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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THERMAL-HYDRAULIC PHENOMENA SUBCOMMITTEE

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MONDAY

AUGUST 21, 2017

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OPEN SESSION

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:30 a.m., Jose March-Leuba, Chairman, presiding.

COMMITTEE MEMBERS:

JOSE MARCH-LEUBA, Chairman

RONALD G. BALLINGER, Member

MICHAEL L. CORRADINI, Member*

WALTER L. KIRCHNER, Member

JOY L. REMPE, Member

ACRS CONSULTANT:

KORD SMITH

DESIGNATED FEDERAL OFFICIAL:

ZENA ABDULLAHI

ALSO PRESENT:

HEUMING CHOW, AREVA*

KEN GEELHOOD, PNNL*

RALPH GRUMMER, AREVA

KEVIN HELLER, NRR

JOSH KAIZER, NRR

ALAN MCGINNIS, AREVA

TOM MICHENER, PNNL

DOUG PRUITT, AREVA

KEVIN QUICK, AREVA

JONATHAN ROWLY, NRR

ANDREA D. VEIL, Executive Director, ACRS

REED ANZALONE, NRR

*Present via telephone

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P R O C E E D I N G S

(8:30 a.m.)

CHAIRMAN MARCH-LEUBA: Okay, so we're going to start, okay? Even though we don't have a court reporter, everything is being recorded, so make sure you talk to the microphone because there is nobody to tell us that they're not listening.

We're in session now. This meeting will come to order. This is a meeting on the thermal-hydraulic subcommittee advisory committee on reactor safeguards. I am Jose March-Leuba, subcommittee chair of the AURORA-B topical report review.

ACRS members in attendance today are Walt Kirchner, Joy Rempe, and Ron Ballinger. Member Corradini is joining us through teleconference. We also are supposed to have here with us Dr. Kord Smith as a consultant, which hopefully will come a little later, and Zena Abdullahi is the designated federal official for this meeting.

The topic of this information meeting is AREVA's topical report ANP-10300P entitled, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios." The according staff review is limited to application of

the AURORA-B evaluation framework to transients and (inaudible) which is intended to be applicable to (inaudible) plants up to the extended operating power flow main which includes CPU.

Today the staff, AREVA, and their consultants will brief us on the AURORA-B evaluation framework, the supporting modifications, and the basis for the safety findings. Part of this committee meeting is closed to the public in order to protect information that is proprietary to AREVA.

We have one bridge line arranged for interested members of the public to listen in. In order to minimize noise, this line will be kept in mute. At the end of the open portion of the meeting, we will request if anyone listening would like to make any comments.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting. A separate closed bridge number is available for Member Corradini of NRC and AREVA staff and consultants.

Everybody, please place your phones in mute to minimize interference during the meeting. As the being is being transcribed, I request that the participants use the microphones located in this room

while addressing the subcommittee. Participants should first identify themselves and speak with sufficient clarity and volume so that they can be really heard.

Typically, when the court reporter is sitting in that corner, you don't have to identify yourselves because you have a name, but because we want to record it, please identify yourselves at least the first couple of times. Afterwards, they will know depending on which microphone comes - each microphone has a different tape recorder.

Let me remind you to please ensure that all devices have been placed in silent mode to minimize disturbance of the meeting. We will now proceed with the meeting. I call upon Mr. Ralph Grummer? No, sorry, there's been a change, Jonathan Rowly from NRR will make some introductory remarks.

MR. ROWLY: Yes, good morning, Jonathan Rowly. I'm the project manager, AREVA project manager for the NRC. Before I actually hand it over to Shana Helton for opening remarks, I just want to let everybody know a few administrative things.

For our guests and visitors, you're on the second floor of Two White Flint North and you need to be escorted at all times. So if you need to leave the

room for any reason, to use the restroom, answer a call, or get some water, or whatever it may be, please let a member of the staff know and we'll escort you out so that you can conduct whatever business that needs to be handled.

In case there is an alarm, we're going to go out in the hallway to your first right, and another right, there is a stairwell, and we're going to take the stairwell down. We're going to bypass the elevators and we're going to meet in front of One White Flint at the flagpole and account for everyone there, and then move away and do whatever we have to do according to what's going on.

Also, safety issues, there's a lot of people in the room, so be aware as you're walking around not to trip over anything or anyone's feet, so please be cautious as you move around the room, so thank you.

As Chairman March-Leuba mentioned, please silence your cell phones. Put them on vibrate or whatever just so that if you do receive a call, we're not bothered during the meeting, so thank you.

MS. HELTON: Thank you, Jonathan. My name is Shana Helton. I'm the Deputy Division Director in the Division of Safety Systems in NRR, and I'll be making

some opening remarks for us on this eclipse day. I see it's a full agenda for a full day's subcommittee, so I'd first like to thank everybody for being here. I recognize it's probably a cloudy day, but I also recognize a lot of people are trying to avoid doing any sort of work related activities so they could get out and see the eclipse this afternoon, so I appreciate everybody being here.

Leading our AURORA-B AOO review, you'll be hearing from Dr. Kevin Heller today. He's sitting right behind me along with John Lehning, and I believe we'll also be hearing from Tom Michener from PNNL who is the technical group leader and provided some contract support for the evaluation of the topical report from AREVA.

Just to give you a broad overview of the AURORA-B topical report before we get into it, AURORA-B is what AREVA named their next generation multi-physics code system for the analysis of a wide array of transient and accident scenarios.

This is a suite of topical reports. Today we're just mainly focusing on the AOO topical, but this is - AURORA-B does refer to a suite of topical reports that the staff has for review right now.

It's an interdisciplinary review

encompassing a large number of scenario, and many of the models and methods that we're going to be discussing today are also used in the AURORA-B control rod drop accident and LOCA analyses. So you'll get kind of a snapshot of the entire suite today of the AURORA-B codes, and we'll focus in and do a deep dive on the AOO for the analysis of transients and some accident scenarios.

That's all I'll say. I'll make my opening remarks brief since it is a good agenda, and thank you again for your time.

PARTICIPANT: Could I ask a process question? I looked through the slides and I can't find a better place to do this, but how will updates be handled? I mean, you've mentioned there are a lot of components that are approved, but approved codes sometimes have errors and they do corrections, or they decide to update for whatever reason, and how do you assure that there's not some unknown interaction when you do an update for this higher level framework?

MS. HELTON: I think you're referring to in general a change process for topical reports. Is that what you're asking?

PARTICIPANT: Yeah, well, I mean, you've got a bunch of approved -

MS. HELTON: Right.

PARTICIPANT: - or soon to be approved components with a big high-level framework that will be approved with this action that we're doing now, or reviewing now, but what if the RELAP component, for example, they find errors in that sometimes I know from the years gone by and so they correct it, and then sometimes would that change make the interactions with the other codes, because there's this data being passed back and forth, and trigger some other problem, and how do you check that you've not messed up your higher level approved framework because one of the little components managed to trigger another component to go into an area that you didn't expect and you get an error?

MS. HELTON: I understand. I'll give it a shot and then I'll turn it over to staff to give a more detailed - in general, we don't have a - so I'll talk to the change process first, and then I think what your question is really getting at is for a suite of codes that are related, if you change one thing, does that change something else in something you've already approved?

PARTICIPANT: So you run through a bunch of test cases -

MS. HELTON: Right.

PARTICIPANT: - for example, to say the higher level framework's still valid even though I found that error in Component A.

MS. HELTON: Got it, so for in general, we don't have a generic change process for topical reports yet, but we're starting to do them on a case by case basis by writing a change process into our safety evaluations for topicals.

This is an area that we've had some public dialogue on, I believe, in the context of the (inaudible) 500 or office instruction for reviewing topical reports. We had a discussion at the regulatory information conference last year and we want to move forward.

I think industry is interested in some sort of a generic change process, and that's certainly one of the types of issues that we need to look at as part of the change process. For this specific AOO topical which is part of this broader suite of AURORA-B codes and how we look at the interrelation, I think you've got something you want to say on that.

MR. LEHNING: Yeah, so this is John Lehning from the NRC staff. So we will talk a little bit, and not in a lot of detail, but toward the end of the day, we will touch on the change process a little bit and

talk about what types of code changes are permissible under the topical report and safety evaluation.

In general, I'd say just until we get to that point, there's a quality assurance program that vendors use when they develop their codes that they use for regulatory actions.

So if it's an error or some such thing as that sort, then the quality assurance program would govern corrections. If the error or change was at such a level that it impacted the information in the topical report, like it may be a small issue -

CHAIRMAN MARCH-LEUBA: Please talk closer to the microphone.

MR. LEHNING: Sorry about that. If it doesn't really affect the outcomes of the validation and things like that, then that's different and probably wouldn't require something like a topical report update, but if it were something that caused the topical report validation or assessment cases to change, then that's something - and the demonstration analyses and the plan analyses to change, that's something that might be a supplement or something like that.

PARTICIPANT: So just to make sure I understand, so let's again pick on RELAP. They find an error. They correct it in RELAP, so they fix that

and it still goes through its validation cases and that's fine, but now since we have AURORA that relies on RELAP, S-RELAP, then you're going to have to run the AURORA validation cases too because both framework as well as the component will be impacted?

MR. LEHNING: That's correct. I mean -

PARTICIPANT: Good, okay.

MR. LEHNING: And it would be obviously - for different evaluation models under AURORA-B, you might use different model assumptions in some of these, for example, control rod drop, LOCA, and AOO. So it might be that one or more of them are affected, and so there would be an extended condition that would need to be done for any of the effected evaluation models to determine whether or not some change needs to be made.

PARTICIPANT: Great, thank you.

MS. HELTON: I'd just like to emphasize the point about Appendix B, so that's something that we're starting to look at more as a staff is the 10 CFR Part 50 Appendix B. There's a number of criterion there, Criterion 3, Criterion 8.

Those would pull in topical reports, we think, so we're starting to look at more for a change process especially. With the change process, you want

to make sure you have appropriate oversight, and that's kind of the link to oversight that we're looking at.

PARTICIPANT: Thank you.

CHAIRMAN MARCH-LEUBA: So following up on that topic, and sorry AREVA, we'll - let us while we have them on the microphone. Yeah, I'm also interested on this topic a lot because typically we think about (inaudible) causing errors, or you find that the correlation you put into (inaudible) when you meant (inaudible) six because you read it wrong from the paper.

But there's also other changes like improvements on correlations that you got new data from an experimental facility and you want to reuse the uncertainty because now you have better data. There has to be clarity from the staff at which point you allow them to run loose and use Appendix B for qualifying it, and we, the staff, review it to make sure it's okay.

Because obviously if a correlation had a coefficient at this (inaudible) go ahead and change and run your validation and you're fine, but if you want to use new data, there has to be clarity from the staff what they can do and they cannot do because often they are making the decision themselves, and more often

than not, they tend to be too conservative because they don't want to be caught.

So if you guys, and you don't need to give me an answer now, but keep in mind there has to be clarity on what they're allowed to do and what they're not.

MS. HELTON: We agree.

CHAIRMAN MARCH-LEUBA: Okay, so with this in mind, now AREVA. I believe Ralph is going to make a presentation or Alan?

MR. McGINNIS: I'm Alan McGinnis. I'm Licensing Manager for AREVA and I'm just going to make a couple of opening remarks. We want to thank the ACRS for having us here today and allowing us the opportunity to provide you with information to utilize in evaluating the staff's safety evaluation for AURORA-B, and I thank Shana. She did an excellent job of summing up what the AURORA-B suite of codes is all about, so I don't need to go back over that.

I would like to say that we're very anxious to begin utilizing this new methodology. It resolves a number of legacy issues like thermal conductivity degradation, and allows us to move forward with an integrated solution for those legacy issues.

And in fact, we anticipate having a license amendment request submitted to the NRC within a year

of approval of this method, so we're going to begin implementing it immediately, so we're very anxious to get these new codes and methods approved and in use.

So I guess I'm going to keep my remarks that short. I'm going to go ahead and introduce my presenters here today. I've got Doug Pruitt who has over 40 years of experience in the industry in thermal hydraulics and codes and methods development, and is also an expert in stability, and I've got Ralph Grummer here with me today who also has over 40 years of experience in the industry in neutronics, core monitoring, and codes and methods development. I'm just going to turn it over to Doug now.

CHAIRMAN MARCH-LEUBA: Let me, since you gave me an opening and I'm the boss of the microphone today, I'll be responsible for running over past 5:00 p.m. today. Given some requests for the staff, we will be having a full committee meeting on this topic in a couple of weeks if everything runs correctly in this subcommittee and we don't have any serious problems.

One concern I have is that this methodology was submitted originally in 2009 and we are now approving the SER (phonetic). So, and I realize there have been some changes of the staff. Things have been resubmitted a couple of times, but if during the full

committee we could address what lessons we have learned for taking seven, eight years to make a review of this methodology that is not groundbreaking.

I mean, this is just an incremental methodology. For God's sake, the plants have only a four-year lifetime. If we take nine years to review things, we'll never make or have any progress, so if during the full committee you guys can address what lessons have been learned so that AREVA can do a better job and the staff can do a better job to get it done in 18 months preferably. Okay, Doug, your turn.

MR. PRUITT: Okay, Doug Pruitt, consultant to AREVA, and it's my pleasure to give an introduction here. I'm going to talk a little bit about the evaluation model development, the application domain, and the summary of the application to a plant.

So as has already been stated, AURORA-B consists of a best estimate multi-physics code system for simulating a coupled fuel, neutronic, and thermal hydraulic BWR system response.

Within that structure, we consider four calculational devices, the MICROBURN-B2 steady-state core simulator that provides the bulk of the information that comes into the system, the MB2-K which is the kinetics equivalent to MICROBURN-B2, RODEX4 which

provides the historic impact of depletion on the fuel rods as well as the closure relationships and dynamic modeling in S-RELAP5, and then S-RELAP5 is the host code that's the two-fluid thermal hydraulic system model that's been approved previously for PWR non-LOCA and Realistic large break LOCA evaluations.

So fundamentally, there's one code, S-RELAP5, which embedded in that is the MB2-K kinetics that can operate as an alternative to the point kinetics model that is in S-RELAP5, as well as the relevant portions of RODEX4 for the transient simulation.

CHAIRMAN MARCH-LEUBA: When you're reading this, I have a question that Dr. Corradini sent in my email because I think his phone is on mute. He is not - I haven't heard him yet. I know he's on the line. He wanted to know what are the high-level, 20 second, differences between S-RELAP5 and RELAP 3.0?

MR. PRUITT: I can't answer that. We start with 2.5. That's where the starting point for our jumping off in S-RELAP5.

CHAIRMAN MARCH-LEUBA: So what are the differences?

MEMBER CORRADINI: Can you hear me?

CHAIRMAN MARCH-LEUBA: Yes, now we hear you.

MEMBER CORRADINI: Okay good, so let me expand. There's a 2000 ACRS report that analyzed S-RELAP, which I assume S stands for Siemens.

MR. PRUITT: Right.

CHAIRMAN MARCH-LEUBA: Mike, Mike? We don't have a court reporter. Can you identify yourself?

CHAIRMAN MARCH-LEUBA: Excuse me, I'm sorry, Corradini, member of - ACRS member. I just wanted to make sure what the take off point was where S-RELAP was being developed versus what we know to be RELAP5 Mod 3 because there's a 2000 ACRS memo that analyzes it, and I assume that's the take off point, but maybe the AREVA folks can help us.

MR. PRUITT: I probably want to defer that until the closed session when we have our S-RELAP5 main programmer here but -

MEMBER CORRADINI: That's fine. That's fine.

MR. PRUITT: - we did take off because I think our LB (phonetic) LOCA was submitted in 2000, so it was prior to 3.0.

MEMBER CORRADINI: Okay, fine, all right. We can come back to it if necessary. That helps me though. And then I sent Jose a web address which is

with one of the ACRS consultant's analysis at that time in 2000 of S-RELAP. Thank you.

MR. PRUITT: Okay.

CHAIRMAN MARCH-LEUBA: I will give you that. We don't need to put it on the record.

MR. PRUITT: Okay, so the development summary, primarily the neutron kinetics, it starts with MICROBURN-B2 steady-state equations and adds the temporal, creates the temporal kinetics equations. It's integrated within S-RELAP5.

All the nodal depletion, spectral history, and other information is passed from MB2 or from CASMO-4 directly into MB2-K for the transient simulation, and it uses the same cross section lookup strategy and form of the cross sections as MICROBURN-B2 uses for consistency.

In the fuel rod performance area, there's a subset of RODEX -

PARTICIPANT: Pardon me.

MR. PRUITT: Yes?

PARTICIPANT: So what version? I should have looked this up in advance, but I'll just ask you in real time. What version of ENDF (phonetic) files do you use for the cross sections?

MR. GRUMMER: This is Ralph Grummer. It's

primarily ENDF 4 with some modification on the fuel of the isotopes.

PARTICIPANT: Okay.

CHAIRMAN MARCH-LEUBA: Sorry, now you've got that one and maybe we can wait until the closed session. Do you have a correction for gadolinium isotopes? In there before it doesn't have isotope gadolinium. It has elemental gadolinium, right?

PARTICIPANT: Elemental, right.

CHAIRMAN MARCH-LEUBA: Yeah, but -

PARTICIPANT: Or isotopic, yeah.

CHAIRMAN MARCH-LEUBA: Yeah, does it have isotopic? In there before I didn't think it had it.

PARTICIPANT: I don't remember specifically where those details were in the report.

CHAIRMAN MARCH-LEUBA: But you do isotopic, right? Okay.

MR. PRUITT: Doug Pruitt. The subset of RODEX4 routines are integrated within S-RELAP5, so that includes all of the information from the irradiation history by RODEX4 to the point of the initiation of the event, and that is then read by S-RELAP5 for each of the fuel rods that's modeled and then within S-RELAP5 which is used to evaluate the temporary transient thermal-mechanical fuel rod, including the fuel/clad

gap and its evolution during the transient as well as all the properties, the temperatures and things are coming in from the RELAP5 fuel conduction solution, and then it provides new heat capacities and thermal conductivities and gap conductance.

S-RELAP5 models have been improved primarily associated with pressure drop in the BWR assembly, so interfacial drag for rod bundles and large diameters have been refined a little bit. Reynolds dependent losses, which is what we run in MICROBURN-B2, are included, and single and two phase friction models consistent with MICROBURN-B2 for the fuel.

PARTICIPANT: May I ask another question here? And maybe it's more appropriate for the closed session. With regard to spacer grids and just going from the different rod bundle configurations, do you see a big effect in your physical models as a result? Do you have to change the models to go from 9x9, 10x10, whatever bundle geometry you're using?

MR. PRUITT: I mean, the form of the correlations are the same.

PARTICIPANT: The same, so you're not changing the correlation.

MR. PRUITT: Yeah, if you change the size of the veins, or the geometry, or the thickness, you're

going to get different loss coefficients, but the correlations are all the same form.

PARTICIPANT: Okay, thank you.

CHAIRMAN MARCH-LEUBA: I was waiting to ask more questions during the closed session, but I think it's already open. Is there only one version of S-RELAP5 for AREVA for both PWR and BWR now or have you guys stopped?

MR. PRUITT: Yeah, it's actually branched out now and the PWR version is primarily owned by the group down in Lynchburg, so they have the same root. There's a big overlap between the two.

CHAIRMAN MARCH-LEUBA: So, but does it have a different name so we know, or you're using -

MR. PRUITT: The PWR version will be an AURORA-B code set.

CHAIRMAN MARCH-LEUBA: Okay, so we have branched out, so this and AURORA-B, S-RELAP5 version, correct?

MR. PRUITT: We'll talk about it a little bit more in the closed session -

CHAIRMAN MARCH-LEUBA: Okay.

MR. PRUITT: - with respect to code control and things like that.

CHAIRMAN MARCH-LEUBA: While I have the

microphone, Dr. Kord Smith has joined us, consultant for ACRS.

MR. PRUITT: Okay, Doug Pruitt just continuing. The component models that have been added or improved, of course there's the jet-pump model, the mechanistic separator model, and an addition of critical power correlations, all that are required to address BWR phenomena.

So AURORA-B in itself is, we have the comprehensive code system for BWR applications, and from that code system, you can pull various components that may be appropriate for a particular evaluation model. So today we'll be discussing the 10300 which presents the fundamental foundational development and qualification of AURORA-B for BWR applications, and the AURORA-B AOO evaluation model for analyzing predominantly core wide transients and accidents.

As noted before, it does not address a control rod drop or control rod withdrawal errors, loss of coolant accidents, late stages of anticipated transients with scram after the Boron injection, and instability events. There are -

MEMBER CORRADINI: So this is Corradini, member. I want to make sure I understand. So is more coming for AURORA-B for these other four, or what is

now used in what I'll call in the AREVA toolkit for those analyses?

CHAIRMAN MARCH-LEUBA: Doug, can you tell him when you change the slides that we're on page nine?

MR. PRUITT: Oh, sorry, we're on page nine.

MEMBER CORRADINI: Yeah, I knew that. Thank you.

MR. PRUITT: So in anticipation of that, we have both the LOCA evaluation model 10332 and 10333 for the control rod drop analysis that are under NRC review currently. So instability events we analyze with the RAMONA5-FA code and that will not change, and then control rod withdrawal errors we typically analyze in a steady-state methodology with MICROBURN-B2.

CHAIRMAN MARCH-LEUBA: How about the long-term ATWS?

MR. PRUITT: Long-term ATWS we do not do currently.

CHAIRMAN MARCH-LEUBA: Oh, that's why you just take advantage of the existing plans?

MR. PRUITT: The same plants and the fuel, minimal changes due to the fuel design differences. Okay, the application domain of course is all BWRs 2 through 6, and the entire power/flow operating map from low power conditions at which core monitoring commences

up to and including operation at extended power flow operating domain which is the extended power flow upright with expanded flow domain.

CHAIRMAN MARCH-LEUBA: Mike, do you want to ask the question about ABWR? Okay, or let me ask it for you.

MEMBER CORRADINI: Yeah.

CHAIRMAN MARCH-LEUBA: Yeah, go ahead.

MEMBER CORRADINI: Well, that's okay. Go ahead, Jose. You know what I was going to ask. You go ahead.

CHAIRMAN MARCH-LEUBA: Right, yeah, why not ABWR?

MR. PRUITT: Well, we submitted for ABWR, but basically that was going to be routed through the new reactor branch, and since it doesn't exist in the U.S. at this point, it was deemed to be too long of a review in order to really - uncertain benefits to the U.S. market.

CHAIRMAN MARCH-LEUBA: That's something I would like to hear from the staff.

PARTICIPANT: Yeah, I guess I would too. I want to understand the technical difficulties versus it takes too long to review.

CHAIRMAN MARCH-LEUBA: It appears to be

a process difficulty that a different person has to sign for it if it applies to ABWR. Is that correct? That's the understanding.

MR. PRUITT: That's my understanding, yeah.

CHAIRMAN MARCH-LEUBA: Whenever the staff comes along and you guys can find out why is it a different person has to sign for that methodology, and if that's the case, let's find out about it.

MR. PRUITT: In interest, I won't go through all of these events, but it is applicable to the Chapter 15 events for cool down events, the heat up events which are primarily pressurization events, loss of coolant flow events whether that's a pump trip or a pump seizure, reactivity events, increase in inventory, decrease in inventory events, as well as anticipated transients without scram, and one of the primary transients there is the peak reactor pressure and demonstration that would meet all of the criteria for that as well as demonstration fuel integrity.

Figures of merit that are associated with methodology are the delta MCPR which demonstrate the event minimum critical power remains above the appropriate limit for the scenario, so typically for 99 percent of our application, that's going to be the

safety limit MCPR, the peak system pressure to demonstrate that the peak pressure is maintained below prescribed limits for AOOs and the ATWS scenario, the time dependent nodal power which is used in conjunction with our thermal-mechanical methods to evaluate cladding strain and fuel centerline temperatures during the event, and then the peak clad temperature and maximum local oxidation to assure fuel integrity is maintained for selected events.

So the event evaluation basically is initiated from a steady-state condition defined by MICROBURN-B2, MICROBURN-B2 depletion to the cycle exposure and the power/flow condition of interest. The AURORA-B input preparation is basically augmented by certified automation codes.

Obviously with a code system this large with the amount of data, almost everything is automated, so the vessel, steam lines, recirc lines, control systems, and protection systems are all constructed from plant specific database.

Core geometry is constructed from MICROBURN-B2 which has the core loading and the power distribution. The core nodalization and initialization is based on the MICROBURN-B2 state-point solution.

So since S-RELAP5 does not model every unique bundle within the system, it does some group based on the powers and fuel types, so that's all dependent on the particular state point, and then the core fuel pins are initialized based on RODEX4 - I call it depletions because that's the word I always use - with MICROBURN-B2 power histories and state-point nodalization, so not only the cycle of interest, but the previous cycle of operation in order to characterize the power history for the second cycle fuel or even maybe third cycle fuel if any of that's in there.

So the plant application, the 10300 system was submitted to establish the foundation methods to address shorter regulatory changes associated with reactivity insertion events and revised LOCA criteria.

The key components of the methodology are the well founded and qualified models and methods for BWR transient applications, conservative benchmarks to reactor turbine trip measurements. The highly ranked plant parameters or parameters that exhibit a range of operating conditions are treated conservatively.

Conservative biasing of transient simulations to bound modeling uncertainties for figures of merit outcomes are based on Monte-Carlo techniques

and approved uncertainties, and the resultant change in MCPR is added to the statistical MCPR safety limit to establish MCPR operating limit, and limiting event boundary conditions are utilized within the RODEX4 statistical methodology to demonstrate fuel centerline melt and clad strain criteria.

PARTICIPANT: May I just ask you to explain your terminology?

MR. PRUITT: Okay.

PARTICIPANT: The first bullet, what is a short term regulatory change?

MR. PRUITT: Well, we were looking out, you know, three or four years thinking that in order to address the CRDA requirements, we really need to have a full three-dimensional model, and so we needed to get that in and get it moving so that we'd be able to address that when it was approved, and same with the dealing with the high cladding embrittlement for LOCA.

PARTICIPANT: Thank you.

MR. PRUITT: So submitted documents, the primary documentation of course is the LTR, the acceptance review questions which clarified the submitted methodology as well as provided validation for the application of MICROBURN-B2 to extended power

uprates with extended flow windows, and then the request for additional information associated with the review itself which really quantify the model uncertainties. That was the primary things that were changed as far as the review, quantifying the model uncertainties and the associated impact on the computed events figures of merit.

The supporting documents, following the EMDAP process, we had a host of documents, BWR design and event descriptions, control system and reactor protection system requirements, the code capabilities and PIRT development, as well as the underlying documents associated with each of the components, the MICROBURN-B2, MB2-K, RODEX4, and S-RELAP5.

So the basic methodology of AURORA-B and the AURORA-B AOO methodology was developed and documented consistent with the EMDAP process delineated in NRC Reg Guide 1.203, and that closes my introduction. Any questions further?

CHAIRMAN MARCH-LEUBA: No, let's move onto the staff presentation. And we are still in open session, so be mindful of proprietary information.

PARTICIPANT: I'm not sure where to start.

CHAIRMAN MARCH-LEUBA: The same rules apply. Make sure to push the push button. The green

light should be on, and say your name a couple of times so the court recorder can identify them.

MR. HELLER: Testing, all right. Good morning, my name is Kevin Heller. I'm with the Nuclear Performance and Code Review Branch in DSS, and I'll introduce -

MR. LEHNING: John Lehning, also from the Nuclear Performance and Code Review Branch.

MR. HELLER: So what I'm going to be presenting is really a high-level overview of the staff's review of the AURORA-B AOO evaluation model, so I figure we'll just jump right into it.

PARTICIPANT: Before you get going, just a general question because we are going to be looking at research activities in the next couple of months, to what event is research involved in your review of these kinds of submittals of major code developments like this or is that done entirely in NRR?

MR. LEHNING: This is John Lehning. I'll take the first shot at that. So generally, these types of reviews are done by NRR. However, if there are certain aspects that we may need help in the general sense - I don't think we got research involved on this particular review, but there could be a need.

For example, if NRR wanted research to perform

confirmatory analysis of a certain type, I've always done that for some instability type reviews or if we needed input decks prepared for a LOCA application, we would get them involved at that point if we needed to, but that has not occurred on this review to my knowledge.

PARTICIPANT: Thank you.

PARTICIPANT: So along those lines, something that came to my mind when I was looking at this, why didn't you ask to have a trace comparison analysis done? I mean, you went through and looked at particular aspects with good diligence and, you know, (inaudible) different and things like that.

But at the top level, would it have been smart to have had a trace comparison now rather than to wait when a plant comes in and do it, and then say, "Well, jeepers, it's predicting a lot differently," than to have it benchmarked like against some of the data like at this point? What was the motivation for not doing it?

MR. LEHNING: That's a good question, and let me speak in general again, and I'll let Kevin talk to the particulars about this review. But as far as a modeling of these type of events in particular, it's very intricate, and it depends in great detail on the

details of the fuel and the specific correlations that are input into the codes.

And my understanding of what, for example, TRACE has, it doesn't have AREVA's particular CPR correlations installed. It doesn't have the - we would need to request quite a lot of information, not only in this case because we're talking multi-physics, so not only for the thermal hydraulic pieces, but also for the MICROBURN type applications, the kinetics, and so there's an awful lot of information.

I mean, and the timing of the review and how long it ended up taking, I think things like that could have been done, but, you know, the need for it depends on the newness of it, the uniqueness, and things like that.

So our feeling was that we could handle the review by the normal types of review that NRR does just by looking at their reviews of the models and the methods of AREVA's that comparative analysis with TRACE wasn't necessary in this case.

MEMBER CORRADINI: So this is Corradini, Member. So let me go back to Walt's original question. Is the normal process for NRR to stay within your team of individuals and do audits that involve looking at documentation and calculations and maybe asking the

applicant to do additional calculations, or is the process that you always look to, perhaps if appropriate, you do audit calculations yourselves? I'm trying to get the overall process.

MR. LEHNING: Yeah, I think you nailed it and that's what we do. I guess there are alternatives that we or the NRC could internally do additional sensitivities of our own with our own codes, and obviously there are some benefits for that in the right applications although it is a pretty high resource amount to do that in every single review, but we often do, and requesting as RAIs and the applicant or the vendor do these additional cases.

And in fact, we asked AREVA to do quite a lot of additional work in the RAIs that we issued to them, and furthermore, we did do with PNNL and with our - we did do some individual confirmatory type calculations ourselves, although it wasn't generally doing full-blown code calculations and so forth. And I think Shana wanted to add a point here too.

MS. HELTON: Yeah, I'll just pipe in and I'll ask the staff to speak to more detail, but we did, as the member question alluded to, take advantage of the audit process throughout this review.

In general with these topical reports,

they're so complex and so detailed, we've been finding that communicating on paper back and forth isn't necessarily the most efficient or effective way to conduct the review, and that getting together under the audit process so that we can really have the technical people on AREVA's side talk to the technical people on NRC's side, and we get a better understanding of what they're asking for and what the scope of the problem is, and we can work that out. So that was quite effective from a general process standpoint, and maybe you want to speak to the audit a little bit more.

MEMBER CORRADINI: But at least for me, that answers the process question. I think that's kind of where Walt was going.

CHAIRMAN MARCH-LEUBA: Yeah, roughly how many audits did you have?

MR. HELLER: This is Kevin Heller. We had at least two audits. It's been a long review. I'm trying to remember. We may have had three. We definitely had two. I do remember that.

And I just wanted to add on to what Shana was saying, and that's those audits allowed us, and by us, I mean both the NRC technical staff, the PNNL technical staff, and the AREVA technical staff to get into a single room and pour over a wealth of calculation

notebooks.

CHAIRMAN MARCH-LEUBA: Before I say what I want to say, let me give you the standard disclosure that this is a subcommittee meeting, and what we're saying are impressions of individual members and not ACRS positions.

That said, I strongly support audits, and the more, the better, and you should have one at the beginning, one in the middle, and one at the end even on the small reviews. There's always a lot of push from management about the travel money. It's irrelevant compared to the amount of time you save, so please back to have more audits instead of less.

MS. HELTON: Oh, we are.

CHAIRMAN MARCH-LEUBA: The industry will support you too.

MS. HELTON: I agree completely and we've been looking for areas where we can because we recognize that you might spend a little bit in the travel dollars, but the efficiency that you gain overall is well worth it. I see Dr. Lukes up at the mic.

MR. LUKES: This is Bob Lukes. I'm the Chief of the Nuclear Performance and Codes Review Branch, and I'd say in the past, other - I've been a branch chief and I've worked in other branches within

the NRC, and there always has been push back against audits. That is not the case with our management at NRR.

We've also been, you know, looking at some of the data and how much audits actually make our process much more efficient in the RAI process. I mean, I think that we're seeing possibly a 50 percent reduction in RAIs.

When we take those RAIs, we go meet with them and discuss them because most of the technical information is like a miscommunication, right. When you see the written word, it's not really - the understanding of that written word is not as easy to do if you can just say, "Well, what did you mean by this? What did you mean by that?" and then we still document those questions as part of our audit plans, but I'd just like to again reinforce that our NRR management is fully supportive of these audits and encouraging them, which is unusual at the NRC like you said.

CHAIRMAN MARCH-LEUBA: Yeah, and this is Jose, and not only do you have the RAIs, the 50 percent RAIs that you send, the licensee understands what you're asking.

MEMBER CORRADINI: This is Member

Corradini. Jose, I think you've raised a very important point that ought to be somewhere in our final letter because I totally agree with how you've characterized it.

CHAIRMAN MARCH-LEUBA: This is Jose. It's already written on my notes, on my to-do notes.

MR. HELLER: This is Kevin Heller. Just to, I guess, put a final point on that and characterize it a little bit more, the first audit that we had with AREVA is what we call an audit for understanding where basically when we perform our review, we go down through and we read through the documentation, and we come up with a list of not what I would call RAIs, but questions. Some of these are clarification. Some of them might be technical nature.

But we had the opportunity to get together with AREVA then and discuss what it was that we were asking, receive some clarification on things, and ultimately distilled down what was going to become an RAI. And through that, we saw in this particular review a reduction of about 50 questions through that first audit for understanding.

CHAIRMAN MARCH-LEUBA: And often my experience, since we all relate, is that the RAI that you issued was only for the (inaudible) for the record

because you already knew the answer -

PARTICIPANT: In a lot of cases.

CHAIRMAN MARCH-LEUBA: - when you left the RAI -

MR. HELLER: Exactly.

CHAIRMAN MARCH-LEUBA: - the audit.

MR. HELLER: Any other questions? Okay, this is Kevin Heller continuing onto slide two. So again what I'm going to be discussing is a high-level overview of the staff's review of the AURORA-B AOO evaluation model, and then when we move into the closed session, we'll get more down into the nitty gritty of the nuances of what it is that we ended up reviewing.

On slide three? So this has been discussed or mentioned by both Shana and by AREVA. I'm just going to mention a couple of high points here though to kind of illustrate some of the needs that we had on this review.

So AURORA-B, again, is a multi-physics, multi-code system, and it's comprised of what are known as component calculational devices. There are other codes, some of which have received prior NRC review and approval. But because it had four of these component calculational devices, and because it is being applied to such a large range of transients, what

we really end up with is a large interdisciplinary review scope.

I'm now on slide four. So the staff recognized up front that this was going to require multiple reviewers over the course of several years in order to complete this complex review, and so as a result, we decided that it would be prudent to contract Pacific Northwest National Laboratory to act as a consultant. And they put together a team of subject matter experts that I quickly just want to read down the names on this group.

Their help was invaluable towards completing this review, Judy Cuta for the thermal-hydraulics, Ken Geelhood, fuel thermal-mechanical, and Ken will actually be joining us later this afternoon via the call in number, Carl Beyer, he was initially for the fuel thermal-mechanical, but he ended up retiring shortly after the review began and Ken came on and took his place, Dr. Gregory Piepel for the statistics, assisted by Dave Engel, Andrew Prichard for the neutronics, and Bruce Schmitt for the thermal-hydraulic and system modeling.

PARTICIPANT: Let me repeat my observation or question from earlier. I have no problem with you

using PNNL as a consultant on this, but it just, when I looked at the material in advance, it just occurred to me that why am I not seeing anyone from RES?

MR. HELLER: This is Kevin Heller. Do you mean in as far as requesting confirmatory calculations?

PARTICIPANT: Or just to assist you in the review as subject matter experts.

PARTICIPANT: That's just not the normal process that we use. We felt that we had the review team, both from the qualified reviewers in NRR, as well as the contractors done at PNNL, so with those people on the team, we felt like we had the adequate review capacity.

PARTICIPANT: I'm not questioning their competence or the adequacy. I'm just raising perhaps an issue that I'll bring up. It's off topic here. But to the extent that we're reviewing RES programs and involvement in regulatory actions, I'm just surprised that RES isn't engaged.

MEMBER BALLINGER: Can I clarify that a little bit? This is Ron Ballinger, ACRS member. Is there not some default process by which you go through to assign or identify people to help out with the review, and shouldn't that default process have an initial step of going around the NRC staff and seeing if there's

expertise there that could be used before going outside? Is that what you're trying to get at?

MS. HELTON: I'll take a crack at this and then I think - this is Shana Helton - and then I think Josh Kaizer has something he'd like to add. But, you know, for topical reports - and Jonathan Rowly, our project manager is here, and he can talk to the process probably better than I can - we look at the program office to lead that technical review.

It's up to the program office to then decide how we get the resources that we need to conduct that review, be it through a user need to research or through the use of contract expertise as we did in this case in PNNL.

One thing, I would have to do some homework to see if it played into this particular review or not, but across the agency, we're resource constrained, and we have to find a balance between using in-house resources versus contract assistance. I see Dr. Kaizer is nodding his head vociferously over there.

So I would suspect that, you know, with all of the in-house activities that we've got going on, we have to have a healthy balance of using the labs and other technical contractors to help support our technical reviews.

PARTICIPANT: But again, would that healthy balance not include efforts to keep people involved on the staff to maintain expertise within the staff? I know resource constraints. Everybody - that's absolutely true, but it's also true that you need to have people that are on the ball on the staff, so that's the balance that I'm wondering about.

MS. HELTON: Yeah, absolutely, and we do try to maintain our technical edge with a number of knowledge management activities. Using topical report reviews as a way to keep those knowledge management activities up to speed is actually an idea that we've been discussing at the management level.

We've been looking at, and we'll be starting it in the fall, with moving people between the offices, between NRO, NRR, and research on temporary assignments so that we can see how everybody does their work and bring knowledge to others in the organization.

PARTICIPANT: But that's an ongoing process.

MS. HELTON: Yes.

PARTICIPANT: It always has been.

MS. HELTON: Yes.

PARTICIPANT: What I'm a little bit concerned about is maintaining the expertise.

MS. HELTON: I hear you.

MR. KAIZER: This is Josh Kaizer, NRC staff. This was an interesting review actually from the Office of Research side because they're the ones that put us in this position in the first place. Dr. Yarsky was the lead reviewer. He got promoted to the Office of Research, and we do maintain a very close contact with research, and I mean, generally it's a staff level.

I mean, if I have a question on thermal hydraulics, I can go to Dr. Bajorek, if I have a question on neutronics, Andy Beland (phonetic). We have one of the original VIPER authors whose name slips me right now, but we maintain those levels of contact, and we do go to the Office of Research when we feel like we need to.

One of the things with PNNL, and it's a very strange lab, I would argue they've been the sub office of the NRC for many years, like Judy Cuta actually was on the first review of a critical heat flux correlation ever in the 1970s. It's the CE1 correlation, and so we have used PNNL to do this type of work for a very long time.

They were the main reviewers for CHF, and Gregory Piepel, Judy and Gregory did a really nice

document about how you should actually review these correlations, and so it kind of depends on when you have a review in front of you, do you feel like you have the expertise?

And Shana had a really good comment. A lot of time during this review, there was a big push to say, "Hey, what can we do that's contracting?" and so this kind of came into PNNL had the right people with Carl Beyer and Ken Geelhood for the fuel side, and they did a lot of that.

We do try to go to the Office of Research, but also like Shana said, a lot of times they have their own schedules and things and stuff they're busy with, and you do try to work with them, but sometimes they just can't fit you in.

PARTICIPANT: And just to add to that too, we also have a more broad knowledge management in maintaining the people at the labs and stuff, and the infrastructure that's there that have been working with us for a long time too is an important thing to continue to keep those contacts active and keep those people engaged on the work we do so they're there when we need them.

PARTICIPANT: I think we've made our point.

PARTICIPANT: Okay.

MR. HELLER: Okay, this is Kevin Heller. On slide five, just throwing up a couple of bullets here for the primary documents that the staff used for their review, of course NUREG-0800, the standard review plan, specifically Chapter 15.0.2, review of transient and accident analysis methods, and of course Regulatory Guide 1.203 was also used for guidance, specifically because it does detail the EMDAP evaluation model development and assessment process that the AURORA-B AOO evaluation model was following in how it was presented within the topical.

Slide six, so what I'm going to do in the next couple of slides, or the next several slides rather, is just go down the specific areas of review within the SRP Chapter 15 and discuss what the staff found as far as what was supplied in the documentation and in the topical report and the staff's assessment of it. And as a final bullet on slide six here, the safety evaluation that the staff developed is based on - this review structure is presented within the SRP.

So the first of the review areas in the standard review plan documentation, acceptance criteria. Submittals should identify specific accident scenarios and plant configurations, and the

submittal of course should contain a complete description of code assessment, theory manuals describing field equations, user manuals discussing code limitations, and what the staff found during the review is the accident scenarios are identified and the code assessments are described within the topical.

As I mentioned earlier, the AURORA-B AOO evaluation model is comprised of a number of different calculational devices, the primary one of which is S-RELAP5. So really the S-RELAP5 theory manual is more or less the backbone to the whole methodology, but it does speak to the transfer of information between the other component devices, and of course those theory manuals needed to be examined and they were provided.

Code limitations were found within the theory manuals as well as the user manuals, and of course prior staff safety evaluations. So ultimately, we found that the documentation supplied was adequate for the review.

And the second area of review on slide eight, evaluation models. There were four general areas of review, four phenomenological areas really, thermal-hydraulics, neutronics, primary system modeling, and fuel thermal-mechanical performance, so we of course took a look at those areas, but during

the staff's review, we identified that there were some areas of focus that were required, as an example, S-RELAP5. As AREVA mentioned earlier, it started out as a PWR code, and so new and existing models and methods were introduced or updated to make it applicable to BWRs, so those had to be examined.

MB2K is a new neutron kinetics method that's based on MICROBURN-B2. It was not thoroughly, or to my knowledge, prior review and approval by the NRC staff, so that had to be examined. MICROBURN-B2 information was supplied for its qualification to extended power uprates and extended flow window conditions.

And I'm just going to pause to make a note here that AREVA was using the term EPFOD, extended power and flow operating domain. As far as the review and the documentation, that's a relatively more recent term. I've been using EFW, so I just want to point out those are equivalent, and I thought about changing the terminology over, but I realized I would just start saying EFW all the time, and I didn't want to confuse anyone.

And of course RODEX4, the full RODEX4 code is part of the AURORA-B AOO evaluation methodology, but there's a subset of the methods that were

incorporated within S-RELAP5 for the calculation of fuel thermal-mechanical properties during the transients, and that's known as the RODEX4 kernel, so the staff identified that that would have to be examined and assessed.

So with that said, slide nine, evaluation model. The review acceptance criteria is the model should be present for all phenomena and components determined important or necessary to simulate scenarios under consideration, and those models and associated numerical solutions should predict the important physical phenomena reasonably well.

MEMBER KIRCHNER: Can I back you up again?

MR. HELLER: Certainly.

MEMBER KIRCHNER: This is Kirchner. I'm just curious why for MICROBURN-B2 qualification for EPU and EFW, I would think that qualification for EPU and EFW would be toward the entire code system, so what about MICROBURN-B2 in particular was a concern that you were qualifying it or looking at its qualifications for EPU and EFW versus RELAP, MB2-K, or RODEX4?

MR. HELLER: So this is Kevin Heller. That's a good question. The AURORA-B AOO evaluation methodology when it was submitted, it was requested that it be reviewed and approved for application EPU

and EFW conditions, but the staff identified that MICROBURN-B2 during its original staff review and approval, it was not assessed on a generic level for EPU and EFW.

There have been plant specific license amendment requests that have come through in recent years that have assessed its qualification on a plant specific basis, but not from a generic perspective.

MEMBER KIRCHNER: Okay, I don't know MICROBURN-B2. I'm trying to think from a physics standpoint why would it, why EPU and EFW would be a stretch for that code?

MR. HELLER: That, we do discuss that in later slides in the closed session, and I -

MEMBER KIRCHNER: Okay, I'll wait for that. Thank you.

MR. HELLER: I don't want to mention anything that might be proprietary, so. Okay, slide nine, so for the evaluation model acceptance criteria, the staff found that what was supplied in the documentation, support for performance of physical models and the numerical solutions were provided by comparisons to experimental data.

There were numerical benchmarks that were supplied, and there was the use of comparisons to higher

order methods. The staff also examined the equations and relationships governing the models within the theory manuals and the prior staff safety evaluations for those codes that had received prior review and approval, and ultimately what the staff found is there was reasonable to excellent code-data comparisons and so the staff concluded that the evaluation models were reasonably predicting the phenomena of importance.

Slide 10, the next area of review was the accident scenario identification process. The acceptance criteria her, the process should identify and rank reactor component and physical phenomena modeling requirements, and the process should include evaluation of physical phenomena to identify those important in determining the figures of merit.

Primarily the staff's assessment, the manner in which the staff went about this is they recognized from SRP Chapter 15.0.2, Section III, it notes that a PIRT, or a phenomenon identification ranking table, is an example of an acceptable structured process for identifying and ranking phenomena.

And within the submittal, AREVA developed a PIRT through multiple iterations between development teams and BWR application engineers. And really the AURORA-B AOO evaluation model PIRT within the topical

itself is a summary level PIRT comprised of highly-ranked phenomena from a series of event level PIRTs which are documented in a separate document that was also supplied for the review.

And the staff observed that there were a number of figures of merit that were supplied, and concluded that those figures of merit were adequate or acceptable for determining, or rather acceptable for the events for which the AURORA-B AOO was going to be applied.

Slide 11, the next area of review was the code assessment, acceptance criteria being that models should be assessed over the entire range of conditions encountered, and the staff found that comparisons of predicted results against separate effects tests and integral effects tests from experimental facilities were supplied.

There were code predictions compared to analytical solutions for the accuracy of numerical methods. Again, higher order methods and numerical benchmarks were used.

The system interaction and global capability was also demonstrated through FIST test facility, or comparison to FIST test facility data, and also through the Peach Bottom Turbine Trip Tests,

and in all cases, the staff found there was reasonable to excellent code-data comparisons.

Slide 12, the uncertainty analysis methodology, the acceptance criteria is it should address all important sources of code uncertainty, including mathematical models in the code and user modeling.

The staff's assessment, AREVA classified or identified there were three areas of biases and uncertainties when it came to the AURORA-B AOO evaluation model, the first of those being due to model structure such as nodalization and time steps, the second being selection of plant parameters and initial conditions, and then lastly, biases and uncertainties in predicting highly ranked and pertinent medium ranked PIRT phenomena.

So the structure and initial conditions the staff found was addressed via sensitivity analyses, and so the bulk of the staff's review efforts for the uncertainty analysis methodology were to examine the manner in which the uncertainties in high and medium ranked PIRT phenomena were addressed, and AREVA is using a non-parametric ordered statistic approach.

A number of the - I have a few bullets underneath that just to kind of provide some additional

detail. A number of the PIRT phenomena and the parameters of interest were addressed via conservative biasing. We'll discuss a couple of those during the closed session.

The staff examined the parameters that were to be utilized within the non-parametric ordered statistic to make sure that the distributions and the sampling ranges were acceptable, and really the approach that AREVA is using is a univariate approach. So ultimately -

MEMBER CORRADINI: If I might, Corradini, member. I'm not an expert in uncertainty. I noted a preponderance of the limitation and conditions were based on the uncertainty categories. Is there something unique about this, or is the uncertainty review similar to what has been done in the other areas, or is this the first multi-physics review that's been done in a while?

CHAIRMAN MARCH-LEUBA: Mike, I'm concerned that this might be proprietary of the method.

MEMBER CORRADINI: Okay, I'm sorry.

CHAIRMAN MARCH-LEUBA: Can we wait half an hour?

MEMBER CORRADINI: Sure, no problem, sorry.

CHAIRMAN MARCH-LEUBA: Because I do have concerns and I want to bring them up, but I think it will get proprietary.

MR. HELLER: Okay, this is Kevin Heller. So just to conclude on this slide, the staff found that the uncertainty analysis methodology was acceptable.

And then the final area of review according to the SRP, the quality assurance plan, acceptance criteria, the code should be maintained under a quality assurance program that meets the requirements of Appendix B to 10 CFR Part 50.

And the staff found that AREVA has an established NRC-approved software quality assurance program, and that AURORA-B was developed and is maintained under this program, so the staff concluded that this was acceptable.

So slide 14, in conclusion, the staff found that the AURORA-B AOO evaluation model is acceptable for simulation of AOOs and certain postulated accidents, and just a couple of bullet points here to kind of add some depth to that.

It's applicable for BWRs with forced recirculation systems. Again, it's BWRs 2 through 6. The ABWR we can discuss during the closed session.

The standard operating domain, the extended power uprate, and EFW domains, it's applicable to those.

Most of the data was supplied for support came from ATRIUM-10 and ATRIUM-10XM fuels, so really the staff - the AURORA-B AOO evaluation methodology approved for those fuels, but the staff did address whether or not other fuels were applicable, and there are methods in place to incorporate additional fuels.

And then the conditions and limitations, this is a large complex review, so naturally the staff had a couple of conditions and limitations, and they fall into three primary different areas.

MR. GRUMMER: The various component calculational device is being applied within limits, the limits from the individual codes and uncertainty distributions and sampling ranges is reviewed and conservative modeling justifications needing to be adhered to. So with that, are there any additional questions?

MEMBER BLEY: Yes, I would like to ask. I note in the Areva presentation that they submitted their LOCA evaluation model in February 2014, and their control rod drop model in March 2014. What is the status of the review of those additions to this AOO

evaluation model?

MR. LEHNING: This is John Lehning. So the--as far as to my knowledge, the control rod drop accident safety evaluation has been drafted and is basically complete, and so that one ought to be in the very near term, I think that there was maybe even efforts to maybe schedule ACRS meetings for that already. And then the LOCA review, that--although it was submitted in 2014, the staff began review in 2016, August 2016, due to resources and the Fukushima event and staffing. Actually, I'm the lead reviewer on that, and we've just sent out our request for additional information or we've sent out a draft, and the formal RAI hasn't been sent out yet. So it's still in the stage of review, and the date for the safety evaluation for the draft is June 2018 is our target.

MR. HELLER: This is Kevin Heller, I just want to add a couple of additional detailed points for the control rod drop accident review. The SE for that has been written, there have been some efforts made to start scheduling for an ACRS subcommittee meeting. The SE, the full submittal I guess of the SE has been--I'm trying to figure out how to put this--I've been working collaboratively with the reviewer on that,

because we recognize that some of the limitations and conditions present within the AURORA-B AOO evaluation model may impact the conclusions within the CRDA SE. So I have supplied the list of conditions and limitations that we have; we've just been waiting to make sure that nothing changes as a result of the ACRS meetings.

CHAIRMAN MARCH-LEUBA: So bringing that--I know that Areva's modus operandi is to issue supplements to everything, and often the supplements (inaudible) to something. But is the plan to merge the CRs for the two, the CRD and the AOO so they're consistent (inaudible)? Not issue a single CR, but make sure that the limitations and conditions (inaudible).

MR. HELLER: This is Kevin Heller. Yes, the intent is to make sure that there's consistency across the SEs.

CHAIRMAN MARCH-LEUBA: Anymore questions from the members? At this point, we are going to conclude the open session, so we are going to allow members of the public in the room to make any comments if they wish to do so. Anybody on the conference line, in the open conference line, if somebody's there, can

you please say hello and identify yourself?

MALE SPEAKER: It's open.

CHAIRMAN MARCH-LEUBA: It's open. Anybody want to make any comments on the open part of the session? Hearing none, we are going to close the open session, and at this moment we will move to closed session.

(Whereupon, the above-entitled matter went off the record.)

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AREVA NP

Introduction to AURORA-B

ACRS Meeting

NRC Two White Flint North
11555 Rockville Pike
Rockville, MD

August 21, 2017

AREVA

AREVA NP

Introduction to AURORA-B

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Agenda

	TOPIC	PRESENTER(S)	TIME
	Opening Remarks	ACRS	8:30 AM - 8:35 AM
II	Introduction to ANP-10300P, "AURORA-B" **(Open)**	AREVA	8:35 AM - 9:00 AM
III	Overview of NRC Staff's review **(Open)**	NRC	9:00 AM - 9:15 AM
IV	Opportunity for public comment	Public	9:15 AM - 9:30 AM
	CLOSED SESSION BEGINS		
V	AURORA-B Evaluation Model Structure	AREVA	9:30 AM - 10:15 AM
	Break		10:15 AM - 10:30 AM
VI	AURORA-B Qualification of Models and Methods **(Closed)**	AREVA	10:30 AM - 11:30 AM
VII	AURORA-B Modeling Uncertainties	AREVA	11:30 AM - 12:30 PM
	LUNCH BREAK		12:30 PM - 1:30 PM
VIII	Technical Evaluation of AURORA-B	PNNL	1:30 PM - 2:50 PM
IX	Assessment of AURORA-B Uncertainty Analysis Methodology	NRC	2:50 PM - 3:50 pm
	BREAK		3:50 PM - 4:05 PM
X	MICROBURN-B2 Qualification for Extended Power Uprates and Expanded Flow Windows	NRC	4:05 PM - 4:35 PM
XI	Conditions and Limitations and Conclusions	NRC	4:35 PM - 4:45 PM
XII	Response to Open Items	AREVA/NRC/PNNL	4:45 PM - 5:15 PM
XIII	ACRS Members Closing Remarks	ACRS	5:15 PM - 5:30 PM
XIV	Adjourn	ACRS	5:30 PM

Presentation Outline

- Introduction to AURORA-B (Open)
  - Evaluation model development
  - AURORA-B AOO Application Domain
  - Summary of the AURORA-B AOO Plant Application
- AURORA-B AOO Evaluation Model Development (Closed)
- AURORA-B AOO BWR Components & Qualification (Closed)
- AURORA-B AOO Modeling Uncertainties (Closed)

AURORA-B

- AURORA-B consists of a best-estimate multi-physics code system for simulating the coupled fuel, neutronic, and thermal hydraulic BWR system response
  - MICROBURN-B2 — Approved, steady-state core simulator
  - MB2-K — 3D kinetics equivalent of the approved MICROBURN-B2 neutronics solution
  - RODEX4 — Approved, best estimate steady-state & transient fuel performance predictions
  - S-RELAP5 — Two-fluid T/H system code approved for PWR non-LOCA and Realistic LOCA evaluations
- Event simulations are performed by S-RELAP5 in which MB2-K and relevant kernels of RODEX4 have been incorporated

AURORA-B Development Summary

Neutron Kinetics

- **Starting with the MICROBURN-B2 steady-state equations, temporal kinetics equations were developed to create the MB2-K kinetics code**
  - **MB2-K is integrated within S-RELAP5**
  - **Nodal depletion, spectral history, and other information passed from MB2 to MB2-K for transient initiation**
  - **MB2-K uses the same cross section lookup strategy and other features found in MB2 for consistency**

AURORA-B Development Summary

Fuel Rod Performance

- **A subset of the RODEX4 routines are integrated within S-RELAP5**
  - **Significant amount of data transferred from the "full" version of RODEX4 includes material properties that reflect the "permanent effects" on the fuel at the desired level of burnup (e.g. molar fission gas content, cladding corrosion, fuel pellet degradation)**
  - **The subset within S-RELAP5 is used to evaluate the "temporary" transient thermal-mechanical fuel rod (including fuel/clad gap) properties as a function of temperature, rod internal pressure, etc.**

AURORA-B Development Summary

S-RELAP5

- **S-RELAP5 physical models have been improved**
  - Interfacial drag for rod bundles and large diameters
  - Reynolds dependent form losses for spacer grids
  - Single and two phase friction models consistent with MICROBURN-B2 for the fuel
- **S-RELAP5 component models have been added or improved**
  - Jet-pump model
  - Mechanistic separator model
  - Critical power correlations

AURORA-B Evaluation Models

- **AURORA-B is a comprehensive code system for BWR analysis**
  - **ANP-10300P presents the foundational development and qualification of AURORA-B for BWR applications and the AURORA-B AOO Evaluation Model (EM) for analyzing "core wide" transients and accidents**
  - **ANP-10300P does not address**
    - Control Rod Drop and Control Rod Withdrawal Error Accidents
    - Loss Of Coolant Accidents
    - Late Stages of the Anticipated Transients Without Scram (after initiation of Boron Injection)
    - Instability Events
  - **ANP-10332P, Revision 0 submitted in February 2014, presents the AURORA-B LOCA EM**
  - **ANP-10333P, Revision 0, submitted in March 2014, presents the AURORA-B CRDA EM**

AURORA-B AOO Application Domain

- **AURORA-B AOO was submitted to address all forced circulation BWR plant types over the full domain of operating conditions:**
  - **BWR product lines 2-6 (BWR/2-6)**
  - **Entire Power/Flow operating map from low power conditions at which core monitoring commences up to and including operation at Extended Power Flow Operating Domain (EPFOD)**

AURORA-B AOO Target Scenarios

- **SRP 15.1 Cool Down Events:**
  - SRP 15.1.1 Feedwater system malfunctions that result in a decrease in feedwater temperature (LFWH)
  - SRP 15.1.2 Feedwater system malfunctions that result in an increase in feedwater flow (FWCF)
  - SRP 15.1.3 Steam pressure regulator malfunctions or failures that result in increased steam flow (PRFO)
- **SRP 15.2 Heat Up Events:**
  - SRP 15.2.1 Loss of external load (generator load rejection)
  - SRP 15.2.2 Turbine trip
  - SRP 15.2.3 Loss of condenser vacuum
  - SRP 15.2.4 Closure of main steam isolation valve
  - SRP 15.2.5 Steam pressure regulator failure (closed)
  - SRP 15.2.6 Loss of non-emergency ac power to the station auxiliaries
  - SRP 15.2.7 Loss of normal feedwater flow

AURORA-B AOO Target Scenarios

- **SRP 15.3 Loss of Coolant Flow Events:**
  - SRP 15.3.1 Recirculation pump trip
  - SRP 15.3.2 Recirculation flow controller malfunction (decreasing flow)
  - SRP 15.3.3 Reactor coolant pump rotor seizure
  - SRP 15.3.4 Reactor coolant pump shaft break
- **SRP 15.4 Reactivity Events:**
  - SRP 15.4.4 Startup of an idle recirculation loop
  - SRP 15.4.5 Recirculation flow controller malfunction which results in increased core flow rate
- **SRP 15.5 Increasing Inventory Events:**
  - SRP 15.5.1 Inadvertent operation of an Emergency Core Cooling System (ECCS) that increases reactor coolant inventory, including high pressure core spray, high pressure coolant injection, or reactor core isolation cooling system

AURORA-B AOO Application Domain Target Scenarios

- **SRP 15.6 Decreasing Inventory Events:**
  - SRP 15.6.1 Inadvertent opening of a pressure relief valve
- **SRP 15.8 Anticipated Transients without Scram:**
  - Protection of the reactor pressure vessel and associated piping from failure due to over pressurization
  - Demonstration that fuel integrity is maintained

Target Scenario Figures of Merit

- ΔMCPR, demonstrate that the event minimum critical power ratio (MCPR) remains above the appropriate limit for the scenario
- Peak System Pressure, to demonstrate that the peak pressure is maintained below prescribed limits for AOOs and the ATWS scenario
- Time dependent nodal power, used in conjunction with thermal-mechanical methods to evaluate cladding strain and fuel centerline temperatures during the event
- Peak Clad Temperature and maximum local oxidation, assure fuel integrity is maintained for selected events

AURORA-B AOO Event Evaluation

- The AURORA-B event analyses is initiated from the steady-state condition defined by MICROBURN-B2
  - MICROBURN-B2 depletion to the cycle exposure and power/flow condition of interest
- AURORA-B input preparation is augmented by certified automation tools
  - Vessel, Steam lines, recirculation lines, control systems and protection systems constructed from plant specific database
  - S-RELAP5 core geometry constructed from MICROBURN-B2
  - Core nodalization and initialization based on MICROBURN-B2 state-point solution
  - Core fuel pins initialized based on RODEX4 depletions with MICROBURN-B2 power histories and state-point nodalization

AURORA-B AOO Plant Application

- ANP-10300P was submitted to establish the foundation methods to address short term regulatory changes associated with reactivity insertion events and revised LOCA criteria.
- Key components of the methodology are:
  - Well founded and qualified models and methods for BWR transient applications
  - Conservative benchmarks to reactor turbine trip measurements
  - Highly ranked plant parameters or parameters that exhibit a range of operating conditions treated conservatively
  - Conservative biasing of transient simulations to bound modeling uncertainties for Figure of Merit (FoM) outcomes based on Monte-Carlo techniques and approved uncertainties
  - Resultant change in MCPR added to the statistical MCPR Safety Limit (SLMCPR) to establish the MCPR Operating Limits (OLMCPR)
  - Limiting event boundary conditions are utilized within the RODEX4 statistical methodology to demonstrate fuel centerline melt and clad strain criteria

AURORA-B AOO Document Roadmap

- **Submitted Documents**
  - ANP-10300, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios
  - ANP-10300Q1P Acceptance Review Questions clarified the submitted methodology and validated the application of MICROBURN-B2 to Extended Power Uprates with Extended Flow Windows
  - ANP-10300Q2P Requests for Additional Information served to quantify model uncertainties and the associated impact on computed event figures of merit.
- **Supporting documents**
  - General BWR Design and Event Descriptions, ANP-2829(P)
  - Control System and Reactor Protection System Requirements for Modeling BWR Events, ANP-2830(P)
  - Identification of Code Capabilities and PIRT Development for BWR Transient Analyses, ANP-2831(P)
  - Underlying documents supporting AURORA-B (MICROBURN-B2, MB2-K, RODEX4, S-RELAP5)
- **AURORA-B and the AURORA-B AOO methodology was developed and documented consistent with the EMDAP process delineated in the NRC Regulation Guide 1.203**

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

NRC Staff's Review of ANP-10300P

AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios

ACRS Subcommittee Meeting Overview

A. Kevin Heller, PhD

John Lehning

Nuclear Performance and Code Review

Division of Safety Systems

Office of Nuclear Reactor Regulation

Tom Michener

Pacific Northwest National Laboratory

Presentation Outline

- Overview (Open Session)
  - Describe NRC staff's review of ANP-10300P
- NRC Staff's assessment of ANP-10300P (Closed Session)
  - Technical evaluation: model and code qualification
  - MICROBURN-B2 Qualification for EPU and EFW
  - Uncertainty analysis
  - Conditions and Limitations and Conclusions

Introduction

AURORA-B

- Multi-physics, multi-code system
  - S-RELAP5 thermal-hydraulic system code
  - MB2-K neutron kinetics code
  - CASMO-4/MICROBURN-B2 lattice physics/core neutronics code system
  - RODEX4 fuel thermal-mechanical code

- ANP-10300P applicability
  - BWRs/2-6
  - Standard operating domain, EPU and EFW (i.e., MELLLA+)
  - Anticipated Operational Occurrences and Postulated accidents
    - Exceptions: (addressed in other applications)
      - LOCA
      - Control rod withdraw error and CRDA
      - Instability and later stages of ATWS

Introduction

- Best estimate with conservatism + uncertainty
- Large, interdisciplinary review scope
  - Multiple reviewers over several years
- Pacific Northwest National Laboratory acted as a consultant
  - Judith Cuta – thermal-hydraulics
  - Ken Geelhood – fuel thermal-mechanical
  - Carl Beyer – fuel thermal-mechanical
  - Gregory Piepel – statistics
  - Dave Engel – statistics
  - Andrew Prichard – neutronics
  - Bruce Schmitt – thermal-hydraulics and system modeling

Review Guidance

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."
  - Chapter 15.0.2, "Review of Transient and Accident Analysis Methods."
- Regulatory Guide 1.203, "Transient and Accident Analysis Methods"
  - Evaluation Model Development and Assessment Process (EMDAP)

Review Scope

SRP Chapter 15.0.2

- Documentation
- Evaluation Models
- Accident Scenario Identification Process
- Code Assessment
- Uncertainty Analysis
- Quality Assurance Plan

Safety Evaluation

- Based on, and follows, the SRP structure

Documentation

Acceptance Criteria

- Submittal should identify specific accident scenarios and plant configurations
- Submittal should contain:
  - Complete description of code assessment
  - Theory manuals describing field equations and closure relationships
  - User manuals discussing code limitations

Staff's Assessment

- Accident scenarios identified and code assessment described in LTR
- Unitary S-RELAP5 theory manual and supporting code theory manuals
- Code limitations within theory manuals, user manuals, staff SEs

Evaluation Models

General areas of review:

- Thermal-Hydraulics (S-RELAP5)
- Neutronics (MICROBURN-B2 and MB2-K)
- Primary System Modeling (S-RELAP5)
- Fuel thermal-mechanical performance (RODEX4)

Focused areas of review

- S-RELAP5 – new and existing models and methods BWR applicability
- MB2-K – new neutron kinetics methods
- MICROBURN-B2 - qualification for EPU and EFW conditions
- RODEX4 “kernel” – subset of RODEX4 models in S-RELAP5

Evaluation Models

Acceptance Criteria

- Models should be present for all phenomena and components determined important or necessary to simulate scenario under consideration
- Chosen models and associated numerical solutions should predict important physical phenomena reasonably well

Staff's Assessment

- Support for performance of physical models and numerical solutions provided by comparison to experimental data (e.g., KATHY test facility void fraction measurement), numerical benchmarks (e.g., Industry Standard Problems) and higher order methods (e.g., MCNP)
- Examination of equations and relationships governing models via theory manuals and staff SEs for acceptability and range of validity
- Reasonable to excellent code-data comparisons

Accident Scenario Identification Process

Acceptance Criteria

- Process should identify and rank reactor component and physical phenomena modeling requirements
- Process should include evaluation of physical phenomena to identify those important in determining figures of merit

Staff's Assessment

- SRP Chapter 15.0.2, Section III notes that a PIRT is an example of an acceptable structured process for identifying and ranking phenomena
- AREVA developed PIRT through multiple iterations between development teams and BWR application engineers
- Summary-level PIRT comprised of highly-ranked phenomena from series of event-PIRTs
- 5 figures of merit: ΔMCPR, peak system pressure, time-dependent nodal power, peak cladding temperature, max local oxidation.

Code Assessment

Acceptance Criteria

- Models should be assessed over entire range of conditions encountered in transient or accident scenarios

Staff's Assessment

- Comparison of predicted results against separate effects tests and integral effects tests from experimental facilities (e.g., KATHY, FRIGG)
- Code predictions compared to analytical solutions for accuracy of numerical methods (e.g., numerical benchmarks, higher order methods)
- System interaction and global capability via prediction of FIST test facility operational transients and Peach Bottom Turbine Trip Tests
- Reasonable to excellent code-data comparisons

Uncertainty Analysis

Acceptance Criteria

- Should address all important sources of code uncertainty, including mathematical models in the code and user modeling (e.g., nodalization)

Staff's Assessment

- AREVA classified three areas of biases and uncertainties:
  - Model structure (e.g., nodalization and time steps size sensitivities)
  - Selection of plant parameters and initial conditions
  - Biases and uncertainties in predicting highly ranked, and pertinent medium ranked, PIRT phenomena
- Structure and initial conditions determined via sensitivity analyses
- Uncertainties in high (and medium) ranked PIRT via non-parametric ordered statistics
  - Conservative biasing of subset of parameters
  - Acceptable parameter distributions and sampling ranges
  - Predominantly univariate approach

Quality Assurance Plan

Acceptance Criteria

- Code should be maintained under a quality assurance program that meets the requirements of Appendix B to 10 CFR Part 50

Staff's Assessment

- AREVA has an established NRC-approved software quality assurance program
- AURORA-B developed and maintained under this program

Conclusion

- The staff found AURORA-B acceptable for simulation of AOOs and certain postulated accidents
  - BWRs with forced recirculation systems
  - Standard operating domain, EPU and EFW (e.g., MELLLA+)
  - ATRIUM-10 and ATRIUM-10XM fuels (with justification for others)
  - Conditions and Limitations
    - Applied within limits of individual code approvals
    - Uncertainty distributions and sampling ranges as-reviewed
    - Conservative modeling justifications

Nomenclature

Acronym	Definition
AOO	Anticipated Operational Occurrences
ATWS	Anticipated transient without scram
BWR	Boiling water reactor
CFR	Code of Federal Regulations
CRDA	Control rod drop accident
EFW	Expanded flow window
EMDAP	Evaluation Model Development and Assessment Process
EPU	Extended power uprate
LOCA	Loss of coolant accident
LWR	Light water reactor
MELLLA+	Maximum extended load line limit analysis plus
MCNP	Monte Carlo N-Particle
PIRT	Phenomena identification and ranking table
SRP	Standard review plan
SE	Safety evaluation
ΔMCPR	Transient change in Minimum critical power ratio