might ask another question like you're asking.

So, what's the product for? And the answer is in the eye of the beholder. For example, are they going to use this for SDP analyses, for event analyses, or is this an encyclopedia of how to do a PRA for consequential steam generator tube ruptures, which is kind of what you are getting into.

MEMBER STETKAR: Yes.

MR. SANCAKTAR: And we have to define what are we going to do with this? Is this an encyclopedia? Is this a catch-all? Or is this a short orderly procedure that tells you (A) do this; (B) do this, look at this? It has to be defined up front with the input of the user or potential users. And how much it will address your type of requirements we will certainly see. I mean, I don't --

MEMBER STETKAR: Well, I guess what I'm struggling with is I can envision this going two different ways. One way is something that provides guidance; for example, take the existing suite of SPAR models and how do you characterize the scenarios that are generated by those models with no other modification of the models whatsoever? How do you characterize that library of scenarios in terms of conditions which you can then plug into your little calculator that you like with no IT support to give me a number for the likelihood that I get a consequential tube rupture on a core damage scenario? That's one way that it could it head.

The other way is if we believe that consequential tube ruptures could be a potentially important contributor to risk, are our current tools developed sufficiently to capture that element of risk? And that's more toward the direction.

And I guess I'm not quite sensing from what you've said so far which of those two -- if I can characterize those as two extremes of --

MR. SANCAKTAR: I have my personal opinion and preference, but I wouldn't want to put it on the table until we find out what the user -- how the user visualize and what they need, and then of course discuss it with them. It's only a matter of money and time. We can look at everything given enough money and enough time.

MEMBER STETKAR: Yes. Right.

MR. SANCAKTAR: So where do you draw the line to satisfy the needs or the perceived needs of NRR?

Yes, Kevin is dying to say something.

MR. COYNE: Well, not dying to say something. Kevin Coyne, Research.

I think that the short answer and what

Selim is saying is that it's basically too soon to tell what exactly the PRA model will look like. We're very early in the process. One of the goals of this briefing was to get this kind of feedback of other things to consider. So the points you brought up are very good points that need to be factored in as we go through the process of developing what the PRA approach would look like.

But we know for a fact that the SDP process would be one application, or that was one that was specifically highlighted under User Need. Bob Palla was the PRA analyst who initiated the User Need. He had specific needs in mind of who he wanted to apply this process that may differ from how the SDP application would work. So we need to get a good handle on what the user office intends to do with the method.

MEMBER STETKAR: In that sense, without out getting in -- too belaboring it, people haven't really -- well, I have to be careful what I say. There was an event that happened at Robinson earlier -- a year ago now, I guess, but -- the fire. You know, one of the consequences of the fire was their steam dump stuck open for an awfully long time. They got a big overcooling event. That is a precursor to this type of condition. It probably was never flagged in terms of risk, that particular issue as a potential risk precursor from this type of issue; seal cooling problems, where the loss of power was, yada, yada, yada. But when I look at significance determination, if you don't have a tool that tells you there might be sensitivity to stuck-open relief valves because your tool doesn't look at that, you don't even know that -- how to evaluate the risk significance of that particular event with respect to this type of contributor. Follow what I'm saying?

So when you strictly look at User Needs coming in from whether NRR or regions in terms of significance determination, at times you have to step back a little bit and say, you know, have you really thought about what all of your needs might be and does the tool that you have do that? I think that's part of what this discussion -- anyway< I get the message that you're still early in that process.

MR. COYNE: Right. And these are the kind of questions we're trying to get to, so this feedback is very helpful I think as we go through that process.

MEMBER SIEBER: John, is your concern

that a simplified tool used by someone, assuming that it will answer all the questions, will lead people to the wrong path and perhaps --

MEMBER STETKAR: It might.

MEMBER SIEBER: -- perform the wrong answers?

MEMBER STETKAR: It might, yes. Well, I'm not sure about do the wrong things in the real world, but at least give you sensitivity that if you're an operator and you have, you know, emergency procedures, that there are good things about reducing steam generator pressure to try to get, you know, maybe lower pressure feedwater supplies in or fire water or something like that. But there are some down sides of that that, for example, you need to be aware of that you just don't want to leave valves open.

MEMBER SIEBER: It seems to me though that there ought to be some warning flags somewhere in this process to make sure -- you know, it looks to me like there's a balance between a lot of different things. And the sequence in which those things can occur determines what kind of action can you take to mitigate it?

MEMBER STETKAR: Exactly. And I think

part of my message is is the basic structure of many -- some Level 1 PRA models for very old plants that may have -- had been concerned about pressurized thermal shock conditions, for example, did spend some extra time looking at too much cooling.

MEMBER SIEBER: Right.

MEMBER STETKAR: But generally that type of issue, too much steam relief in particular, is not something that people wire into the structure of their model. So they don't even have that knob to tweak . They don't even develop the scenarios that give you that information about, you know, what conditions are, what the timing was to factor into, you know, then the consequential analysis.

MEMBER SIEBER: Well, I think your issue is a concern. And I think that as this goes on we have to pay attention as to how people use these tools.

MEMBER STETKAR: It's actually not hard to change the models if you just know that you need to change them. But again, it's time and money.

MEMBER SIEBER: To me, I envision a simplified tool as an Android app, if you know what I mean.

MR. ZOULIS: This is Antonios Zoulis

from Division of Risk Assessment.

Again, as Kevin mentioned, we're interested in your feedback and we appreciate it, but I just don't want to leave this meeting with the false understanding of the phenomenon that we're interested in. You mentioned low and over-cooling, but the phenomenon that we're looking at is low, dry and high. And to get to those three, there are only so many limited sequences that will get you there. Are there some that we don't know? Perhaps there are. But I don't want you to -- because you mentioned the March event, I was intimately involved with that event in Region II, that just because it had over-cooling, it did not increase the chance of core damage. They had AFW injection. There wasn't a LOCA. So the conditions that were present did not warrant or even come close to that we would get a consequential steam generator tube rupture. So we need to keep that in perspective.

Those are the three conditions, and as Mr. Lee mentioned earlier, it has to be low, it has to be dry and it has to be high. And to get to those conditions in a PWR is not easy.

MEMBER STETKAR: Okay. I'm sorry. In risk-assessment space it can be relatively easy if you have no main feedwater, no emergency feedwater and now I'm on a trajectory to dry. I'm also a trajectory to high. Now all I need is low. And there are many things that will get me low. In fact, there are many things that operators might be instructed to do that will get me low. For example, depressurizing for condensate injection or depressurizing for that miraculous fire water injection with subsequent failure of that.

So my point is that many risk assessments ignore the low part of it. They send you to core damage because you had no feedwater. You are high and dry. You don't know whether you're low or not. And the conditional probability of being low in pressure on the secondary side may be much higher than your existing risk models tell you because they don't include that information about the secondary pressure. Just not a question that's ever asked. This just says they tried to depressurize. They didn't get it. Fine, I have no feedwater. It's modeled as a dry, high situation.

MR. ZOULIS: I think you just defined a station blackout event, but that's okay. We don't need to belabor the point. We'll let Selim continue with his presentation.

CHAIR REMPE: Let's do go ahead.

MR. SANCAKTAR: Okay. We basically talk a lot. The first one, we have a basis document for the correlations or equations, the software uses for calculating when the tube flaw either leaks or ruptures. And we are having it reviewed by the premier expert on the subject matter as we speak. And so, we want to make sure that what we are using is kosher and we can continue with the subject.

We expect to have the product within the next two years after we get input from other disciplines. It's a necessity, we have to do it otherwise we can't do it. So when I say two years, I'm assuming everything goes according to the plan.

And then once we have something that is acceptable to us and to NRR and other offices, then we can address the remaining two tasks of how you place this into the regulatory context. We are not worrying about it at this point.

Okay. That's all I had. If you have questions, I'll be happy to try to answer them without causing any damage.

DR. IYENGAR: Thank you very much. I think it's been an extremely fruitful exchange.

MR. CSONTOS: Raj, hold on.

DR. IYENGAR: Yes?

MR. COYNE: At great risk here I'll bring up a point. You know, part of the simplified wording in the User Need, Selim had done an earlier effort that we briefed you on at the closure of the steam generator action plan to do essentially a scoping analysis of steam generator tube rupture based on some earlier work done by both the ?DE and DSA. One of the base assumptions in that earlier approach was that the steam generators will be pressurized during these scenarios. The thermal hydraulic models were run with -- I'm going to forget the exact size, but I think a 0.25 --

MR. SANCAKTAR: 0.25 square inch.

MR. COYNE: -- square-inch hole.

MR. SANCAKTAR: Coefficient to -- on the secondary sufficient to depressurize.

MR. COYNE: Right. So all these scenarios assume that the secondary side would become depressurized from a thermal hydraulic standpoint. So although it wasn't explicitly modeled in the PRA, the --

MEMBER STETKAR: You basically assume that anything that is dry is low?

MR. COYNE: Right. So the high and dry,

you know --

MEMBER STETKAR: Okay.

MR. COYNE: -- might be low.

MEMBER STETKAR: Well, if that's the case, then a lot of, you know, my concerns regarding the fundamental structure of, you know, the Level I models leading into this probably alleviate it. You know, it's --

MR. COYNE: Right.

MEMBER STETKAR: So that's a conservative assumption, but --

MR. COYNE: It probably is, but I think, you know, in light of how we're going to go forward, if we continue with using that assumption, I think we still need to consider the point you brought up and make sure that that accommodates these kind of issues. But I did want to make that point that --

MEMBER STETKAR: That's important. That helps. That is a good point. Thanks.

DR. IYENGAR: Thank you, Kevin. So it was a extremely fruitful and engaging discussion, and we will take all these points back and find the appropriate solution so that we can get the most thorough and robust product that the NRR wants.

And I just want to; perhaps not

regurgitate, but just to re-emphasize that this is a early-on stage in a multi-year project which involves several disciples and several divisions of Office of Research. We are making sure that we are coordinating well between the various experts. We do have two external contracts, in-house work going on. Information needs to be fed in many different ways. So we are actively engaged in the process and of course we will take all your input back and into consideration and perhaps meet you back at some point, at appropriate point as we march along the project.

If you do have any questions or comments --

CHAIR REMPE: Okay. Thank you. I would like to visit at the end of this discussion period when is an appropriate time, but I think it might be good to just go through and summarize what the comments that we think are important are. And I've actually asked Christopher to start the process. I have some notes that -- I am hoping his notes are better taken than even mine. And I can add my comments, but we'll go back to the committee members to --

MEMBER SHACK: Can I just put one

question in before we start that?

CHAIR REMPE: Yes. Okay.

MEMBER SHACK: What is the status of the work on the CE plants?

DR. IYENGAR: Chris Boyd has done some preliminary calculations, CFD calculations on that, and that's where we stand on the CE plant.

MEMBER SHACK: So you haven't done any structural calculations yet?

DR. IYENGAR: No, not yet. Not yet. I think that ANL had done some preliminary work, I mean, some work on the CE. Unfortunately, all that information is lost. No data available which would have help us tremendously if they had a final model. But we do have some of the monthly reports that they -- we don't have the data.

MR. BROWN: Okay. All right.

CHAIR REMPE: Okay. So you want to start off?

MR. BROWN: Sure. Thanks, Dr. Rempe. I just wanted to echo John Stetkar's comments. I basically will try to track that to see if the staff is going to do anything, because I don't know when we're going to meet again, so I want to try to track that.

And also another item that I liked at --

CHAIR REMPE: So, that's the comment about are they identifying all the key scenarios?

MR. BROWN: Yes, the scenarios.

MEMBER STETKAR: Although, I must admit, if indeed that assumption is applied that essentially every scenario for which the secondary side of the steam generator is dry is treated as a low-pressure scenario, if that's the case, then I'd have to think pretty hard, but you've probably got most of my concerns handled that way. And whether that's realistic or not is a different issue, but in terms of identifying scenarios that are both dry and low-pressure from, you know, a variety of causes, that may solve that issue.

MR. BROWN: As I said, I don't know when we're going to meet again, so I want to kind of keep that fresh --

MEMBER STETKAR: Yes, I mean, I think, you know, just a general concern, as a point of awareness or sensitivity, when you're having these discussions; the staff, you know, with whoever your contractor is, you know, looking at the scope of what they're doing for this project, it's worth keeping it in mind certainly. But that may solve --

you know, your assumption may solve the problem.

MR. BROWN: Yes. The other item I'd like to track is that, Raj, you committed to providing us some clarification on the User Need task.

DR. IYENGAR: On the once-through steam generator?

MR. BROWN: Yes, and that's page --

DR. IYENGAR: Yes, I got that written down.

MR. BROWN -- 4, the User Need. So I'll --

DR. IYENGAR: Right.

MR. BROWN: -- be talking with you further about that. And I know Said had asked a question on the thermal conductivity experiments.

MEMBER ABDEL-KHALIK: No, no, no. This is the testing of aux feedwater.

DR. IYENGAR: Aux feedwater.

MR. BROWN: Okay. That was slide 37, if I recall. That's the one that you committed -- you didn't have folks here to answer any questions.

MR. COYNE: We'd have to think about who the right person to answer it is.

MEMBER ABDEL-KHALIK: Yes, whether

that's a good practice or not.

MR. BROWN: I want to track that one.

Also, Dana brought up about the flaw shapes. Should we consider flaw shapes? And it was also what is industry doing in this particular area of this work being done?

Harold had brought up benefits to other plants. In particular, he's working with the AP1000. Brought that up.

And there was a discussion about should the one-seventh scale data be redone?

Dr. Rempe, would you like to add some more --

MEMBER RAY: Chris, I was particularly thinking about it in terms of the steam generator.

MR. BROWN: Yes. Okay. And if you want to add more to it when you go around, that's good.

CHAIR REMPE: On the one-seventh scale, others with more background than me; like Dana, has pointed out the fact that this program could be used to shape if it's decided additional experiments are needed what that experiment should be, that when the tests were done there wasn't a lot of knowledge at that time. And so, as we go along maybe we can decide yes something else is needed and get the right test this time, is the way I think he's casted, and I think that makes sense to me.

MR. BROWN: Okay.

MR. CSONTOS: I think it goes to a larger point brought -- Corradini, about the testing, is that right? I mean, you asked me early on this morning about testing; or not this morning, but this afternoon.

MEMBER CORRADINI: It was something.

MR. CSONTOS: It was sometime today. But you asked about confirmation of what we're doing here, and I think that kind of goes into that.

CHAIR REMPE: Right. Okay. Do we want to go around the table and see if there's any other items that come to mind that we should offer up as a way to improve what they're proposing to do on this research effort?

Want to start, Jack?

MEMBER SIEBER: I have no additional items.

MEMBER RAY: Nor myself.

MEMBER BLEY: Yes, I'm kind of mixed mind on this thing. You know, this is a really interesting problem and there's a lot to learn, and it's kind of exciting. I'd like -- you know, being involved, seeing what's going on is very interesting.

On the other hand, supposing we learn everything we set out to learn, it strikes me first it will be tempting to become a little over-confident and maybe miss some of the contributions to uncertainty, which I think will almost certainly remain large if we're honest about the range of possibilities for a plant with extensive experience, a plant that's had many transients, many operational cycles, various insults, including occasional bad chemistry or maybe even mixed during installation or maintenance that we don't know about.

So I think when we're all done, we're still not going to be real sure exactly what's going to happen in any particular plant. And I wonder if something simpler than completely understanding the phenomena; which I'd love to do, might even be more effective in reducing the risk of what's for most plants a very unlikely scenario. For some plants with the right external conditions it might not be as rare as I'd like it to be.

But the simpler things might be things like SAMGs and maybe hardware that makes it easier to depressurize or to anticipate the need to do that, things that could reduce the likelihood or the amount of release if this doesn't go the way we convince ourselves it's going to go or even some general purpose devices. And this is something I've just got an itch for it, came up years ago when we'd first done some PRAs. What could I do to make my plant better?

Well, for any particular scenario there's really a good fix. But when we don't know for sure what scenario we're looking for, some not really nearly as good fix might be a better one. And various people have come up with ways to stash generators, pumps. One place we worked with designed a skid gadget that had those things on it and had one at the site and anticipated leaving one somewhere away, could easily be heloed in, that had things I didn't even know existed. Well, for the generator you could pull it up close and run cables and they've loaded -- the thing was loaded with cables you could run in and hook right up to a pump.

But the other thing it had that I didn't know was for the pump on board that you'd drive with a generator, you know, you could have a suction that would go to the local water supply, but they had identified; and I don't know if these came out of the oil industry or where, quick coupling devices. You could lop off six feet of pipe in the plant and hook up a quick coupling device that will just clamp on that end and actually pump water in. So something that maybe is only a factor of 10, you know, 0.1 on reliability, might buy you a lot, but there might be other things.

So I think we can spend a lot and learn a lot of useful things and maybe not solve this problem the way we're headed. I won't say don't do it, but I'm wondering if there's an easier solution. And I also wonder even if we do the best possible, we might not know what we think we're going to know when we're all done.

CHAIR REMPE: So you're basically saying instead of addressing the task and the User Need to look for something different?

MEMBER BLEY: And that's a possibility that maybe ought to be entertained all around. And I wonder what industry's doing here and if they're taking an approach; and I don't know for sure.

CHAIR REMPE: Well, I think definitely we want to look at what industry's doing.

MEMBER BLEY: Yes.

CHAIR REMPE: And then basically add on,

look for something else, too. It sounds like a good idea to me. But, go ahead, Said.

MEMBER ABDEL-KHALIK: Well, I mean, you know, of all the questions that were raised today I think I was disturbed most by the question that was raised by Dennis, and the question about what is industry doing? Are they involved with you and why aren't they? I would go even further than that: Are they aware of what you're doing? Because ultimately, I mean, you know, if you're fully successful this will have some impact in regulatory space and you want the people who would be affected to be aware of, you know, which direction you're heading, what you're doing.

CHAIR REMPE: Bill?

MEMBER SHACK: I think the work is interesting. Again, I have feelings somewhat like Dennis. I mean, you know, I think you're going to go to the CE plant and you're going to find things are bad and no matter how much you analyze it, it's going to be bad. And, you know, should you be sort of thinking about things to do rather than verifying that, yes, it's pretty bad? And, you know, I think we've gotten enough insights on the Westinghouse style of plants that I'm not sure that understanding them better will get you a whole lot.

You know, it just came back to my original question of just what is the regulatory impact of this? And as I say, you know, I'd feel better if I knew that everybody's SAMGs were cognizant of this. Maybe the Westinghouse people are. You know, I'd like to know what the CE people think that they could do.

So, I don't know. As I say, I think technically it's interesting. I think the approach of -- you know, now that we sort of understand locally where the sensitive thing is, that the problem is computationally more feasible than I might have thought once upon a time. But I'm still not sure what I'd do with the information if I had it.

CHAIR REMPE: John?

MEMBER STETKAR: I don't have any more, but, Dennis, you raise a really good point and something I didn't see here; and that is, you know, given what we know, looking at SAMGs and the B.5.b stuff, you know, and perhaps what's in place might be relatively effective. In other words, it might not be much more than you would want to do or that you could do.

I'd also, you know, just warn people, don't just talk about CE plants, because I think as Dana pointed out some, of the new plants coming in may be susceptible to the same -- EPR has very, very shallow loop seals and they've got a system that --

MEMBER SHACK: Just aren't any of those at the moment, but there are --

MEMBER STETKAR: There aren't, but, you know, we should keep them in mind, and systems that really like to blow down the secondary side an awful lot. So, you know, some of this stuff, regardless of which direction it goes, you know, isn't just the legacy that's sitting out there. You might learn things for some of the new plants coming in also.

CHAIR REMPE: Mike?

MEMBER CORRADINI: So, I guess I -- the picture that you happily said you couldn't show because you didn't have it in your software package, I started here 30 years ago as a consultant and Professor Curr usually asked the question when anything was with Class -- in those days it was called the Class 9 Accident Subcommittee, what are you going to do, how do you know when you're going to get done, and what value is it?

So, I'm still struggling with -- the

what are you going to do part I'm clear. I want to know how do you know when you're done and what's the value you're going to get out of this relative to the bigger picture that Dennis is asking? Right? And so, I'd like to see instead of a project execution thing, I'd like to see a -- I'm sorry to sound so industrial. I start here. I have a branch point that says I have scoured all this stuff first. And bringing in the pump, bringing in the pipe, may not be the most optimally-beautiful elegant rigorous way to solve the problem, but by God, I solved 90 percent of the problem. Now I do three-dimensional calculations and I solve five percent of the problem, but I might have to spend money to experimentally be clear that whatever I just calculated I actually believe.

I'm looking for a project execution graphic that says here's the first question I asked. Here are the things I first thought of just falling off the turnip truck.

MEMBER BLEY: The decision diagram.

MEMBER CORRADINI: Decision diagram, yes. That's what I'm missing here. Instead of a proxy execution diagram. Because I think you guys are onto something. The guy that wants to be on your committee happened to leave, right? But Dana I think has been thinking about this long and hard, so I wish he was here to tell me that I'm off base. But I really think a decision matrix or a design talking through this is very important because you're into a good amount of effort here.

MEMBER BLEY: In decision analysis there's a concept that's pretty simple. It's the expected value of perfect information. You lay out the decision diagram and you say what if I get everything I could hope for? What am I going to do with it? It's a real good exercise to go through. I like what Mike said, yes.

MEMBER CORRADINI: Because I think this is great. I just -- the more you start doing very complicated calculations where the pipe should be here, but it was over here, all of a sudden these geometrical things start compounding. Then you're going to ask yourself questions. And now you're into percent -- not even 10 percent, but just percents of uncertainty that unless you have an experiment to verify it, I'm not sure if I believe that you're five percent better than you were before. You see where I'm going with it?

And I think it was somebody over here

that said that with whatever measures they've taken for other things to affect the plant may confound your analysis.

MEMBER BLEY: Right.

DR. IYENGAR: The weld overlay, yes.

MEMBER CORRADINI: So I really do think you're onto something. I just think you want to lay it out in some fashion that really helps you think through where you get the more bang for your time. Not buck, but time.

MEMBER RAY: Joy, having heard my colleagues, could I now say something more?

CHAIR REMPE: Sure.

MEMBER RAY: Particularly since Bill identified me as the CE person. The reason we always thought the steam generators, even though they were vulnerable to this phenomenon; we just were looking at more so than Westinghouse, were better was because their natural circulation capabilities was better, which is I think why it's part of the AP1000 design. In any event, the ability to naturally circulate was quite good in that plant design.

MEMBER SIEBER: It doesn't naturally circulate if you can't remove heat.

MEMBER RAY: What, Jack?

MEMBER SIEBER: It doesn't naturally circulate if you can't remove it.

MEMBER RAY: That's correct.

MEMBER SIEBER: The other thing I want to comment on is the turbine-driven aux feedwater, because what Said said stimulated my thinking, what's the industry doing? At least when I was in the industry the great campaign was to get rid of turbine-drive aux feed pump because they're so damn much trouble to maintain and pass this regular surveillance test. And at my plant we had -- every day when I came in, I had the core damage frequency updated and it was always the same thing. When the thing would spike, it was because the turbine-driven aux feed pump was out of service for some reason, maintenance or surveillance testing or whatever. So it was a very big player in core damage frequency.

And so, I would never buy into this idea that we ought to try and get rid of turbine-drive aux feed pumps. But a lot of people do and think that a motor-driven pump is a heck of a lot better because I just go over and flip the switch and bingo it runs and that's the end of it. Now I'm all done. I go onto whatever else I got to do.

So, that's my comment on what's the industry doing. I think they're trying to get rid of something that I always thought of as being a important feature of the plant and one that I'd like to see more of. That's it.

CHAIR REMPE: Okay. It's looks like you have a burning desire to say something, Richard.

MR. LEE: My conversation with Chris Boyd is that if he redo this analysis now is that you may move those two points down a little bit, but the difference between the two will remain the same. So in other words, for CE plant it doesn't matter much whether you have flow tubes or not because if the flow go into certain, only selective group of two. It will put a lot of stress on those tube and has a possibility of failing those tube.

If you continue this analysis, one thing you need to remember, once you fail more tubes you will be sucking a lot of hot steam through the -- this pipings here. So you can also -- perhaps the surge line may fail. So in other words, a steam generator tube rupture for certain time, but other component like ex vessel, which is the surge line or the hot leg will fail. So in other words, your time of duration of releases to the containment bypass may be limited. So one can investigate when will the other components will fail that will stop the fission products going out. I think that's the type of things that you can evaluate too here.

CHAIR REMPE: Okay.

MR. LEE: So this is the point that -- from the T-H point of view we -- that's what Chris has -- came to a conclusion. So I think the group need to re-discuss what you want to do.

CHAIR REMPE: Okay. Sam, do you still have another comment?

MEMBER ARMIJO: Yes, I just caught the end of what Dennis was saying. I was happy to hear it. You know, it just seems to me with the materials we have in these plants and the designs of the plants, after we do all this more sophisticated calculation, we'll pretty much be in the same position we are now. Nothing much is going to change very different that will make our conclusions very different, so the emphasis should be more on what can you do about it with what we already know and whether it's operator actions, different devices, focus on that rather than, you know, getting less -- reducing the uncertainty in what we already know, because I don't think it's going to change fundamentally.

MEMBER SHACK: Well, there is the SOARCA-like statement though that Richard was attacking here. And if you -- understanding consequences is something that we do want to do and --

MR. LEE: Right. Perhaps the duration of the so-called -

(Simultaneous speaking.)

MEMBER SHACK: -- if -- yes, is important.

MR. LEE: Okay?

MEMBER ARMIJO: Well, that's important across the board. I mean --

MEMBER BLEY: And the SAMGs.

MEMBER ARMIJO: Yes.

CHAIR REMPE: So, I think then expanding the existing list to include additional items is the way to look at it.

MR. LEE: And I think since Fukushima the Commission has agreed that they going to start re-looking at all the plants, and this is one of the sequences that I think we will examine closely.

MEMBER RAY: Well, couldn't this cause you to say, gee, I really ought to have a second turbine-drive aux feed pump and another water supply for the secondary side, I'm talking about, because --

MR. LEE: I'm sure we can discuss this with industry and you will see what the response is.

CHAIR REMPE: I think that we're over time. And so, I would like to briefly suggest that if it's agreeable to you; we've given you a lot of suggestions, we'll come up with a list of those questions that we've brought up. Is six months in your opinion an appropriate time frame to come back to us with a revised perhaps plan and a report on your progress?

DR. IYENGAR: I certainly can talk to our NRR counterparts and research and probably get back to you on that. Or would Kevin or Al want to chime in?

MR. COYNE: We probably need to think a little more. My initial reaction is six months might be early in light of the additional work that needs to be done particularly with contractors. Chris Boyd needs to do his C&D work. We need to get the MELCOR decks for the CE plant. Raj is one of the key people on the DE analysis and he's on rotation right now. So nine to twelve seems more --

that we'd have tangible results to share at that point.

CHAIR REMPE: That sounds fine. I know Christopher wanted to have an idea on the schedule. As you can see, we have a lot of input. So it's up to you how often you want it.

MR. COYNE: No, we appreciate that. No, it's one of the objectives, so --

MR. CSONTOS: Yes, Raj comes back on September.

CHAIR REMPE: Okay.

MR. CSONTOS: So maybe give us a couple more months after that.

CHAIR REMPE: Then I guess I will close the meeting.

(Whereupon, the above-entitled matter was concluded at 4:41 p.m.)

Consequential Steam Generator Tube Rupture (C-SGTR)

Subcommittee Briefing

Advisory Committee On Reactor Safeguards
April 6, 2011

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Purpose

- Provide project status update on C-SGTR activities

- Outline the project plan that had been developed and discussed with NRR technical staff

- Early engagement with ACRS to gain insight and obtain feedback

Origin of User Need, User Need Details & Regulatory Implications

Antonios Zoulis, NRR

Outline

- Background
- User Need
- Summary

Background

- As part of the closure of the NRC’s Steam Generator Action Plan in 2009, items were identified that needed further work:
  - Further T-H analyses to address CE plants issues
  - Development of updated SG Flaw distributions and enhanced RCS structural analyses
  - Development of guidance and tools to support future risk assessments
  - Document summarizing key research and state-of-knowledge

Background (Cont.)

- Staff decided to pursue further research items in a follow-on NRR user need to RES (ML092010380)
- This approach to closing out the SGAP was presented to, and endorsed by, the Advisory Committee on Reactor Safeguards in October 2009

User Need – NRR-2010-005

- Thermal-Hydraulic Analyses
  - Request updated CFD and system code models for CE plants
  - Report on impact of incore instrument tube failure on natural circulation for both Westinghouse and CE plants

User Need

- Materials and Structural Analyses
  - Update SG flaw distributions for current population of SGs
  - Structural analysis of both Westinghouse and CE RCS components to establish confidence in the prediction of RCS piping failure

User Need

- Risk Assessment
  - Develop an efficient method for assessing the risk associated with C-SGTR/leakage in DBA and severe accident events
  - Reassess conditional SG tube failure probabilities based on updated flaw distributions and T-H analyses
  - Develop draft Regulatory Guidance on risk-informed decision making regarding C-SGTR
  - Develop Risk Assessment Standardization Project (RASP) Handbook guidance and update Inspection Manual Chapter (IMC) 0609 appendices to support risk assessments (SDP) for the Reactor Oversight Program

- Prepare a summary report compiling key insights and state-of-knowledge

Summary

- Develop and understand the C-SGTR phenomena and its implication to risk assessments

- Develop efficient tools to be used by SRAs and risk analysts to evaluate findings, risk-informed applications, and future issues involving SGs

- Document and develop guidance to capture knowledge

RES Project Plan to Address User Need

Raj Mohan Iyengar, RES

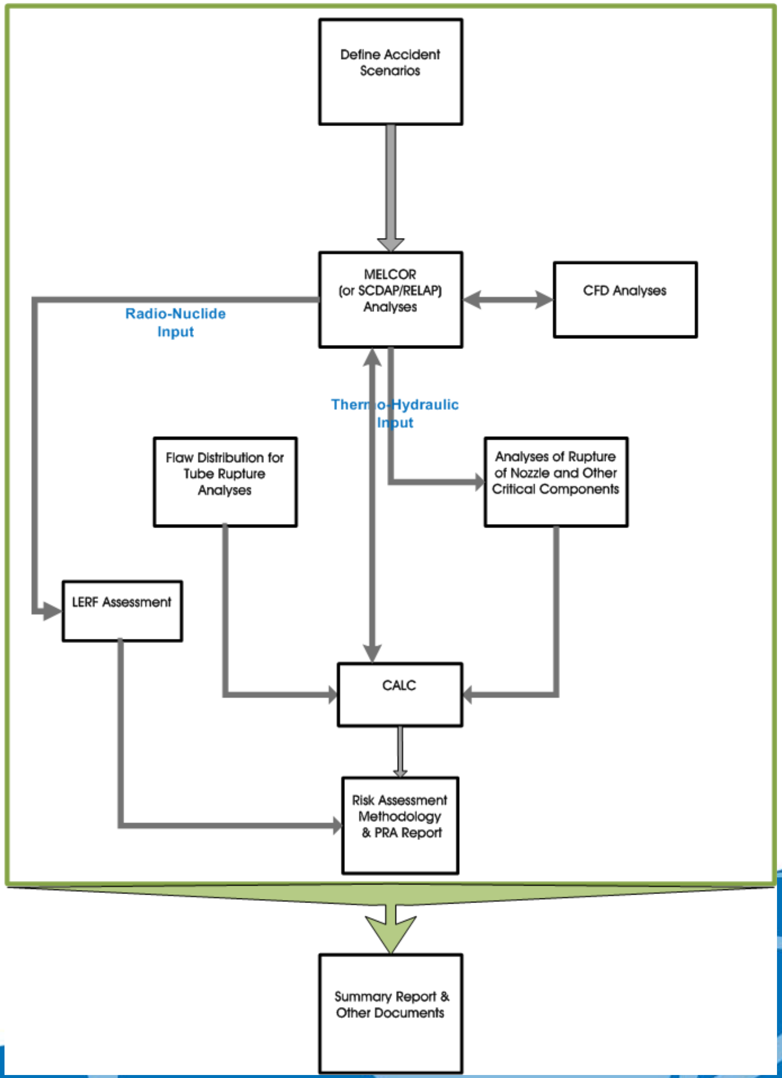
User Need Tasks

Item	Description	Priority	NRR Lead	RES Lead
1.1.A.i	Update existing computational fluid dynamics (CFD) and system code models (either the MELCOR or RELAP/SCDAP code) for a representative CE plant	High	Antonios Zoulis, DRA/APLA	Michael Salay DSA/FSTB
1.1.A.ii	Evaluate the expected T-H behavior and accident progression for selected risk-significant accidents from the associated PRA	High	Antonios Zoulis DRA/APLA	Michael Salay DSA/FSTB
1.1.B.i	A technical assessment of the impact of incore instrument tube failures on natural circulation for Westinghouse plants	Medium	Antonios Zoulis, DRA/APLA	Michael Salay DSA/FSTB
1.1.B.ii	A technical assessment of the impact of incore instrument tube failures on natural circulation for CE plants	Medium	Antonios Zoulis, DRA/APLA	Michael Salay DSA/FSTB
1.2.A	Updated SG flaw distributions representative of the current population of SGs	High	Emmett Murphy, DCI/CSGB	Charlie Harris DE/CMB
1.2.B.i	Structural analysis of Westinghouse RCS components to establish confidence in the prediction of RCS piping failure	High	Emmett Murphy, DCI/CSGB	Raj Iyengar DE/CIB
1.2.B.ii	Structural analysis of CE RCS components to establish confidence in the prediction of RCS piping failure	High	Emmett Murphy, DCI/CSGB	Raj Iyengar DE/CIB
1.3.A.i	Develop a simplified method for assessing the risk associated with consequential tube rupture/leakage in DBA and severe accident events	High	Antonios Zoulis, DRA/APLA	Selim Sancaktar DRA/PRAB
1.3.A.ii	Modify risk assessment tool to account for elevated axial tube loads due to thermal expansion between the SG shell and tubes during steam line break, loss of coolant accidents, and loss of main feedwater events (work to be sequenced with existing User Need NRR-2008-004 - ML082200693)	High	Antonios Zoulis, DRA/APLA	Selim Sancaktar DRA/PRAB and Charlie Harris DE/CMB
1.3.B	Reassess conditional SG tube failure probabilities based on updated flaw distributions and updated T-H analyses	High	Antonios Zoulis, DRA/APLA	Selim Sancaktar DRA/PRAB
1.3.C.i	Develop draft Regulatory Guidance on Risk-Informed Decision Making Regarding C-SGTR	High	Antonios Zoulis, DRA/APLA	Selim Sancaktar DRA/PRAB
1.3.C.ii	Develop draft RASP Handbook section on assessment of C-SGTR suitable to support revisions to the Inspection Manual Chapter (IMC) 0609 appendices supporting the SDP process	High	Antonios Zoulis, DRA/APLA	Selim Sancaktar DRA/PRAB
1.4	Prepare summary report compiling key research results	High	Antonios Zoulis, DRA/APLA	Raj Iyengar DE/CIB

Simplified Project Flow Chart

Communication & Engagement

- RES Task Groups meet at least once a month
- Expect to provide status update and receive feedback from NRR on a quarterly basis
- Technical Engagement with ACRS



Define Accident Scenarios

MELCOR (or SCDAP/RELAP) Analyses

CFD Analyses

Radio-Nuclide Input

Thermo-Hydraulic Input

Flaw Distribution for Tube Rupture Analyses

Analyses of Rupture of Nozzle and Other Critical Components

LERF Assessment

CALC

Risk Assessment Methodology & PRA Report

Summary Report & Other Documents

Research Products

- Simplified Method to Assess Risk Associated with Consequential Tube Rupture and a Summary Report

- Draft Regulatory Guidance on Risk-Informed Decision Making Regarding C-SGTR (Nature of this document will be determined later in the project)

- Draft RASP Handbook section on assessment of C-SGTR suitable to support revisions to the Inspection Manual Chapter (IMC) 0609 appendices supporting the Significance Determination Process (SDP)

- Summary report compiling key research results

Phenomenological Aspects of the C-SGTR

Richard Lee, RES

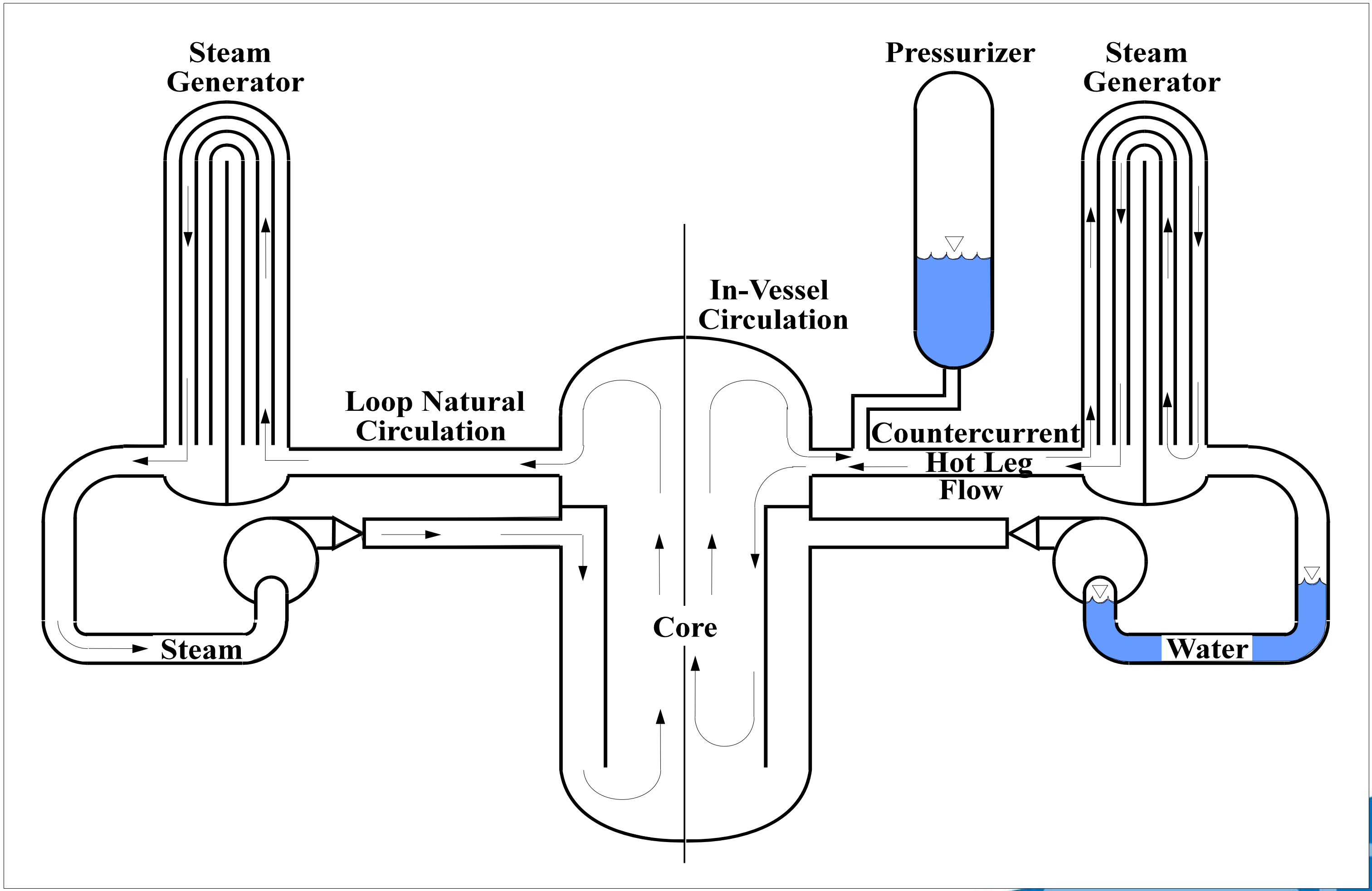
Steam Generator Tube Ruptures

- Steam generator tube ruptures are design basis events
  - Plants are designed to cope
  - Have for all events to date
- Progresses to Severe Accident only if something else happens
  - Failure to diagnose and respond can result in core melt
  - Multiple tube failure results in less time to react
- SGTRs (as initiating events) have been considered in risk analyses
  - Low probability to progress to SA but large consequences
    - Containment Bypass
    - Risk-dominant accident in PWRs at the time of NUREG-1150
- Recently risk analyses consider *consequential* SGTR

Severe Accident Induced Failure

- A primary system break induced by the high temperatures (and pressures) associated with severe accident conditions.
  - water level below the top of the fuel
  - superheated steam above core
- The severe accident conditions, created by the overheated core, are carried out into the RCS loops through natural circulation.
  - severe accidents are associated with core damage, high temperatures, and radionuclide releases
    - core temperatures over 2500 K
  - temperatures in the RCS challenge the structural integrity of the system
    - testing shows that a new steam generator tube will creep rupture at system pressure if exposed to temperatures above (approximately) 1170 -1200 K
- Significant induced failure points include the lower head, hot leg, pressurizer surge line, and SG tubing.

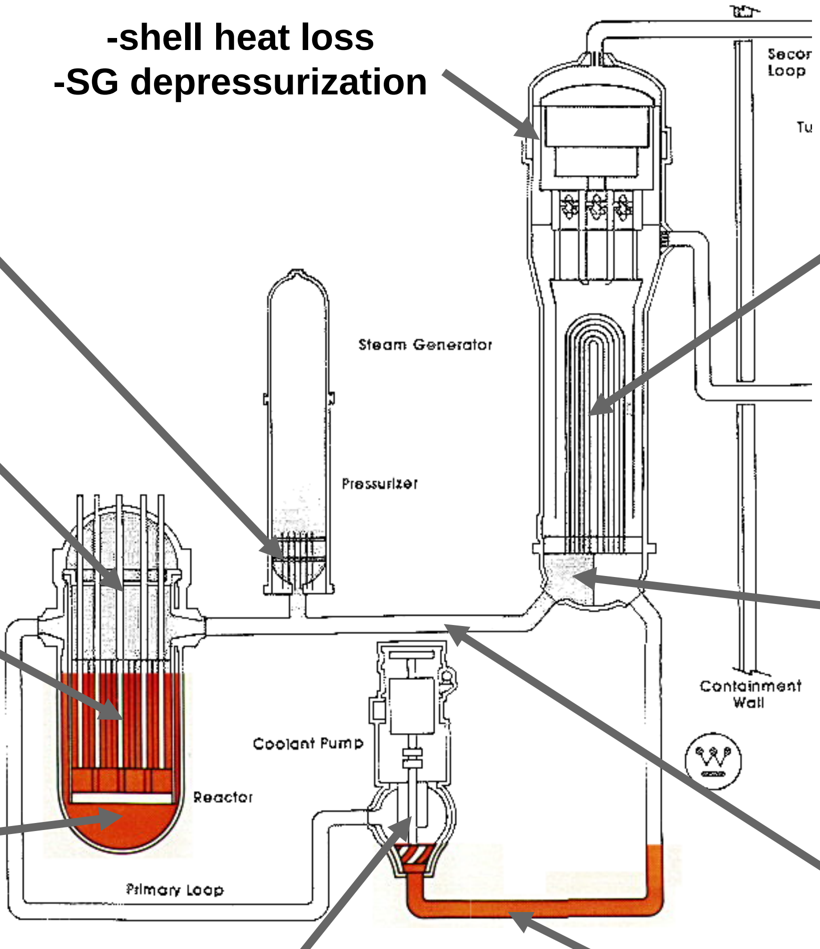
Severe Accident Natural Circulation Flows



High – Dry – Low

- The challenge to the tubes under counter-current flow conditions is maximized when the plant is in a “high-dry-low” condition
  - <u>High</u> primary side pressure
    - RCS must remain intact with no significant leaks
  - <u>Dry</u> steam generator secondary side
    - auxiliary feedwater systems fail
  - <u>Low</u> pressure on the secondary side
    - leakage or valve failure must occur to depressurize the secondary side

System Code Modeling Considerations



-shell heat loss
-SG depressurization

-tube heat transfer
-secondary flows
-mass flow
-hot tube fraction
-leakage
-plugging
-vertical node count

-pressurizer draining
-surge line orientation

-natural circulation
-core bypass flow

-oxidation rate
-core blockage
-nodalization
-natural circulation

-inlet plenum mixing
-recirculation ratio
-plume T distribution

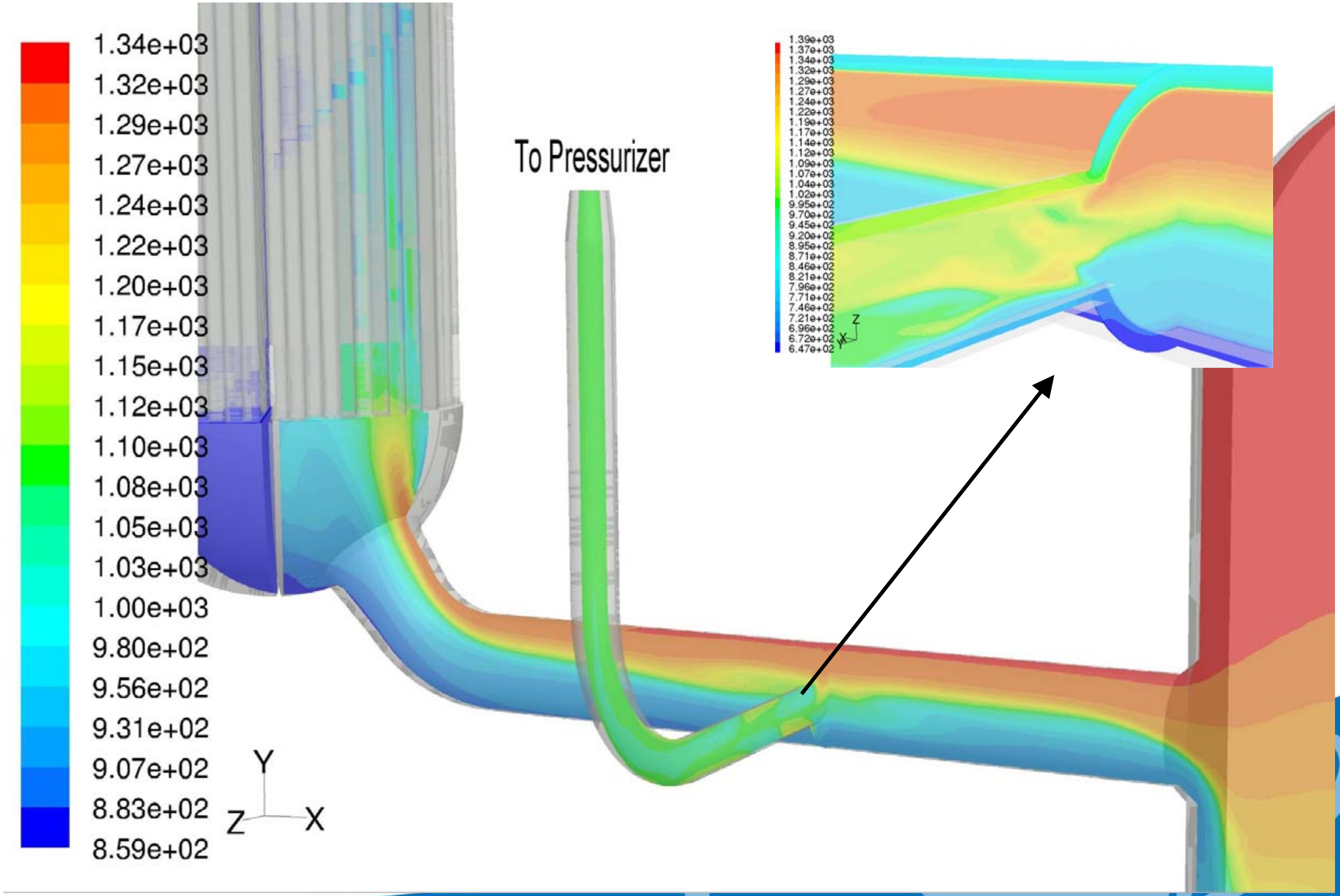
-nodalization
-downcomer clearing

-HL flow rate
-entrainment
-radiation modeling
-entrance effects

-pump seal leakage
-suction height

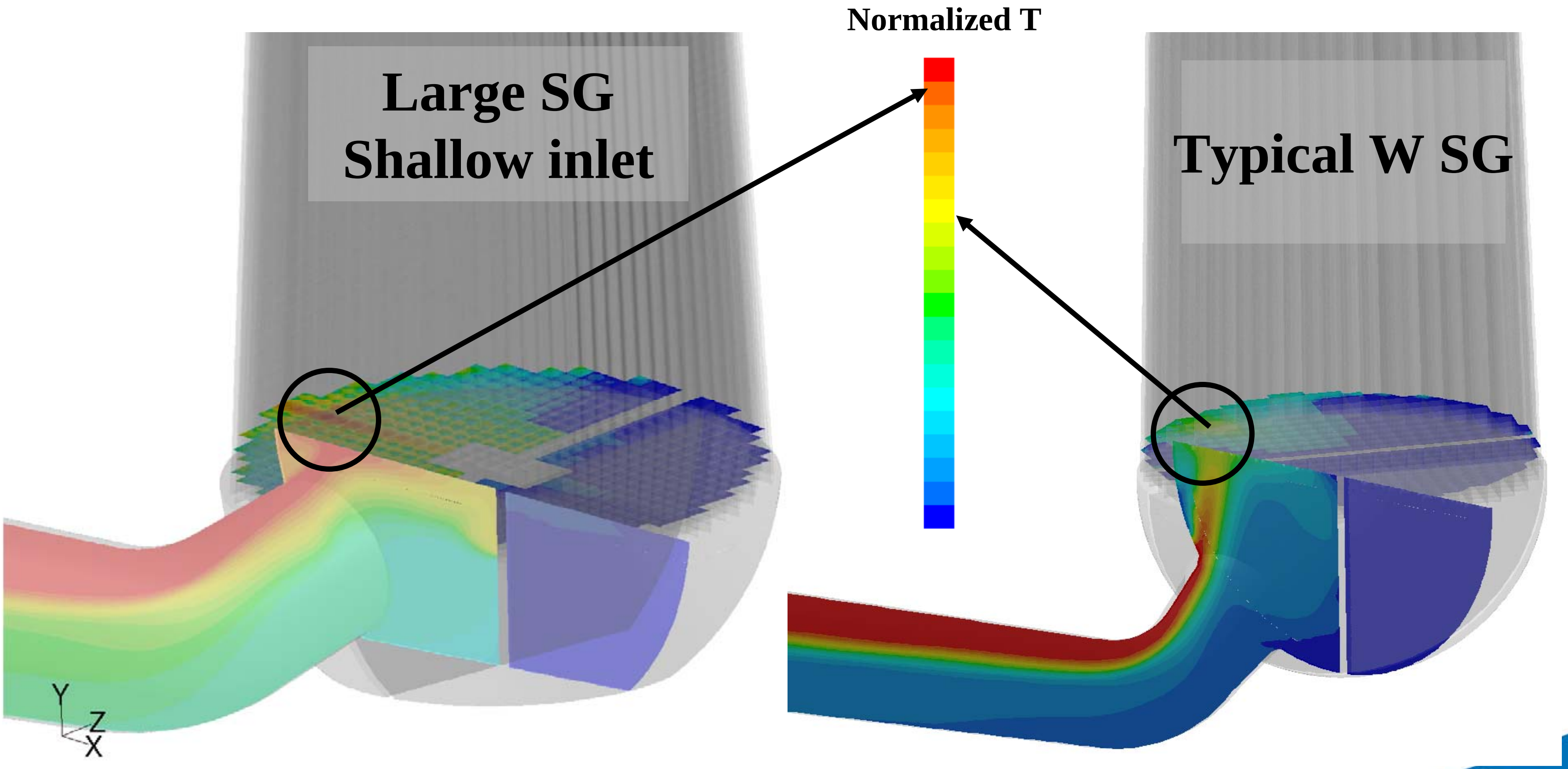
-loop seal clearing
-flashing; depth

Surge line Flows and Mixing Predicted



Impact of Inlet Plenum Mixing

CFD Predictions for two SG designs



Normalized T

Large SG
Shallow inlet

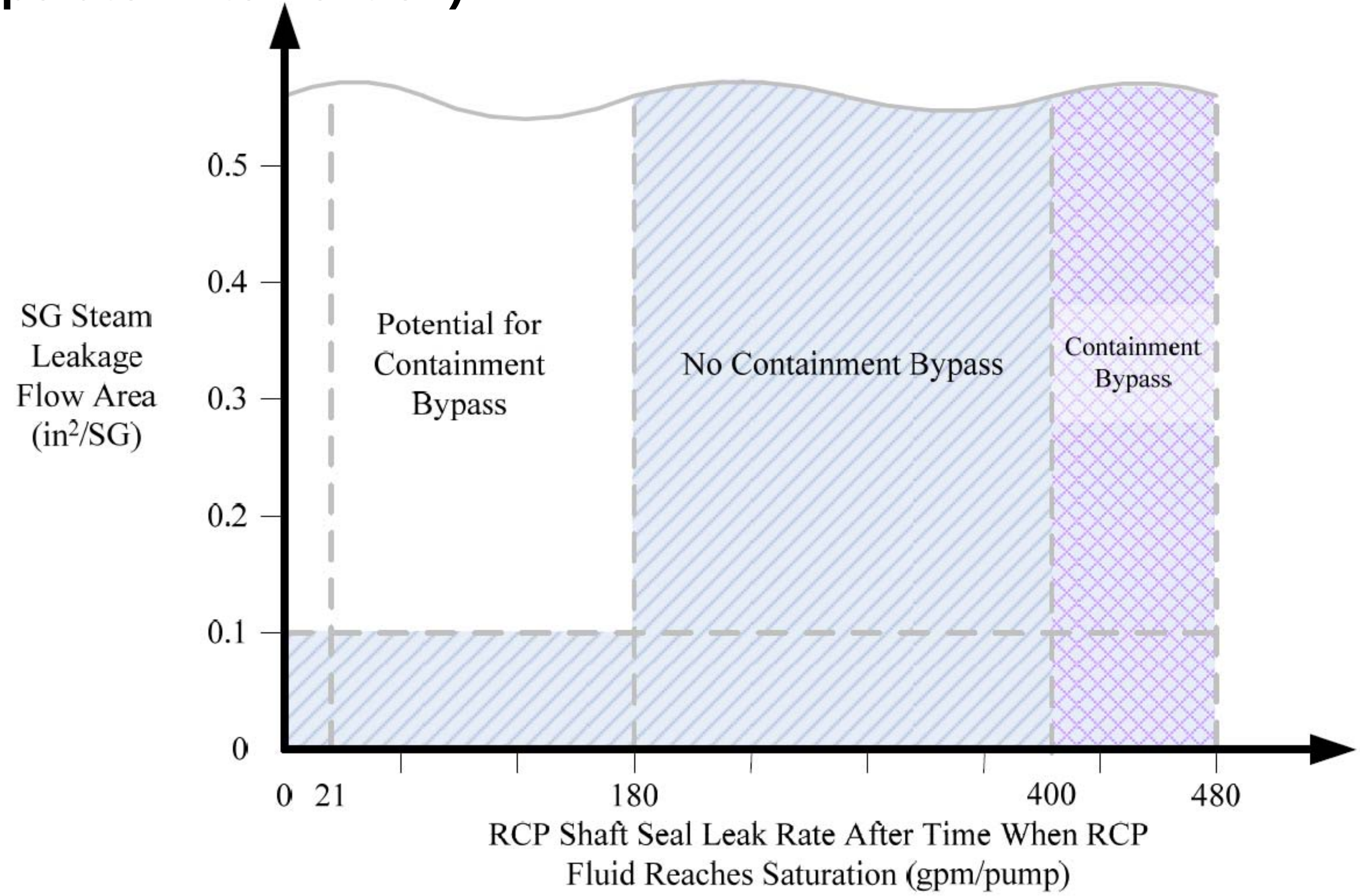
Typical W SG

inlet plenum geometry affects mixing

(temperature contours shown)

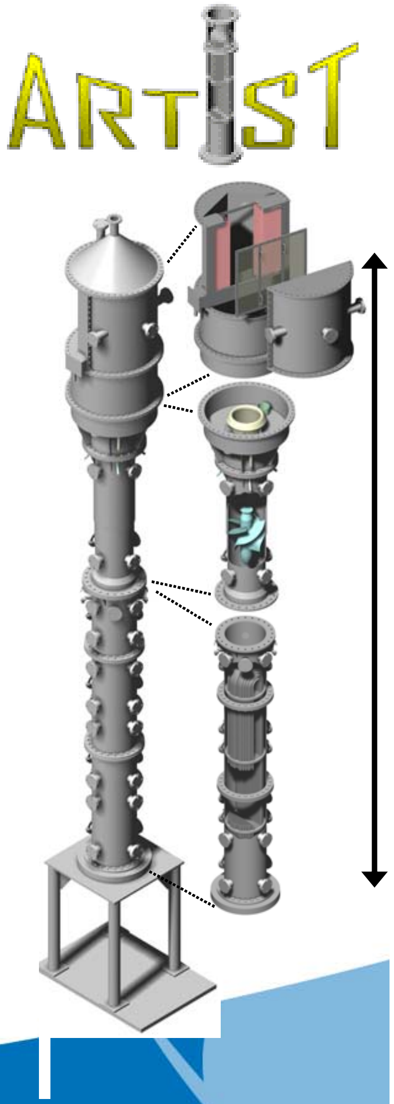
Sample Map of Containment Bypass Potential

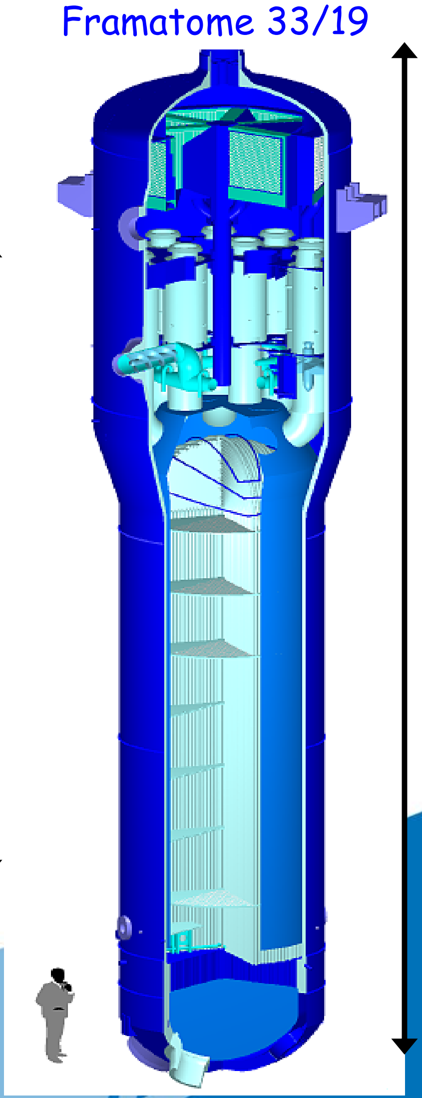
Considering Primary and Secondary Side Leakage Rates (no operator intervention)



What happens to FPs that make it to SG? (1/2)

- Discrepancies in predictions of SG decontamination factors (DFs) = FP mass into tubes/FP mass out of SG
  - Predictions range from 5 to 10,000
    - Affects risk importance of this type of accident
  - To resolve this issue, NRC participated in the AeRosol Trapping In a STeam generator (ARTIST) project
    - Multinational project, conducted at PSI in Switzerland, involved Separate Effects tests and Integral tests of decontamination for both dry and wet conditions

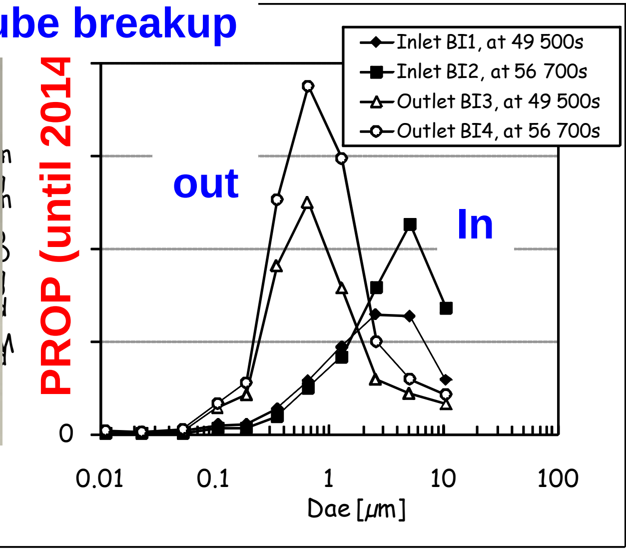




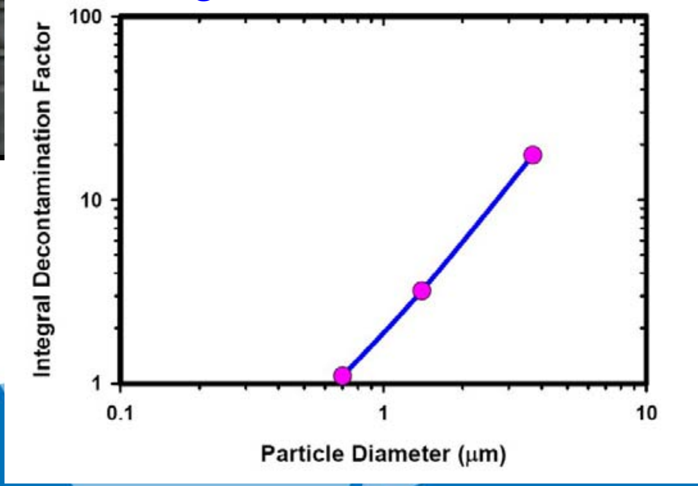
What happens to FPs that make it to SG? (2/2)

- What was found:
  - Agglomerates can break-up when going through tubes
    - FPs emanating from degrading core are multi-component agglomerates
  - Particles can bounce
  - Low decontamination observed on SG secondary side

Through-tube breakup



Integral Decontamination



Technical Approach

Richard Lee, Charles Harris,
Raj Iyengar, and Selim Sancaktar
RES

TH Analyses

- Update existing CFD and system code models for a CE plant
- Provide un-failed thermal hydraulic behavior for selected accidents (Item1.1.A.ii)
  - Boundary conditions for failure calculations (T, P)
    - spatially variant tube T
  - TH uncertainty estimate
  - Component failure time estimates
  - Run needed sensitivities (complementary to prior analyses)
- Provide failed thermal hydraulic and volatile (Cs, I, Te) releases based upon provided failures
  - Potential iterative process with failure models needed to obtain releases.
    - Preliminary calculations indicate that temperatures in CE SG will be hot enough for unflawed tubes to fail prior to other RCS components.
      - Likely sufficient to depressurize system preventing failure of other RCS components
- Provide assessment impact of instrument tube failures for Westinghouse and CE plants

TH status

- Update existing CFD and system code models for a CE plant (Calvert Cliffs)
  - – Generate CFD model of CE hot leg and SG lower plenum
    - Obtained plant info, drawings.
    - Preliminary CFD model developed. Running initial calculations.
  - Generate MELCOR CE deck
    - Obtained some plant info, drawings, R5 deck.
    - Obtained previous MELCOR and SCDAP/RELAP MELCOR decks
    - Deck generation in progress - building upon pre-existing CE (MELCOR and SCDAP/RELAP) decks.
    - Taking into account lessons learned from the previous C-SGTR analysis
  - Communication between MELCOR and FLUENT deck developers
    - ensure consistency between decks
    - Provide mixing parameters
- TH analyses will be conducted with these models
- Will use results of pre-existing analyses for Westinghouse plants if needed
- Instrument tube failure impact
  - – Review of existing analysis – due to lower priority and later deadline, will focus on subsequent to TH calculations

TH Uncertainties

- Base failure timing calculation (tubes & RCS components)
  - Relative failure timing (tubes vs RCS)
- Major TH uncertainties identified in previous analyses – considering:
  - Loop seal clearing – limiting calculations, don’t expect a definitive answer
  - Pump shaft seal leakage sensitivity
  - Secondary leakage sensitivity
  - TDAFW availability sensitivity
  - Battery availability sensitivity
  - Stress multiplier sensitivity

Flaw Distribution in SGs

Condition of SG Tubes

- Represent current fleet
  - Describe flaws in CE, W, B&W
    - Number, size
    - Type, location
    - Total leak area
  - New Materials
    - Alloy 600TT, alloy 690

Condition of SG Tubes

- Update NUREG on flaw distributions
  - NUREG/CR-6521   (1998)
    - Original statistics still valid
    - 1998 - applied to Alloy 600MA

    - Adjust for new materials
    - Incorporate newer ISI data
      - number, size, type, location

Failure of RCS Components

Failure Prediction of RCS Components

Tasks

- Identify, characterize, and model relevant RCS nozzles to assess their potential for failure during a severe accident for both Westinghouse and CE plants

- Develop finite-element models, addressing variables such as nozzle geometries/configurations, boundary conditions, loading conditions, fabrication effects, primary water stress corrosion cracking mitigations, and degraded conditions

Challenges

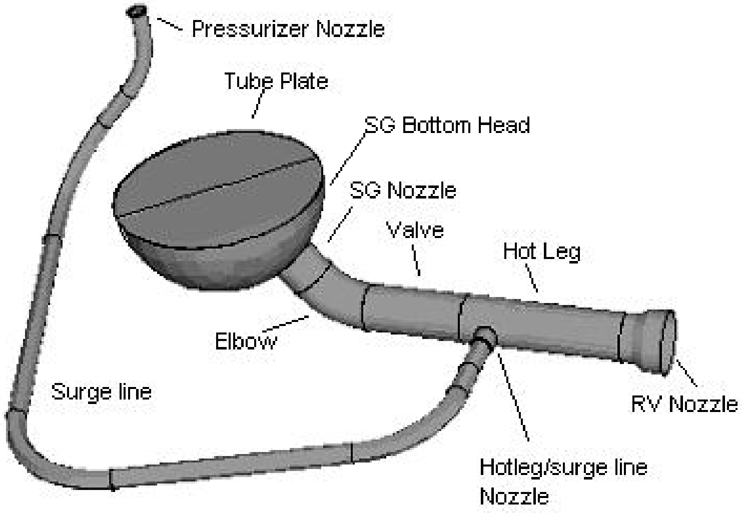
- Develop failure model for critical RCS components based on numerical experiments – for consistency with the tube rupture assessment

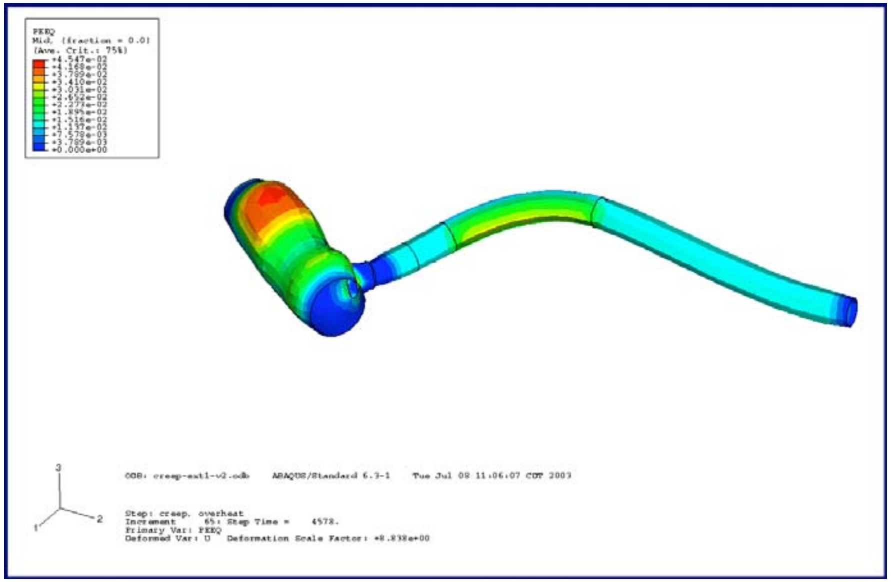
- Resulting methodology will be more conducive to the procedure adopted in the C-SGTR risk assessment method to be developed as part of the Task 1.3.A

Failure Prediction of RCS Components

Approach

Validate three-dimensional sub-model of Hot-leg nozzle with shell model of the hot-leg to surge line. This would allow for the development of failure envelope of generic hot-leg nozzle for different thickness of pipe and overlay welds.





```
ODB: creep-ext1-v2.odb    ABAQUS/Standard 6.3-1    Tue Jul 08 11:06:07 CDT 2003

Step: creep, overheat
Increment     65: Step Time =    4578.
Primary Var: PEEQ
Deformed Var: U   Deformation Scale Factor: +8.838e+00
```

Software Tool

ABAQUS - general purpose finite element analysis software will be used to predict failure time of hot-leg nozzle. Weakest link - the hot-leg nozzle(previous ANL study)

Uncertainties

- Material Properties – Data available
- Geometry - Geometric dimensions, Defect, Weld Overlay
- Failure Models – Creep Rupture, Tensile Properties
- Thermal Properties – Conductivity, Thermal expansion coefficient

PRA-Related Activities

User Need Summary

PRA-related activities are captured in tasks 3 and 4 of the user need.

3.A A user-friendly methodology for assessing the risk associated with consequential tube rupture/leakage in DBA and severe accident events.

3.B A reassessment of the conditional probabilities of C-SGTR based on updated flaw distributions and updated T-H analyses.

3.C Regulatory guidance on risk-informed decision-making regarding C-SGTR.

4. Report compiling and summarizing key research, building upon NUREG-1570, work performed as part of SGAP activities, and this user need.

Current Activities

- Two PRA-related projects are underway:

1. A contract was recently placed for creation of a PRA report to address task 3.A
2. A second contract is underway to create a C-SGTR calculator to estimate SG tube leakage probabilities under different conditions and for different SG designs.

PRA Report

- Task 3.A requires that
  - a simplified method for assessing the risk associated with C-SGTR events is to be developed and its use is illustrated taking advantage of updated SG and T-H data.
  - the method should be based on standard PRA techniques and the reference documents supplied by the NRC and should be documented in a report acceptable to RES and the NRR.
  - The method should address design basis accident and severe accident events.
- The report will support risk-informing the regulatory process by assisting the NRC staff to make risk informed decisions concerning C-SGTR events.

- The method and the report will be used to facilitate the quantification of C-SGTR events in future NRC and/or licensee risk models, and the development of guidance for future risk assessments.

C-SGTR Calculator

- A software package is developed to estimate SG tube leakage probabilities for given RCS and secondary side conditions (scenario parameters)
- The basis document for the software is being peer reviewed by expert(s) cognizant with the subject matter.

PRA Effort - Conclusion

- The PRA report and the C-SGTR calculator are expected to be ready within the next two years, after incorporating input from other disciplines (T&H analyses, behavior of other RCS components, additional SG tube failure data, etc.).

- Afterwards, the task of providing regulatory guidance on risk-informed decision-making regarding C-SGTR can be addressed.

CONCLUSION

- A multi-year project involving interdisciplinary technical work by several RES divisions
- A comprehensive project plan developed
- Ongoing continuous engagement and coordination with various divisions