Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	675th Meeting, Advisory Committee on Reactor Safeguards (ACRS), Open Session
Docket Number:	N/A
Location:	Video Teleconference
Date:	Wednesday, July 8, 2020

Work Order No.: NRC-0962 Pages 1-280

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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675TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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WEDNESDAY

JULY 8, 2020

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The Advisory Committee met via Video Teleconference, at 9:31 a.m. EDT, Matthew W. Sunseri, Chairman, presiding.

COMMITTEE MEMBERS:

MATTHEW W. SUNSERI, Chairman
JOY L. REMPE, Vice Chairman
WALTER L. KIRCHNER, Member-at-Large
RONALD G. BALLINGER, Member
DENNIS BLEY, Member
VESNA B. DIMITRIJEVIC, Member
JOSE MARCH-LEUBA, Member
DAVID A. PETTI, Member

PETER RICCARDELLA, Member

ACRS CONSULTANT:

MICHAEL CORRADINI

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

CHRISTIANA LUI

QUYNH NGUYEN

MICHAEL SNODDERLY

ALSO PRESENT:

ANTONIO BARRETT, NRR

BRUCE BAVOL, NRR

JOSHUA BORROMEO, NRR

ANNA BRADFORD, NRR

BEN BRISTOL, NuScale

MARK CHITTY, NuScale

PAUL DEMKOWICZ, Idaho National Laboratory

MICHAEL DUDEK, NRR

SARAH FIELDS, Public Participant

CRAIG HARBUCK, NRR

JORDAN HOELLMAN, NRR

PAUL INFANGER, NuScale

MARIELIZ JOHNSON, NRR
SHANLAI LU, NRR
MICHAEL MELTON, NuScale
SCOTT MOORE, Executive Director, ACRS
ETIENNE MULLIN, NuScale
TONY NAKANISHI, NRR
STEVEN NESBIT, EPRI
RYAN NOLAN, NRR
REBECCA NORRIS, NuScale
REBECCA PATTON, NRR
TOM SCARBROUGH, NRR
JEFFREY SCHMIDT, NRR
JOHN SEGALA, NRR
ALEXANDRA SIWY, NRR
ANDREW SOWDER, EPRI
DINESH TANEJA, NRR
CARL THURSTON, NRR
BOYCE TRAVIS, NRR
CHRISTOPHER VAN WERT, NRR
YUKEN WONG, NRR
PETER YARSKY, RES

AGENDA

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P R O C E E D I N G S

(9:31 a.m. EDT)

CHAIR SUNSERI: It's 9:31. The meeting will now come to order. This is the first day of the 675th Meeting of the Advisory Committee on Reactor Safeguards. I am Matthew Sunseri, Chair of the ACRS. This is a virtual meeting. I will now call the roll, starting with Ron Ballinger.

MR. BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley.

(No audible response.)

CHAIR SUNSERI: All right. Hopefully Dennis will be joining us soon. Charles Brown. I had to excuse Charles from this week's deliberations. He has business outside of the ACRS to take care of and will not participate in the full week's briefing.

Vesna Dimitrijevic.

MS. DIMITRIJEVIC: I'm here.

CHAIR SUNSERI: Walt Kirchner.

MR. KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba.

MR. MARCH-LEUBA: Yes, I'm here.

CHAIR SUNSERI: Dave Petti.

MR. PETTI: Here.

CHAIR SUNSERI: Joy Rempe.

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella.

MR. RICCARDELLA: Here.

CHAIR SUNSERI: And myself, Matt Sunseri. So I'll just reach back and check. Has Dennis Bley joined us yet?

(No audible response.)

CHAIR SUNSERI: Okay. Well we'll continue on. We have a quorum.

The ACRS was established by the Atomic Energy Act as governed by the Federal Advisory Committee Act. The ACRS section of the U.S. NRC public website provides information about the history of the ACRS, and provides documents such as our charter, bylaws, Federal Register Notices for meetings, letter reports, and transcripts of all full and subcommittee meetings, including all slides presented at the meetings.

The committee provides its advice on safety matters to the Commission through its publicly-available letter reports. The Federal Register Notice announcing this meeting was published on June 15th, 2020, and provides an agenda and instructions for interested parties to provide written documents or request opportunities to address the committee.

The designated federal official for this meeting is Mr. Christopher Brown. A phone line has been opened to allow members of the public listen in at the presentation and committee discussion. We have received no written comments or requests to make oral statements from the members of the public regarding today's session.

There will be an opportunity for public comment, and we have set aside time in the agenda for comments from members of the public attending or listening in. Written comments may be forwarded to Mr. Christopher Brown, the DFO.

A transcript of the open portions of the meeting is being kept, and it is requested that the speakers identify themselves and speak with sufficient clarity and volume so that they can be readily heard. Additionally, since this is a virtual meeting, participants should mute themselves while not speaking.

During today's committee we will cover the following topics. The first one will be the EPRI Topical Report on Uranium Oxycarbide Tristructural Isotropic Coated Particle Fuel Performance. And we are going to call that TRISO through the remainder of the meeting.

We will also discuss NuScale Area of Focus on Boron Redistribution. And that is expected to continue all week. And the rest of the time will be covered preparing reports.

We had an agenda item at the first thing of this morning's meeting of Branch Technical Position 7-19, Guidance for Diversity and Defense-in-Depth on Digital I&C Systems. This topic has been removed from our agenda at the request of staff.

However, I will provide, since we -- this is a last minute change to our agenda, I will provide an opportunity for any members of the public listening in to provide comments on that topic should they have some.

One last item of housekeeping here. During the TRISO discussions, Members Petti and Rempe are recusing themselves from the deliberations due to --

(Telephonic interference.)

VICE CHAIR REMPE: Matt, I've lost sound. Has anyone else lost sound?

MR. MOORE: This is Scott. I also have lost sound now.

(Off-mic comments.)

(Pause.)

VICE CHAIR REMPE: Okay, folks. Matt just called me, and his whole system is crashed so he can't even call in. So he gave me a list of things to say, and I will try and finish up for him.

In the middle of his announcement about Dave Petti and myself having to recuse ourselves we did want to note that we will be making factual comments. But because of our recusing ourselves we are not allow -- we are not going to be voting on the ultimate letter.

Then he also pointed, wanted to note that the discussion on Branch Technical Position is being deferred. So we are going to recess until 1:15 East Coast Time, and we will come back and start the discussion about the TRISO fuel.

But he did say if there are any --

MEMBER KIRCHNER: Joy.

VICE CHAIR REMPE: Yes?

MEMBER KIRCHNER: This is Walt. Pardon my interruption. No, I think we are going to recess and then start at the scheduled time later this morning for TRISO. This afternoon is scheduled for NuScale.

MR. MOORE: That's correct. This is Scott Moore. Vice Chairman, it's 11:15 that we will be restarting.

VICE CHAIR REMPE: Convening for the TRISO. You're right. I'm sorry. I apologize. Thank you, Walt, and thank you, Scott. I don't have the agenda up because I thought --

MR. MOORE: Sure.

VICE CHAIR REMPE: So anyway, so at 11:15 East Coast time we will come back and discuss the TRISO, and have the presentations on that. And then we'll go to NuScale this afternoon.

But he did ask that I allow time for public comment on the Branch Technical Position 7-19 at this time. I assume the public line is open, Thomas?

MR. DASHIELL: The public line is open.

VICE CHAIR REMPE: And I assume that there are no comments since I'm not hearing anything.

(No audible response.)

VICE CHAIR REMPE: Okay. Do any members have any comments?

(No audible response.)

VICE CHAIR REMPE: Not hearing anything, then I, unless I'm told otherwise, since this is a little unexpected here, I will recess us until 11:15 East Coast Time. Does that sound good to everybody?

MR. MOORE: Yes.

VICE CHAIR REMPE: Thank you. Okay. Talk to you all in a few hours then.

(Whereupon, the above-entitled matter went off the record at 9:42 a.m. and resumed at 11:15 a.m.)

CHAIR SUNSERI: Okay. This is Matt Sunseri. It is 11:15 and we will reconvene the ACRS meeting. I will begin with a roll call. Ron Ballinger.

MR. BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley.

MR. BLEY: Here.

CHAIR SUNSERI: Vesna Dimitrijevic.

MS. DIMITRIJEVIC: Here.

CHAIR SUNSERI: Walt Kirchner.

MR. KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba.

MR. MARCH-LEUBA: Yes.

CHAIR SUNSERI: Dave Petti.

MR. PETTI: Here.

CHAIR SUNSERI: Joy Rempe.

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella. Let's see, I don't see --

MR. RICCARDELLA: I'm here.

CHAIR SUNSERI: All right, Pete. And then myself.

So we have all present. I will remind the committee that Members Petti and Rempe are recusing themselves. They can participate in factual clarifications, if necessary.

And we noted in our opening session I had dropped off, and for some reason my VPN line keeps getting disconnected. Looks like a server problem. It happened at least once during the recess. So I have asked Walt Kirchner to seamlessly take over should I drop off and have to reboot my computer again to get back on. So thank you to Walt for that.

And with those opening comments I will now turn to Ron Ballinger, chair of the subcommittee, for the EPRI presentation on TRISO. Ron.

MR. BALLINGER: Yes. Thank you, Mr. Chairman. This meeting is -- we'll have presentations by EPRI. I know, I think, as well as the staff related to the Topical Report EPRI-AR1, which is titled Uranium Oxycarbide -- and I'm not even going to use the word Tristructural Isotopic, I'm just going to call it TRISO -- Coated Particle Fuel Performance. It's a TR that we have been asked to write a letter on.

We had an earlier meeting, I think on May the 20 -- May the 6th, excuse me, of this year where we had presentations by EPRI and its consultants and the staff. And so this, this meeting will provide I think abbreviated presentations from those, from those presentations.

Our expectation is to provide a letter during this full committee meeting on this topic. And so I'd like to ask John Segala, he's the Chief, Advanced Reactor Policy Branch, Division of Advanced Reactors and Non-Power Production and Utilization Facilities -- we ought to shorten some of these things up I guess -- to make some introductory comments. And then I think the first presenter is Andrew Sowder from EPRI. So John, the floor is yours.

MR. SEGALA: Thank you very much. As you said, we are here today to brief the ACRS on the staff safety evaluation for the EPRI TRISO Coated Particle Fuel Performance Topical Report.

Since it's been awhile since we briefed the ACRS full committee on our advanced reactor readiness activities, I wanted to take a moment to step back and provide some context for the subject of today's meeting.

Back in 2017, we briefed the ACRS on NRC's vision and strategy document and our implementation action plans for enhancing our readiness to effectively and efficiently review and regulate advanced reactors.

The near-term implementation action plan activities are divided up into six strategies: Strategy 1 on training; Strategy 2 on computer codes; Strategy 3 on developing guidance; Strategy 4 on industry consensus codes and standards; Strategy 5 on policy issues; and Strategy 6 on communications.

At that time, the ACRS recommended that NRC focus its near-term IAP activities on Strategies 3 and 5, which the NRC staff has been doing.

Supporting Strategy 3, on July 20th we are scheduled to brief the ACRS subcommittee on our plans to develop a new technology-inclusive risk-informed and performance-based regulatory framework for advanced reactors, which is required by the Nuclear Energy Innovation and Modernization Act, or NEIMA. This is a high priority for the NRC. And we are calling this new regulation 10 CFR Part 53.

We have a rulemaking plan which in SECY-20-0032 up in front of the commission. And we will be briefing the ACRS on an NRC staff white paper outlining specific considerations and questions regarding Part 53.

We will also be providing an overview of the final Regulatory Guide 1.233, which endorsed the licensing modernization project described in NEI-1804 document, and the NRC's response to the public comments received on the associated draft guide.

This TRISO Topical Report which we're discussing today is also a high priority for the NRC. And it also supports Strategy 3 of the near-term implementation action plans for the high temperature reactor designs using TRISO fuel.

The data supporting this topical report, as you know, is built off of a long history dating back to 2005 as part of the DOE and NRC's work on the next generation nuclear plant, or NGNP, and DOE's advanced gas reactor fuel development and qualification program, which is still continuing today.

Today we will be providing a high-level summary of the findings from the Topical Report and discussing changes the NRC staff made to the limitations and conditions in its safety evaluation as a result of the follow-on items discussed at the subcommittee meeting.

We are looking forward to hearing from the ACRS today on this important topic and any insights and feedback you all may have. And as you stated, we understand that the ACRS is planning to write us a letter. And this completes my opening remarks. Thank you.

MR. BALLINGER: Okay. Thank you very much, John. So I guess first up is Andrew, and the floor is yours.

MR. SOWDER: Okay. Thank you. I want to thank the ACRS for the opportunity to present today, and the NRC for its ongoing commitment to reviewing this Topical Report, and all the team members who made this report possible.

Without further ado, if there's any questions about EPRI or the context for why we were involved in the project, I'd be happy to answer those after the presentation. But time is short, so let's move on to just the general overview of the Topical Report at issue. Next slide.

So the Topical Report was generated and submitted to the NRC on May 31st of last year. This was also released as a publicly-available report simultaneously. So everything in the report is intended for the public and is the result of work, publicly-funded work at the Idaho National Laboratory in Oak Ridge as part of the advanced gas reactor fuel development qualification program, which was initiated almost two decades ago.

The overall scope of the Topical Report, it's important to recognize that this explicitly focuses on Programs AGR-1 and AGR-2 only. And these two campaigns were selected as they focus in on fuel performance.

The intent was to isolate to the extent possible the results from the influence of specific design, reactor design, and fuel design parameters and influences such as the compacts, recognizing that that cannot be coupled completely. But the fuel performance of the particle fuel itself we felt was a logical subject to focus on and would be as widely and generically applicable for benefitting the most developers and other stakeholders. Next slide.

It's important to recognize the long history and the international context in which TRISO fuel was originally developed and has evolved. That international experience is rich with lessons learned, and has demonstrated that high quality fuel can be fabricated in a repeatable consistent manner, and that fuel performance with low inturbid failures is achievable.

However, it is also important to recognize that this Topical Report, as we state clearly in the report itself, does not rely upon the data or experience from the international and previous work for inclusion in the Topical Report. The Topical Report itself addresses only AGR-1 and AGR-2 results with respect to fuel performance. Next slide.

MR. HOELLMAN: This is Slide 4.

MR. SOWDER: Yes. So Slide 4 showing the graphics here, mainly just to focus on the fact that this is really the topic at hand. It's the TRISO coated part fuel itself. The figure on the left demonstrates the fuel kernel, which indicates that AGR-1 and AGR in general was -- the focus was on UCO.

MR. BALLINGER: Did somebody just get cut out?

CHAIR SUNSERI: Apparently. This is Matt, I'm still -- I mean it looks like the connection is still good. We must have lost the presenter.

MR. BALLINGER: We lost Andrew.

MR. NESBIT: Yeah. This is Steve Nesbit working on behalf of EPRI. I think we can go ahead, and I think Andrew will probably rejoin us shortly. Maybe that was him. Andrew, is that you?

(No audible response.)

MR. NESBIT: I think we should, given the time, we should probably go ahead with the presentation. And I'll step in and try to do that in Andrew's absence until he rejoins us, if that's okay?

MR. BALLINGER: Yes. Thanks for picking up the slack.

MR. NESBIT: Not at all. So we are here on Slide 4. And Andrew was talking about the fact that we're focusing on the performance of the coated particles itself. It has a long record internationally. But we're focused on the AGR-1 and AGR-2 tests.

So you see the diagrams of the fuels themselves with the kernels, and then surrounded by the carbon buffer layer, the pyrolytic carbon, inner pyrolytic carbon layer, silicon carbide, the outer pyrolytic carbon layer. And that's consistent with basically TRISO fuel throughout.

The particles are combined together in the compacts. They can be in cylindrical form, as shown along the top on the right-hand side. They can be in a spherical form, as shown in a pebble bed type configuration as shown below.

The diagram shows the relative sizes of the different particles here. Obviously the particles are very, very small. And then the compacts are larger and manipulated in the reactor itself. Next slide please.

So now we're on Slide 5. Want to talk for a minute about the fact that this project was a collaboration between public and private entities. So EPRI is the overall project manager, shown there in the box in the middle, working on the development of the Topical Report and the submission for review. And then working with the NRC on the review process.

I know, as the technical lead on the AGR program, they carried out the AGR program. And they're the ones who provided the primary content for the Topical Report itself and spearheaded the response to the request for additional information that came up in the review.

Want to mention on the left side of the slide the High Temperature Reactor Technical Working Group. And the entities are listed there: Framatome, X-Energy, StarCore, Kairos Power, BWXT. These are entities that are either developing reactors that rely on TRISO fuel, and/or involved in fabrication of TRISO fuel.

So and then, of course, the NRC is the regulatory reviewer. So a couple of things I'll mention. DOE co-funded this along with EPRI. So many thanks to DOE and their role in this project. Industry provided in-kind support. And the NRC agreed to review this RFP. And so far I think we can say it's been a very successful enterprise.

MR. SOWDER: Hey Steve, can you all hear me now? I apologize.

MR. NESBIT: You're back, Andrew. Do you want to take over? I was just talking about Slide 5.

MR. SOWDER: Sure. Why not. Let's give this a try. So moving on to Slide 6. Sounds like you were right on cue there. Next slide.

So I'm not going to go over the content in detail, but this is simply to emphasize the three kind of parts of the report. The first four sections are mainly provided for historical context and background.

The last Section 9, and then the appendix, are additional information and references. The emphasis here is that Sections 5 through 8 are really the meat of the report, explicitly presented to the NRC for their review, and support the conclusions that are presented for NRC's approval. Next slide.

So paraphrasing the meat of the conclusions, the first conclusion presented to the NRC is that testing of UCO TRISO-coated fuel particles in AGR-1 and AGR-2 provides a foundational basis for use of these particle designs in the fuel elements of TRISO fueled high temperature reactor design. That is, those designs are pebble or prismatic fuel and helium or salt coolant. Next slide.

Second conclusion, paraphrased and summarized, is UCO TRISO-coated fuel particles that satisfy the parameter envelope defined by the measured particle layer properties in Table 5, can be relied on to provide satisfactory performance. Next slide.

And the third conclusion: aggregate AGR-1 and AGR-2 fission product release data and fuel failure fractions summarized in the Topical Report can be used to support licensing of reactors employing UCO TRISO-coated fuel particles that satisfy the parameter envelope defined by measured particle layer properties in Table 5.5 from AGR-1 and AGR-2.

MR. MARCH-LEUBA: Hi. This is -- let me interrupt. This is Jose March-Leuba. Previously the representation during the whole report we say that there is a lot of international data that we didn't use, we focus only to year one and year two. For thermohydraulic correlations, it is considered the way to do it is to divide some of your data points, develop your correlation, and then on a completely different data set verify the correlation.

So what you are doing here, you are really developing a correlation for fission product release. Was there any intent or is there any plans to validate these “correlations” against system data, international data, which will have a much broader range of parameters for publication. It will help on it. Is there any plans for that?

MR. SOWDER: Well this is Andrew from EPRI. Speaking as EPRI and in respect to this actual Topical Report, that was not in the scope.

What you're suggesting sounds valid, and actually interesting and useful. I suspect that would be left up either to the people who would end up seeing this Topical Report, to the developers, the licensees, as well as maybe even that might be something that INL might take up.

I'd turn it over to Paul at INL to respond if that has been considered.

MR. DEMKOWICZ: Yeah, this is Paul. I'm not sure that I caught the entire gist of the original comment. We have, of course, compared our data to the international database with the fission product release. But we cannot vouch for the QA of the data from the international community. So that is a potential issue for us.

But this is not a -- we're not doing a model validation in this report at all, so.

MR. MARCH-LEUBA: But we are developing -- I'm calling that correlation because I come from the thermohydraulic side of the house. It is a correlation. And we, the expectation is an applicant that wants to use this fuel will just take it and use it, and will not do anything else with respect to the particle performance.

If there are data sets out there which it doesn't fit, it would be -- and it's probably because they collected bad data or they fabricated bad fuel, but it will be interesting to review. I'm just offering.

MEMBER PETTI: So Jose.

MR. MARCH-LEUBA: Yes?

MEMBER PETTI: You're talking about the source term data. This is not what the subject is here. There is a large database that you can find in the IAEA that has the correlations that you're talking about.

The program has used those and had it in some of the fuel performance models around the world frankly, and there's been huge benchmarking activities done through the GEN-4 project and the IAEA. The goal of the program is to develop data for UCO TRISO, and from the source term perspective, to eventually compare to that older data to see, you know, if it just confirm the older data sets, or is there is something different here.

Because the older data is U02-based TRISO fuel. The international UCO is a little different. So it's sort of a hybrid answer, but that is in fact the goal of the source term product program. But that's not where we are today. That would be announced in a subsequent Topical Report.

MR. MARCH-LEUBA: So it is a process in process that will accomplish this validation, right? That's what you're saying?

MR. PETTI: Correct.

MR. MARCH-LEUBA: Okay. Thank you.

MEMBER KIRCHNER: Paul, this is Walt Kirchner. Just a question on AGR-1 and AGR-2. Was all that fuel produced by BWXT?

MR. DEMKOWICZ: No. So we'll --

MEMBER KIRCHNER: More correctly, I should say were all the TRISO particles produced by BWXT?

MR. DEMKOWICZ: No. So we'll get into that in the next presentation, but --

MEMBER KIRCHNER: Okay. All right.

MR. DEMKOWICZ: Those particles are for AGR-2.

MR. BALLINGER: Can I ask, Paul, just to go forward with Walt's question. But they -- if I can use the terminology, the recipe was the same although other people, more than one source developed it. Is that approximately true?

MR. DEMKOWICZ: Yeah. Again, this is -- these are all questions that I get into it in the next presentation. But --

MR. BALLINGER: Okay, fine. No problem.

MR. DEMKOWICZ: Okay, yes.

MR. SOWDER: And this is the conclusion of this presentation, so we can actually move on to Paul's if that's okay.

MR. BALLINGER: Is this the last slide? Okay, I guess it is.

MR. SOWDER: Correct.

MR. BALLINGER: So okay. Let's move on then. Thank you.

MR. DEMKOWICZ: Okay. Thank you, Dr. Ballinger. My name is Paul Demkowicz. I am the current technical director of the AGR program. And this presentation is a very brief overview of the AGR program and the results of the AGR-1 and 2 experiments that are presented in the Topical Report.

And in addition to that, I will get into a little bit of detail on some of the issues that were raised during the subcommittee meeting on May 6th. Next slide.

Okay. So the AGR program, the main objective was to provide data for fuel qualification to support reactor licensing, and to establish a domestic commercial vendor for TRISO fuel. And the motivation of this is to reduce market entry risk for reactor designers.

The focus of the program, of course, as we've heard already, is UCO TRISO fuel as opposed to U02 that was developed by the Germans in the 1980s. And there are several different elements of the program.

We do fuel fabrication and characterization. We do irradiation testing and ATR under a range of conditions. We perform post-radiation examination and high temperature safety testing. There is development of fuel performance models, and also some fission product transport experiments that we just heard a little bit about. Next slide.

So this is a time line and an outline of the program. There were four radiation experiments that the program was built around. And this is where we'll talk a little bit about the nature of the fuel.

So the AGR-1 experiment was the first. And it was an early test of lab scale UCO fuel performance, as well as a shakedown of the multi-capital instrumented test stream design.

So the kernels for all of these experiments were made at BWXT. For AGR-1, the coated particles and the fuel compacts were made at Oak Ridge in lab scale processes.

For AGR-2, it represented a step-wide scale-up of the fabrication process. So the coated particles remain at BWXT in a 6-inch coder, and the fuel compacts were still made at Oak Ridge in lab scale process. And this experiment included UCO and U02 fuel.

AGR-3/4, as Dave Petti was talking about just a bit ago, is a very different experiment. It was designed to assess fission product transport, to support source term calculations. It included the designed to fail or DTF particles. These are particles with very thin coatings that are designed to fail and release fission products, so we can look at their transport in the post-radiation examination.

And then AGR-5/6/7 is our final fuel qualification test and our high temperature performance margin test. And for that experiment, the kernels, the coated particles, and the compacts were all made at BWXT on engineering scale processes.

So the time line shows the fuel fabrication, irradiation and PIE campaigns in different colors. And you can see that the AGR-5/6/7 irradiation is just about complete. In fact, we have about two weeks left. And we're nearing the completion of the AGR-2 PIE. We're in the middle of the AGR-3/4 PIE. And the AGR-5/6/7 PIE we'll be starting early next year.

MR. CORRADINI: So can I ask a question, Paul, here about 3/4 again?

MR. DEMKOWICZ: Yes.

MR. CORRADINI: 3/4 is not just the kernels, but it's all -- or the TRISO particles, but it's also the compact there within that's your design to fail? Or is it strictly trying to look at retention within the kernels -- particles?

MR. DEMKOWICZ: It's everything. So when those DTF particles fail you'll get fission product release. And in the PIE we are expecting to go and look at retention in the kernels, retention in the matrix, and then retention in the parts that are outside of the fuel compacts.

MR. CORRADINI: Okay.

MR. DEMKOWICZ: Though it's really the whole thing.

MR. CORRADINI: So it's -- to put it, it is a function of whether it's a compact or a pebble for 3/4? That's kind of what language is for the source term.

MR. DEMKOWICZ: The matrix would be important for that. So I mean it is going to have an effect, the amount of matrix that's there, yes.

MR. CORRADINI: But you aren't able -- you're able to unravel that in the PIE, I'm just trying to understand -- I know 5, 6, and 7 is clearly related to the compact. I wasn't sure about 3/4. That's why I was asking the question.

MR. DEMKOWICZ: Yeah. That's right. We are -- in the PIE, we are looking at the transport on all of the components. You could apply that data to any fuel form.

MR. CORRADINI: Okay. Thank you.

MR. BALLINGER: This is Ron. With regard to 3/4 and pebbles, pebbles are designed much differently than compacts from what I understood. And so the barrier sequence and things like that in a pebble might be quite different than in a compact. Am I correct?

MR. DEMKOWICZ: The difference in a pebble is that it generally is a different packing fraction, so you have a different volume fraction of matrix. And it may be a different matrix formulation. You know, so there are several different matrix formulations. We only use one in AGR-3/4.

And so those things are factors. But what we're doing, you know, in the experiment is looking at the important parameters that govern fission product transport in matrix material, so diffusivity and sorptivity and that kind of thing. And those can be applied to a certain extent to other fuel forms.

MR. BALLINGER: Got it. Thanks.

MR. DEMKOWICZ: Okay. Next slide please. Okay, we are on Slide 4. Just a real quick summary of the AGR-1 and 2 fuel irradiations. These were both done in the advanced test reactor in large B positions.

Each experiment has six independent capsules, and they contain 12 fuel compacts each. The AGR-1 experiment had about 300,000 UCO particles, and the AGR-2 has about 114,000 UCO particles.

These were approximately two-year irradiation times in terms of reactor days, and that would simulate about a three-year reactor lifetime. The temperature was controlled in the capsules with helium and neon gas mixtures. And we'll talk about that at length in the next five or six slides. The fission gas release for each capsule independently was monitored throughout the experiment to assess the condition of the fuel.

The graphic on the right is a four-parameter fuel performance envelope in terms of burn-up, fast fluids, temperature, and the power density. And AGR-2 Capsule 2 was plotted separately because it intentionally was operated at a significantly higher temperature. And we just wanted to show that while it had a higher temperature, it was in the middle of the range for burn-up and fast fluids. Okay, next slide.

Okay. We're on Slide 5. So there was some discussion and a number of questions in the subcommittee meeting on May 6th about the temperature measurement and calculation of temperatures in AGR-1 and 2. And so I wanted to go into a bit more detail and explain that in more depth than what we did at the subcommittee meeting.

So in terms of thermocouples in the two

experiments, the AGR-1 experiment had type N thermocouples and high temperature moly niobium thermocouples, about equal numbers of them. And they both experienced about the same in pile failure rates.

For AGR-2 it was decided to go with only type N thermocouples, and fewer of them because they were larger diameter than most of the type Ns in AGR-1. So there was one observation from AGR-1 that none of the large type Ns failed, even though the smaller type Ns and some of the moly niobiums failed.

So they went with the larger type N thermocouples. And because they're larger, you can't get as many in. So --

VICE CHAIR REMPE: Paul, factual correction. Did you just say that none of the type Ns failed in AGR-1? That's not true. About half of them failed, just like the moly niobiums ones, right?

MR. DEMKOWICZ: Right, I didn't say that they didn't fail, so --

VICE CHAIR REMPE: Oh, I thought I heard you say that none of them failed in HTR-1 and that's not true?

MR. DEMKOWICZ: It was similar failure rates as stated on the slide there.

VICE CHAIR REMPE: Okay, that's what I

thought. Thank you.

MR. DEMKOWICZ: Yes. So, in HTR-2, all of these TCs had failed by the end of the irradiation. However, while they were functioning, the observation was that they exhibited less drift when compared to the thermocouples in AGR-1, so it was kind of a mixed bag. They didn't last as long, but they had less drift while they were active.

In terms of temperature measurement, the approach is to place the TCs in the graphite holders surrounding the compacts. The diagram on the right is one of the capsules from AGR-1 that shows the TCs in the graphite hole through the circles of the location of the fuel compacts.

The TC temperatures are calculated with the thermal model and compared to measurements, and this is most important during the early cycles because this is when most of your TCs are still functioning and they haven't experienced any drifts, so you get a validation or a benchmark of your thermal model, and then fuel temperatures are calculated using this benchmarked thermal model.

For both experiments, nearly all of the TCs were at temperatures less than 1,000 degrees. There were a few exceptions in both experiments, two in AGR-2 and three in AGR-1 where TCs were in the range up to 1,100 degrees, and there was one thermocouple in AGR-1 that spent a short time up to 1,200 degrees.

So, the approach was very similar between AGR-1 and 2 in terms of measurement and modeling. The one thing to point out is that for fuel experiments in ATR, a great many of them, including all of the AFC experiments, the ATF-1 experiment that's a test of accident tolerant fuel, and of course the plate field experiments have no thermometry whatsoever.

So, the approach for the AGR program in terms of temperature measurement was very rigorous, and most other experiments rely 100 percent on the model to determine fuel temperatures with no feedback. Okay, next?

The physics model that we used is an MCMP origin coupled code. It includes the daily depletion of the TRISO fuel in our experiment, the ATR driver fuel, the capsule components in our experiment, and it accounts for the shim cylinder rotation in the ATR reactor.

We compare the model with post-irradiation measurements of actinide isotopics in the fuel, the fuel burn up, and there are flux wires in both of these experiments that we compared the total neutron flux to the model.

And the model also accounted for the relocation of the AGR-2 experiment that was discussed in the report and it came up in the subcommittee meeting. This had a minimal effect on the overall experiment because it was a low fluence location, and that's the third to left cycle on the plot. You can see that the heat rate was relatively low and it was a very short duration cycle.

The thermal model is a 3D finite element model. There are about 350,000 nodes per capsule. If you look at individual compacts, that works out to roughly one node per particle in the compact, so about 3,000 to 4,000 nodes in a single compact.

And the model considers all of the relevant phenomena, including conduction and radiation, the heat rates in the fuel that come from the physics model, heat rates in the graphite and metallic components, the shrinkage of the graphite, and changes in thermal conductivity with fluence and the thermal conductivity of the compacts. Okay, next slide?

So, thermocouple drift is recognized as a very important phenomenon and something that we need to understand that is going on in the experiment, and so this is evaluated continuously throughout the experiment.

And the idea is to compare the TC readings to the calculated temperatures which would capture things like operating condition changes, or shim cylinder rotations, or power changes in the lobe, and also to compare the TC readings to other TCs.

And so there was a lot of on drift monitoring like the chart on the right that compares one TC to another and to the model, and the idea is to identify if a control TC, the one that's being used to control the capsule's temperature, is drifting or failed, and then control is shifted to an alternate TC that's functioning.

If there are no more functioning TCs in the capsule, then control is based entirely on the model predictions. Okay, next slide?

Temperature uncertainty of the model was determined for both AGR-1 and 2, and these considered the contribution in uncertainty in all of the fuel temperature calculation input parameters.

So, it looked at things like the fuel, uncertainty in the fuel heat rate, the gap width between the graphite and the capsule shell, the graphite thermal conductivity, the fuel compact conductivity, the gas fraction of neon in the capsule, the shell and graphite emissivities, and the non-fuel component heat rates, and those come from the physics simulations.

So, for all of these input parameters, sensitivity studies were performed, and that looks at identifying the relative impact of that parameter on temperature, and then the uncertainty in these individual temperatures or for these individual parameters were estimated, and then a total uncertainty in the calculated fuel temperature is determined.

The volume average and time average temperature uncertainties at 1 sigma for AGR-1 and 2. The range for the different capsules is shown in the bullets there. The figure on the right is the instantaneous volume average and peak temperatures in the AGR-2 Capsule 2 as an example.

And one observation is that the instantaneous -- the uncertainty on the instantaneous temperatures tends to be higher than what it is on the time and average temperatures because when you propagate the uncertainty, it's a root mean squared process, and so you get a slightly smaller uncertainty on the time averages, but you can see that the 1 sigma uncertainties in general on both the volume average and the peak temperatures there, it's about 100 degrees. Next slide?

Oh, one thing I wanted to address on that last slide is there was a question as to why the AGR-2 uncertainties here are less than AGR-1, and the reason is that it is mainly because uncertainties on most of these parameters were the exact same between the two experiments in terms of conductivities, fuel heat rates and things like that, but the gap width for AGR-2 that controls your temperature was larger than AGR-1, and therefore when you have changes in the gap, the relative change is smaller, so the relative uncertainty is smaller for AGR-2. Okay, next?

Another important issue is temperature bias. If you are -- often you're modeled relative to what's actually going on, so we look at this as well continuously throughout the irradiations.

And it's assessed by looking at what we call the TC residuals, and this is the measured temperature of the TC minus what it is calculated to be in the model.

And in particular, we focus on the early cycles when the TC drift was, in most cases, was negligible. And the plot shows all of the TC residuals for AGR-2 Capsule 2.

You can see essentially when TCs failed by when those traces end, and as I mentioned earlier, all of the TCs had failed in Capsule 2 by the end.

The green trace at the top is TC 3 from Capsule 6. It was determined to be unreliable from the beginning. It was offset and it was drifting badly, so if we exclude that one, for Capsules 2, 3, and 6, the overall bias was close to zero.

And if you look at the plots, what that is saying is that if we look at the mean of those residuals, it is averaging close to zero.

For Capsule 5 on the other hand, it's the second from the top. I know that text is small. There were two TCs and they both were reading, or the residuals were low and the average was about minus 60, and that indicates about a 60-degree over-prediction in fuel temperature.

So, as a result of the known uncertainty in temperature and the potential for bias that I just talked about, I would note that higher temperature capsules were included in the experiment plan.

That includes AGR-2 Capsule 2 and the AGR-7 irradiation, which is Capsule 3 of the current irradiation, and these were included to address this risk of potential temperature bias and uncertainty. Okay, next slide?

So, we did a survey of some of the data that we have for PIE in terms of fission product release to see what it could tell us about the potential for uncertainty or bias in our uncalculated fuel temperatures, and there's two examples here.

And in general, the fission product release data that we have, it supports the magnitude of the uncertainties and biases that I just talked about.

So, one example on the left is the level of release of silver 110-M from individual compacts. All of those data points is the -- it's essentially the fraction that is retained in the compact as a function of temperature, and it includes the AGR-1 and the AGR-2, and I've also thrown in the AGR-3/4 irradiation for comparison.

And while there's a good deal of scatter in the data and there are some reasons for that that we don't really have time to get into, but it's interesting that if you fit all of those datasets with an inverse logistic function, that the inflection points are all within about 30 degrees.

On the right is data for the strontium and europium release from AGR-2, AGR-1 and 2 capsules, and it's the average capsule release, so there is a data point for each capsule.

And the main observation here is that the Capsules 6 and 5 in AGR-2 which were at similar temperatures as the AGR-1 had very similar release of strontium and europium, whereas Capsule 2 which ran about 200 degrees hotter had a notably higher release of both of those, so it's confirmation that AGR-2 capsule fuel was indeed a much hotter capsule.

And again, what these are showing is not a real fine determination of the uncertainty in temperature. It is looking at or it's confirming that our uncertainty is on the order of 100 degrees and not on the order of 200 or 300 degrees. Okay, next slide?

And I just wanted to point out that there are a pretty large number of publications relevant to AGR-1 and 2 temperature measurement calculation and uncertainty.

The references in the green and blue were referenced in the topical report. I've thrown in the yellow, which is the data qualification reports and the thermocouple data analysis reports for both experiments.

And then also there are over a dozen peer-reviewed technical journal articles and conference papers and those can be reviewed at your leisure to understand more about what was done to measure temperature, to evaluate TC response, to calculate fuel temperatures, and to quantify the uncertainty. Okay, next slide?

So, I've condensed the result summary into one slide here and I'll just run through this real quick. The fission gas release during AGR-1 indicated that we had zero failures of TRISO particles.

In AGR-2, as discussed in the report, there were some issues with how the R over B, the fission gas data was measured in the latter half of that experiment, so PIE has indicated that we have less than or equal to four failures.

The kernels and coatings generally held up very well in all of the irradiation conditions. That includes Capsule 2 from AGR-2 that was at very high temperature.

The PIE has helped to elucidate the mechanism of failure of the SIC layer, which is very important, and that's discussed in more detail in the report.

The high temperature performance of the

fuel has been very exceptional, with low coating failure rates between 1,600 and 1,800 degrees C in pure helium, and the fission product release data has been obtained on some of the key isotopes like silver, cesium, europium, strontium, and krypton.

And finally, if we look at our failure fraction calculations, and these are all the upper limit in the plot there at 95 percent confidence for sodium carbide failure, which is a less severe mode of failure where the SIC layer fails, but a carbon layer has stayed intact, and full TRISO failures, which is in red, and that's where all three of the layers have failed and the particle can release gas.

There is significant margin between our measured failure rates and the historic performance specs for modular high temperature gas-cooled reactors by about a factor of ten. Next slide?

MEMBER KIRCHNER: Paul, this is Walt Kirchner again.

MR. DEMKOWICZ: Yes?

MEMBER KIRCHNER: Just a quick clarification question. On your previous plots of experimental data, that was the capsule temperature, not the estimated particle temperature, is that correct? Because those temperatures are much lower than these temperatures.

MR. DEMKOWICZ: Right, so that was all for irradiation, so that would all be taking place during irradiation. These temperatures, the 16, 17, and 1,800, that data is collected during --

MEMBER KIRCHNER: These results are driving the fuel to failure at higher temperatures under PIE conditions?

MR. DEMKOWICZ: That's correct.

MEMBER KIRCHNER: Thank you.

MR. CORRADINI: So, Paul, Walt gets it, but I guess I don't. The first two plots or the first two points that are titled irradiation are the data, and then the ones at 16, 17, and 18 are what again? Can you just say it again, please?

MR. DEMKOWICZ: Yes, so there are two different types of failures that are included here, and this is really an advance in our program in even being able to measure the blue data points. We can go in and find particles where the SIC layer only has failed.

This is a less severe mode of failure where the SIC layer has failed, but the OPyC, the outer carbon layer, is intact, and so that particle doesn't release fission gas. The red is a TRISO failure, we call it, because all of those dense layers have failed and the particle is releasing gas.

So, it's basically, it's two modes of failures that we've quantified, during the irradiation, that's what the irradiation column is for, and during our post-irradiation safety testing at 16, 17, and 1,800. So, this is all experimental data.

MR. CORRADINI: Okay, so it's a separate test after the irradiation?

MR. DEMKOWICZ: Right.

MR. CORRADINI: But the knowing that it's 16, 17, and 18 is calculated or calculated and measured? That's maybe where I was going with this.

MR. DEMKOWICZ: Yeah, it's not calculated. These are furnace tests where you've got much more fine control of temperatures and --

MR. CORRADINI: Oh, okay.

MR. DEMKOWICZ: Yeah.

MR. CORRADINI: Okay, thank you. Sorry, I forgot. Thank you.

MR. DEMKOWICZ: Any other questions on that slide? Okay, next slide, which is the final, I just wanted to mention about the RAIs. The staff submitted four technical RAIs and the topics are there. We discussed these in the subcommittee meeting a bit.

I'll just reiterate that we felt that the RAIs reflected a pretty careful reading of the report and a good grasp of the key issues by the staff, and as a result of these RAIs, we have provided responses, and that includes additional information and some more extended technical discussion, and some revisions to the topical report.

That is the end of my presentation. I'd be happy to take any additional questions.

MEMBER BLEY: Paul, this is Dennis Bley. I've gone back through our transcript from the last meeting and I think you addressed most of the things people brought up during that meeting.

Dr. Rempe brought up a couple of times asking you why in the tests you had done, peak temperature instrumentation, the very accurate ones weren't used, but I think she was really pointing forward. Are you planning to do anything like that in the future tests?

MR. DEMKOWICZ: So, the AGR-5/6/7 experiment that's in the reactor now is, I would consider it the state of the art for where we are now in terms of thermometry and these in-pile experiments. And I say that because we improved both the Type N thermocouples and the moly/niobium.

So, there were some identified issues with both, and there were some identified issues with the moly/niobium thermocouples from the AGR-1 experiment in that the annealing schedule, it resulted in excess drift I think I would say in those thermocouples.

What they have done at the lab in the last few years is to understand better the annealing schedule. You have to anneal it at a sufficiently high temperature over the entire length of the TC, and the result in AGR-5/6/7 was much better or a much more stable response from both the moly/niobium and from the Type Ns.

The Type Ns that we did, we worked with several different entities. One of them was the University of Cambridge that came up with, you know, essentially a Type N TC that was optimized for in-pile use, and both of those have worked a lot better.

But I would note that we still have the same problem in that all of the TCs in our bottom capsule, Capsule 1, and there was a lot of them in AGR-5/6/7, have failed, so you still have this problem of the longevity of TCs, but the stability of them was improved in 5/6/7.

So, yeah, we've taken lessons learned from all of these experiments and tried to improve the subsequent experiments, and I'm sure that there's going to be a lot of lessons learned from 5/6/7 in this regard as well that can be applied in future irradiation experiments.

MEMBER BLEY: Okay, thanks, but it sounds like you're not thinking of going to any simple peak temperature measurements in the future?

MR. DEMKOWICZ: I'm not sure what you mean, a direct measurement of the fuel you mean?

MEMBER BLEY: No, melt wires or things like that are what Joy had brought up that last time around.

MR. DEMKOWICZ: Right, so we actually did not use melt wires for the first time in 5/6/7 because the observations from AGR-1 and 2 were that they were actually of pretty limited usefulness.

One problem is, you know, it's complex to fabricate and you have to insert them, and then the PIE is fairly involved and you lose about half of them in the process.

And it turns out that the higher the temperature of the melt wire, the more likely it is for it to have reacted with the graphite and you lose it, and we just didn't get a lot of use out of them, and so we didn't even use them in 5/6/7.

I actually just had a conversation about this with our experiment designer and we were agreeing that it probably calls for some more advanced melt wire designs essentially than what's been used in the past.

MEMBER BLEY: Okay.

VICE CHAIR REMPE: So, Paul, first, there were no melt wires is my understanding in AGR-2. They were only used in AGR-1 and they were purchased from another source, not INL, and they were encapsulated in metal as opposed to something that you could see through, which in more recent years, has been used successfully by encapsulating them in quartz and then you just look at it, and we actually did quite a bit of that.

Again, I'm trying to stay factual here, but again, you learn from experience, and it seems like -- and there are, you know, certain things you have to consider, but it has been used successfully at ATR, and I think it was in EPRI tests.

MR. DEMKOWICZ: So, that's incorrect though. We did use melt wires in AGR-2.

VICE CHAIR REMPE: Oh, okay, so it was my understanding you didn't, but I don't think you got them with quartz encapsulation. I thought it was just for, you know, a niobium tube is what I thought they had put the ones for AGR-1 in, and I did not know about AGR-2. What about AGR-3? What was the use in the capsules for AGR-3?

MR. DEMKOWICZ: The approach was similar to AGR-1 and 2. They were in vanadium. The capsules were vanadium.

VICE CHAIR REMPE: Oh, vanadium, thank you. I'm sorry. I couldn't remember what they used.

(Simultaneous speaking.)

VICE CHAIR REMPE: What about thermocouples in the capsules for AGR-3/4?

MR. DEMKOWICZ: So, AGR-3/4 had the added benefit of these exterior rings, and so you could put thermocouples much further outboard from the fuel than you could for AGR-1 and 2.

You know, AGR-1 and 2, I showed the cross section. There is no place in that graphite where you're going to put a thermocouple that's not really close to a compact.

In AGR-3/4, you could put them further outboard, and I don't recall off the top of my head what types or what the distribution was, but all of them survived for the entire experiment.

VICE CHAIR REMPE: Were there any in or they were just outboard? Clarify, please.

MR. DEMKOWICZ: In? What do you mean in?

VICE CHAIR REMPE: Well, I can show this picture from AGR-1 earlier in your slide, the thermocouples, and do they have similar thermocouple positions in AGR-3/4, which of course we've not reviewed, but were there anything within the capsule?

MR. DEMKOWICZ: Yeah, all of the thermocouples were in the capsule. What I mean is if -- yeah, we didn't have time to go into AGR-3/4 and that's not the subject here, but --

VICE CHAIR REMPE: Right.

MR. DEMKOWICZ: -- it was a very different capsule design. It didn't look like this at all.

What you had is a stack of compacts in the middle and then three different rings of graphite, and so you could put thermocouples a good distance away from the fuel compacts where they weren't as hot, and their survivability, not surprisingly, was a lot better.

VICE CHAIR REMPE: So, they had then in as well as out is what you're telling us on the record?

MR. DEMKOWICZ: All of the thermocouples were inside the capsule. It's a question of where inside that capsule cross section they were, and they were further away from the fuel compacts --

VICE CHAIR REMPE: That's what I was trying to get to. Thank you.

MR. DEMKOWICZ: Yeah.

MEMBER KIRCHNER: Paul, this is Walt Kirchner. Can you go back to your last slide, please? Would you elaborate, under the RAIs, sub-bullet number two? So, where I'm going, it's a leading question.

My sense is that the Table 5.5 is necessary, but not sufficient, so what other important fuel properties or coating process parameters need to be added to Table 5.5 to use your results of the topical report?

MR. DEMKOWICZ: So, some of the specific items that the staff brought up and have now been added in that discussion, and it's in that section where Table 5.5 resides, I forget the number, but are things about essentially particle design, so the buffer to volume, or the kernel to buffer volume ratio relative to peak burn up. That's been discussed.

The kernel stoichiometry in terms of the oxide carbide mixture was added. In terms of coating process parameters, the fact that it's an uninterrupted coating process --

MEMBER KIRCHNER: Okay.

MR. DEMKOWICZ: -- had been added more prominently basically as a requirement to get the right types of coating properties. So, these weren't added to Table 5.5 per se. They were added to the discussion in that section and noted as necessary to get the right performance.

MEMBER KIRCHNER: All right, thank you.

MEMBER BALLINGER: Okay, this is Ron. Are there any other questions on this presentation? Hearing none, we thank you again, Paul. I think we should just now transition to the staff presentation. Is -- Travis, are you ready to go?

MR. TRAVIS: Yeah, give me just a moment to set up the presenter status and all of that.

MR. HOELLMAN: Hey, Boyce, do you want to share or do you want me to continue?

MR. TRAVIS: If you have it up, go ahead and continue. I'll have it up as a backup if it doesn't work, but --

MR. HOELLMAN: Okay.

MR. TRAVIS: Is everyone able to see it okay?

MR. HOELLMAN: It looks okay to me.

MR. TRAVIS: Okay.

MR. HOELLMAN: Go ahead, Boyce.

MR. TRAVIS: Okay, good afternoon, everyone. I will try to keep this brief in terms of my comments so that there's time to address questions and whatnot. You can move onto slide two.

So, at a high level, the purpose of the topical report and stated goal was to provide a foundational basis for establishing fuel performance for TRISO particles.

And I guess I'll note here that as we noted in our limitations and conditions, the scope was confined to the particles themselves. Factors outside of the particle would be addressed by a vendor or subsequent licensee or applicant referencing this topical report.

The topical report lays out a set of performance criteria. They are noted in Table 5.5, and as Dr. Kirchner noted, or Member Kirchner noted, there is some other discussion in the topical report that also confines what constitutes an acceptable particle.

For the most part, these are identified either explicitly in the topical report or alluded to in the staff's limitations and conditions in the safety evaluation on the topical report.

These performance criteria are based on empirical data from the AGR-1 and 2 tests in irradiation and the performance is outlined within the topical report.

And so as part of this presentation, I'll start by providing a high level summary of the findings in the topical report, and then I'll step through some new discussion, the changes to the staff's safety evaluation, and some follow-up items from the subcommittee meeting. So, if you move onto slide three?

So, the technical review team for this project, Jordan Hoellman, who is moving the slides for me, is the project manager. My name is Boyce Travis. I'm a reactor systems engineer and the lead reviewer for this topical presenting on behalf of the staff.

Other members of the review team from my branch were Jeff Schmidt, Chris Van Wert, and Antonio Barrett, who I believe are all on the line in this presentation as well. So, if we move onto the next slide, slide four?

Yeah, so this is a reused slide from the previous presentation, but I've included it here because I think it does a good job of filling in what the role of this topical report constitutes.

So, as part of a license application for a TRISO fuel design, there's going to be a lot of other factors that go into it. A large part of that license application is going to be the safety demonstration. And for a TRISO fuel reactor design, we expect the fuel qualification to perform a large part of that safety demonstration.

This topical report makes up a reasonable-sized portion, but not all of what would constitute fuel qualification for a vendor that's using a TRISO-fueled reactor design, and so there are other factors outside of the particle itself and/or conditions that this topical report does not confine.

So, for instance, very high temperatures or specific transient ramp power or temperature ramps that don't fall within the scope of this topical report would have to be the subject of future licensing submittals.

And so this topical report is, as noted, a foundational basis for a future TRISO license application and makes up a large part, but not all of what we would expect to see for a fuel qualification for a TRISO fuel design.

Next slide, slide five? So, I'm not going to read these conclusions. I'll just kind of paraphrase what's here. EPRI has already gone over this.

Ultimately, the topical report concludes that the testing in AGR-1 and 2 constitutes a valid performance demonstration over a range of operating conditions, which is outlined in the report.

The kernels were manufactured in a variety of different ways and exhibited some property variations, but within the specifications that are outlined in the report, no matter the manufacturing process, they exhibited similar irradiation and accident safety, or accident performance as defined by the performance that's described in the topical.

And then the aggregate data from these two tests, as summarized in the report, again, all of this is part of the data that's referenced in the report, can be used to support licensing of reactors that are going to use UCO TRISO purely from the perspective of the particle itself for this report.

Other forms, or other impacts of the fuel outside of the particle would be the responsibility of anyone that's referencing this report as part of a future submittal.

So, if you'll move onto slide six? Slide six kind of provides a high-level review background of what the staff went through in this topical report.

In effect, the information presented here would allow applicants or licensees who reference this report to use the AGR data based on adhering to the manufacturing specifications in Table 5.5 and the discussions in the topical report, and subject to the operational and performance ranges that are detailed in the TR.

And so that's the other piece going back to the discussion we had earlier of Table 5.5 doesn't perform everything.

It's kind of the, as Dr. Corradini mentioned, the recipe, but there are other aspects of what you put the final particle in, the conditions you subject it to related to burn up, and time average temperature that this report has boundaries on.

And if you went beyond those boundaries, including uncertainty as we'll discuss later, then you would need to justify that, going beyond those boundaries, either through additional testing data, another reference, or work that's done outside of the scope of this topical report as a licensee or vendor.

Staff conducted an audit and asked five RAIs. The responses are noted on the ADAMS ML numbers on the slide. I'll note that staff found the audit extremely useful.

It was a huge efficiency boost to be able to go out to Idaho and speak with the experts who did some of this testing and gain a better and more focused look at what some of the background there, and develop a small number of RAIs that allowed us to, you know, really hone the review in on the safety evaluation that resulted as a part of this project.

And then as a result of our review and the subject of the RAIs, the scope of the topical report was narrowed somewhat to the tested particle ranges that are now in Table 5.5 of the report, and some additional performance parameters that we noted earlier were identified as limits that the particles are subject to in order to reference the report.

So, if you'll move onto slide seven? I'll be starting on the new information discussion here. So, as a result of the previous ACRS meeting, staff decided to revise limitation one and condition two.

If you'll remember, there are a total of five limitations and conditions that were the subject of this topical report. We felt that upon reflection, a couple of these could use some further refinement.

And so the yellow highlighted portion here in limitation one, we added some discussion to this limitation to say that it's any performance beyond the particle of the fuel form, including other influences of a specific reactor design beyond that fuel form to account for some discussions as we expect there to be a fairly broad spectrum of applicants and licensees that may use a TRISO fuel design using various different coolants, different fuel forms.

As we've already noted, there are compacts and pebbles that we are 100 percent aware of that exist as fuel forms. There may be others, and so we just wanted to emphasize that impacts of your reactor design's typing on these particles need to be assessed by you, the reactor designer.

This report governs only what happens inside and up to the particle boundary, and so, again, those would be the subject of a future submittal and not under the scope of this review. If you'll move on --

MEMBER KIRCHNER: So --

MR. TRAVIS: Go ahead, sorry.

MEMBER KIRCHNER: So, Boyce, this is -- may I interrupt? This is Walt Kirchner speaking.

MR. TRAVIS: Yeah, of course.

MEMBER KIRCHNER: So, I understand the limitation here and confining it to the TRISO particle. Now, you have an applicant come in. They have to put the particle into some fuel form, usually with a binder. The binders vary.

The packing density varies for different shapes like the compacts and for the pebbles, and there may be other fuel forms that are used. Would this require then in-pile testing?

MR. TRAVIS: So, I'm going to hedge a little when I respond to that. I don't think it necessitates in-pile testing necessarily if there is a -- so, I guess, let me step back.

It would require in-pile testing in some form or fashion. There has been a lot of in-pile testing conducting, including what's been done in these AGR experiments.

And so if a vendor or licensee could justify that their packing fraction, their binder method looks or is sufficiently similar to what's already been tested in a reactor design, I think the staff would be receptive to exploring that.

I don't think that every individual -- I don't necessarily think that every individual designer would have to do additional in-pile testing for their own fuel form if that makes sense.

MEMBER KIRCHNER: Yeah, fair enough.

Thank you.

MR. TRAVIS: Yeah, of course.

MEMBER BLEY: This is Dennis Bley.

MEMBER KIRCHNER: So, so --

MEMBER BLEY: Oh, I'm sorry. Go ahead, Walt.

MR. CORRADINI: This is Corradini. Travis, I guess I wanted to make sure I understood the additional words of what you're covering. Are the additional words in yellow basically things that we haven't thought of, but may come about?

MR. TRAVIS: In some sense, yes. In other senses, it's more in the -- so, this was, I think, directly to address a concern.

For instance, if a reactor design were to use a non-helium coolant and it had some impact that propagated through the fuel form to the particle, that is also -- like if there is a particle interaction other than the binder or the fuel form, that also is the subject of that vendor designer.

MR. CORRADINI: Okay.

MR. TRAVIS: So, I mean, yes to your question, but also the specific concern we were looking at here is we are aware of other things that might theoretically impact the particle, and we want to make sure that it's clear that those are -- that particle interactions with other reactor effects, not just the fuel form, are the subject of this.

MEMBER KIRCHNER: Yeah, other coolants --

(Simultaneous speaking.)

MEMBER KIRCHNER: -- are going to be a challenge. Almost all of the database experiences helium or whatever was used in the in-pile capsules, but usually it's, you know, it's a noble gas, but it's usually helium there as well.

So, once one goes to a different coolant, then that raises a number of questions about the potential for attack of the particle fuel by the actual coolant. Thank you.

MR. TRAVIS: I heard a couple more questions and I don't know if Dr. Corradini got to finish.

MR. CORRADINI: No, Walt's faster than I am, but he caught what I was trying to get at. Thank you very much.

MR. TRAVIS: Yep, any further questions?

MR. SCHULTZ: Boyce, this is Steve Schultz.

MR. TRAVIS: Sure.

MR. SCHULTZ: Are you expecting

information coming from AGR-5 to 7 tests that are going to be incorporated into future evaluations either related to the fuel form or to additional information related to the particle?

MR. TRAVIS: So, I'm going to say yes, but very tentatively. I think that in most cases, especially related to source term considerations, vendors are going to cite other data from the AGR program in order to fully flesh out what their fuel qualification looks like, but at this point, I don't know exactly what portion of that they're going to cite, and so it would kind of be speculation.

So, I will say that I do expect other data sources to be needed for most of the reactor designs that come in.

MR. SCHULTZ: That helps. Thank you.

MR. TRAVIS: If there's no other questions, I will move onto slide eight. Okay, so slide eight includes the other revision to the topical we made as a result of the previous ACRS discussions, and this relates to the discussion of uncertainty, and so we've added the text highlighted in yellow here in condition two.

I guess I'll note that the expectation of how this condition is applied has not changed based on that added text, but as the ACRS noted, some of that was based on an implicit understanding of what was going to be done regarding uncertainty and going forward on how this topical is being referenced.

This text was an effort to more explicitly lay out what the expectation is regarding uncertainty in the analytical justification that's used when referencing this topical report.

And so with that, I'll move onto slide nine, and I have two slides here that will talk briefly about items from the subcommittee meeting that resulted, or that were questions kind of directed more at the staff safety evaluation.

There was a question at the subcommittee regarding how burn up and depletion were characterized, both somewhat in the topical report, but more in how the staff described the information in the safety evaluation regarding these.

Burn up and depletion were resolved fully via calculation in MCMP and Origin. The staff's information is derived from these references that are documented in the topical report.

And I guess I will note that boron gradually burns out over the early portion of the experiment and was one of the drivers for the behavior that was discussed in the subcommittee meeting.

And so we didn't feel that it was necessary to change the description in the safety evaluation based on the information that's provided both in the topical report, but more importantly, in the references that are identified on this slide and referenced in the topical report.

And so moving onto slide ten, this is regarding uncertainty for a little more discussion on what we discussed, why, and the result of the changes that we made to condition two.

Again, we brought up uncertainty a number of times during the subcommittee meeting. The uncertainty for these experiments is comprised of a number of different experimental inputs, all of which played a role, and Paul went into much greater detail during his presentation.

I guess we would just note here that the gap width in particular accounts for a number of effects, including things like expansion or contraction, that change during the course of the experiment, and so can act as a large driver on uncertainty.

The data that was measured on the uncertainty is summarized in Section 6.5. As Paul mentioned, the references that were on the slide, some of which are references 78 through 80 in the topical report, go into further detail.

The staff did, we looked into those references in some greater detail, and I think we're comfortable with how it's characterized in the report. It is an average value, but the band is characterized appropriately based on the data.

And we expect that an applicant referencing the report will have considered those uncertainties as part of when they reference that data as part of their analytical, whatever analytical product they're using to finish qualifying their fuel form.

And so I have one more slide in conclusion, slide 11. Ultimately, the conclusion in the report is that the experiments were conducted under an adequate quality assurance program that produced the data.

The TRISO particles, if they're manufactured in accordance with the specifications in the topical report, including table 5.5, will perform adequately to the level as described in the topical report, up to temperature, burn up, values that are explicitly identified in the topical report and are based on that data that is valid and can be referenced by someone coming in with a TRISO particle design that meets the specifications that are outlined in the TR.

And so based on the review of the TR and the information provided in the RAI responses and the updates to the topical report, staff agrees with the conclusions that have been requested subject to the limitations and conditions that are identified in the safety evaluation were previously discussed.

So, that concludes my presentation. I'd be happy to take any further questions.

MEMBER BALLINGER: Well, this is Ron. It looks like there are no further questions. Thank you very much for the presentation, and actually thank everybody for their presentations. But we now, I think, need to go and ask for public comments, and I'm assuming, Thomas, is the line open?

MR. DASHIELL: The bridge line is open for comments.

MEMBER BALLINGER: Thank you. So, are there any members of the public that would like to make a comment? Please identify yourself and make your comment. We've got to give them a few seconds to unmute their microphone. I think we're done. I think hearing no comments, I think we're done with the presentations.

Once again, thank you very much for the presentations. Once again, we will be producing a letter for this topical report for the SE, and so with that, I'll turn it back to you, Matt. Thank you.

CHAIR SUNSERI: Thank you, Ron, and thank you to the staff and all of the other presenters that presented today. So, my question for you, Ron, is you have a report prepared, a draft report prepared for this. It's about 250 lines. How long would it take for you to read that in?

MEMBER BALLINGER: If you would like me to make a prediction, I don't want to.

CHAIR SUNSERI: Well, let me say it differently. Do you think you could have that read in by 1:00? That would give you 25 minutes, 20 minutes.

MEMBER BALLINGER: Yes, I think so.

CHAIR SUNSERI: Okay, so that's going to cut into our lunch break a little bit, but I think it's the best use of our time to do that, so can we get that letter up?

And while that letter is coming up, if anybody needs to take a bathroom break, please go ahead and do so right now, but we're going to continue through with the reading of the staff letter.

MEMBER BALLINGER: Yeah, I should -- no, I don't -- I sent -- I made some minor changes to the letter actually early this morning and sent them to Chris, so I'm reading from the one that I have. I'm not exactly sure whether Chris had a chance to address the, to input those changes. So, Chris, are you -- did you get the thing this morning?

MR. BROWN: Yeah, I'll give you a call on your cell phone.

MEMBER BALLINGER: Okay, all right, so in any case, I'll read from the latest version that I have.

CHAIR SUNSERI: Well, so, are we going to have it on the screen? Is Sandra prepared to put this up or did we get ahead of her?

MR. BROWN: If not, I'll run it, absolutely.

MR. MOORE: Sandra, this is Scott. Are you on and are you hearing this?

PARTICIPANT: Yes, I'm on.

MR. MOORE: Okay, so -- go ahead.

PARTICIPANT: I was going to say what letter do I need to pull up?

MR. BROWN: Sandra, I'll handle it. Don't worry about it.

MEMBER BALLINGER: Yeah, the title of the revision would be Revision 1.1.

MR. BROWN: Thank you.

MR. HOELLMAN: Okay, Chris, I'm going to stop sharing so you can do it, okay?

MR. BROWN: Thank you.

MR. MOORE: Chris, this is Scott. So, you're going to show it on the screen or you're going to give it to Sandra?

MR. BROWN: Scott, I'm talking to Sandra now and we're pulling it up shortly.

MR. MOORE: Okay.

VICE CHAIR REMPE: Someone, the court reporter is asking a question about being off the record. I think the answer is yes, but I'm not the person to answer that question. Matt, can you answer, or are you there, that you can answer the court reporter's question?

CHAIR SUNSERI: Yeah, yeah, so we -- that's correct. So, for the court reporter, we will go off the transcript from now, from this point, and we will resume at 1:45 p.m. We'll be back on the transcript at 1:45 p.m.

(Whereupon, the above-entitled matter went off the record at 12:38 p.m. and resumed at 1:46 p.m.)

CHAIR SUNSERI: So, welcome back. It's 1:45, 1:46 now. We are going back into session for the ACRS presentation on the NuScale Area of Focus: Boron Redistribution, and I will begin with a roll call. Members, please acknowledge your attendance. Ron Ballinger?

MEMBER BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley?

MEMBER BLEY: Here.

CHAIR SUNSERI: Vesna Dimitrijevic?

MEMBER DIMITRIJEVIC: Here.

CHAIR SUNSERI: Walt Kirchner?

MEMBER KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba?

MEMBER MARCH-LEUBA: Yes.

CHAIR SUNSERI: Dave Petti?

MEMBER PETTI: Here.

CHAIR SUNSERI: Joy Rempe?

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella?

MEMBER RICCARDELLA: I'm here.

CHAIR SUNSERI: And myself, so we have full attendance with the exception of Charlie who is excused, and we're going to start with the NuScale boron dilution discussion.

We will begin in open session, and at some point, there will be a transition to a closed session. You should have a separate email for that closed session invitation.

I would remind everybody do not share that with anybody that doesn't need it, and don't post it on the message bar because then it becomes no longer privately held information.

So, with that, I will now turn over to Walt for us kicking off this session. Walt?

MEMBER KIRCHNER: Thank you, Mr. Chairman. Today, we're going to hear from both the applicant and the staff on what we had previously called boron redistribution focus area, but our real attention today and interest is in the area of boron dilution events that would occur after uncovery of the riser in the nuclear power module.

So, we are going to hear first from NuScale and then from the staff in open session as the Chairman has indicated. We will then move to a closed session later this afternoon. We'll have a different link for that, and again, tomorrow morning, we'll be in closed session to hear further from the staff.

We are also going to provide time needed to hear a differing view from the staff, a staff member specifically, and that will be part of the closed session.

And for the public, the reason that it will be part of the closed session is we're dealing with both export control and proprietary information. I'm sure at some point that material will be available to the public.

Normally I don't do this, but this time, we're on the last leg of our review of the NuScale design certification application and the staff's SER, and we're at a rather important juncture with a significant technical issue.

So, to frame the meeting and express at least my interest as the subcommittee chair, and hopefully on behalf of the full committee, I am most interested to hear from both the applicant and the staff about their analyses and evaluations of these boron dilution events which are both AOO category and design-basis events such as a DHRS cool down event, that would be an AOO, or a small break LOCA design-basis accident-like event.

We would like to hear bounding analyses that give us high confidence that we can assess the boron dilution problem, know what the concentrations are in the primary system and in cases up to 72 hours.

Also, we are much interested to know what happens at ECCS actuation. There are new set points, for example, and/or if the 24-hour timer actuates the system.

And finally, and we're interested in that, by the way, because depressurization of the system could lead to a number of event sequences of concern, perhaps such a manometer oscillation in the primary system with power feedback, so further just to focus things.

And finally, we need to see that there is a path to recovery that does not result in a potential reactivity insertion accident and possible subsequent core damage.

The nuclear power module cannot be left in a cliff state. That would not complete the Chapter 15 evaluations, and so we're looking for that. To qualify that, we're not looking for operating procedures. We're looking for a physical description or basis for recovery from such a boron dilution event.

So, with that, I am going to turn to our lead in this focus area, Jose March-Leuba, for any comments before we go to the applicant.

MEMBER MARCH-LEUBA: Thanks, Walt. Yes,

I do have comments and they're going to be very negative because I'm extremely dissatisfied with both the SER and the FSAR.

Back in February, we reached the consensus that, an item I had been highly pushing for several months, that the boration of the downcomer was a serious condition, and we stopped the specification and we went to work on it, and came up with a good solution for some of the events by drilling these bypass orifices in the high upper part of the downcomer, but it only solved it halfway because after you have an ECCS actuation, you will drop the level below those orifices and you continue to de-borate.

So, for any ECCS actuation, which is an AOO, many, many transients lead to it, you will start to de-borate the downcomer. Will it take an hour, ten hours, 100 hours? I don't know because the analysis hasn't been performed. It's been ignored.

So, if you allow it, if you let it go, and I've said it many times, if you have an ECCS actuation, you have weeks to work with this because there is no way the operator is going to start recovering within hours. That operator is going to need approvals from committee upon committee.

They're going to have to get a signature from the Vatican before they can recover, so there will be plenty of time to de-borate, which means that you park right at the core inlet in the lower plane de-borated water.

And the worst-case scenario, which is end of cycle, that may be worth $20, $25 worth of positive reactivity, and you're just waiting for a provocation to put that positive reactivity into the core. Those provocations exist.

My favorite one is the initiation of one of the non-safety grade systems like CFDS which we would push it into the core. At low reactivity, we push it in.

The applicant has chosen to completely ignore this extremely dangerous condition. Let me say it again, dangerous, that condition. I have reviewed many power reactors. I haven't seen a condition in the power reactor that is more dangerous than having $20 worth of reactivity waiting to get into the core, and the applicant has chosen to ignore it.

There is a lot of lip service going around to risk-informed issues. However, the applicant has chosen not to evaluate the risk of this condition and the risk of operator actions on either of the actuations or any of these conditions that can put those $20, $25 of reactivity into the core.

They just don't want to do it. There is a lot of lip service to risks, but they don't want to complete the risk of the most risky condition we have in this reactor. I find that unsustainable. You cannot support it.

MEMBER KIRCHNER: Okay, Jose, and for everyone on the line, this is Walt Kirchner again. You've heard one member's opinions. Remember we speak as a committee. I'm hopeful that today and tomorrow perhaps, Jose, both the applicant and the staff disprove your contentions.

Again, I would go back and just assert one more time we're interested up to 72 hours, and the reasons are several, but we will work with the staff on that particular point as a cut off.

It is my opinion, and now you're listening to yet another member's opinion, that this system will not be left for weeks while there are conference calls with the NRC, that this will be addressed through either tech specs or EOPs, and operator intervention will take place at 72 hours, if not sooner.

But let's hear from both the applicant and the staff on these issues, but as a courtesy, let me turn -- any other members wish to make an opening comment?

CHAIR SUNSERI: Walt, this is Matt. I just want to emphasize a point you made, being a former operator myself. I think it's very important for everyone to understand that the control room of this plant will be run by a senior licensed operator licensed by the Nuclear Regulatory Commission.

And that person is the sole decision maker on what happens with this reactor. They will have their procedures. They will march through those procedures at the pace necessary independent of time pressures, but reacting to physical plant parameters, to take, to address the conditions of the core.

So you know, I heard you say that there won't be conference calls and all that stuff. Notwithstanding the fact that there will be a technical support center advising that licensed operator, notwithstanding the fact that there will be an emergency operating center thinking about offsite risk and advising that person.

But I just wanted to emphasize that the decision making is retained by the licensed SRO. And they'll be making those decisions in real time and in accordance with their approved procedures.

That's all I have to add. Thanks.

MEMBER MARCH-LEUBA: Matt, I don't want to start an argument. But what the FSAR says, is that once you reach the ECCS operations, the RRB opens.

You are in a safe and a stable condition. And your operator is finished with his job. He doesn't have to do anything else. That's what the FSAR says today.

MEMBER KIRCHNER: So may I -- Jose, let's then save that and explore it with both the Applicant and the staff. Because now, we're getting into a discussion mode.

So with that, I'll be a little peremptory. And I'm going to turn first to NuScale. Is Paul Infanger going to be the first presenter?

MS. NORRIS: This is Rebecca Norris. I'm actually doing the introduction. And Paul will be the primary.

MEMBER KIRCHNER: Okay. Well please Rebecca. Sorry, my apologies. Go ahead, Rebecca.

MS. NORRIS: Oh, no problem. So thank you, Member Kirchner and Member March-Leuba. So first of all, good morning or afternoon, depending on what coast you're on. I am Rebecca Norris with NuScale Power. I am the supervisor for the boron redistribution audit that just closed. And also the associated design changes.

So first I would like to say that we do disagree that the -- with Member March-Leuba that the reactor will be placed in a dangerous position. However, we want to leave that to the NRC's presentation, because we have defended that position with them. And they will be presenting their SER conclusions.

And if we need to provide input at that time, we can. This presentation that we are about to give you, is just describing a high level overview. No further design changes were implemented since the June 3rd to 4th ACRS meeting, where we gave the initial presentation of design changes.

And additionally I want to thank the staff for their thorough review of the safety and completeness of our design solution. Safety has been and will continue to be NuScale's top priority. And we appreciate the staff's flexible response when the need for a late breaking design change became apparent a few months ago.

So with that, I will turn over to Paul Infanger for the body of the presentation.

MEMBER KIRCHNER: Paul, do you have your mic unmuted?

MS. NORRIS: This is Rebecca again. It seems we're having a little technical difficulty. If you can give us a moment or two to try to address it.

MEMBER KIRCHNER: Surely.

MR. INFANGER: I think I was muted there by the program. Hello, can you hear me now?

CHAIR SUNSERI: Yes, Paul. We can hear you. Go ahead please.

MR. INFANGER: All right. Thank you. Good day and welcome, this is our presentation of kind of an update for what we have done last month.

And we're going to be updating what we have provided to the staff as part of our boron redistribution issue. We have provided some information about the boron redistribution audit.

And we will provide a summary of our final design changes. And also discuss what information we added to the design certification, Revision 4.1 on the boron redistribution.

We also made some changes to the local topical report for the boron redistribution. And also there was a separate issue that came up during the boron redistribution audit, related to GDC-33. And we had mentioned that in the June 3rd and 4th meeting.

But at that point, everything was predecisional. And we didn't know exactly what the resolution would be. And that process is complete. And that information was submitted in the DCA Revision 4.1. And we'll go through a little bit about what we did for that. And then we'll talk a little bit our conclusions.

So just as a recap, we made two presentations on June 3rd and 4th. We provided an overview in the public meeting. And then we had a separate session for a closed meeting, where we provided a lot of technical detail into how we calculated the flow through the new riser holes. And answered some questions that came up during the open in the first closed session.

So the basic -- the basic issue was that, you know, under certain conditions ECCS actuation or respiration of the natural circulation with BHRS, could transport polluted coolants to the reactor core from a downcomer that has lower boron concentration. And we presented the design solutions that we developed to prevent or mitigate the boron distribution.

MEMBER MARCH-LEUBA: Let me stop you right there. Because this sentence is a little misleading. Do you agree or do you disagree that after the RRB is open, will the coolant design with holes, the downcomer continues to de-borate, or continues to be boron redistribution?

MR. INFANGER: Yeah. Once you've actuated ECCS, the level will be below the holes. And at that point, you will, the downcomer will dilute. Yes.

MEMBER MARCH-LEUBA: And we don't know how long you have to stay there. It can be an hour, or it can be 10 hours. It can be 100 hours. So you decided not to analyze that position.

MR. INFANGER: Yes. So check the 15 and scope is 72 hours. Beyond that case is in Chapter 19 and in Operations.

MEMBER MARCH-LEUBA: So how long does it take for the downcomer to de-borate after the ARB is open?

MR. INFANGER: I don't have the time --

MEMBER MARCH-LEUBA: So it could be less than 32 hours, right?

MR. INFANGER: I --

MEMBER MARCH-LEUBA: Remember, this is working full steam. All of the steam generated is exposed to this environment. And all of the upper parts of the containment is open to the steam environment and condensing on the wall with a very cold UHS.

So whatever calculation you did for the new calculation, you wouldn't be bounding for this condition. So you -- is it true that you did not calculate this condition? For this occurrence here?

MR. INFANGER: Yes. When you -- once you actually ECCS the pressures between the reactor pressure vessel and the containment equalize. And initially, the initial flow is out into the containment. And then the flow that starts when ECCS starts its natural circulation process, the flow is very slow.

And it's just the condensate level difference from it condensing in the containment. So there's no unusual --

MEMBER MARCH-LEUBA: But I just got that same thing -- on a humongously large surface, just the outer shell of the containment, which is in contact with the pool, which should be at 70 or 80 degrees. So you are -- I mean whatever steam makes it there is condensing.

But we have established -- we're not going to argue about the physics. We have established that NuScale does not know how long it takes for this condition to de-borate.

MR. INFANGER: We do. I don't -- I didn't prepare that information for this presentation. So --

MEMBER MARCH-LEUBA: You do. You have a document, a documentary calculation for that?

MR. INFANGER: We have calculations. And they have been audited by the staff.

MEMBER MARCH-LEUBA: Can I see them?

MR. INFANGER: We submitted that information on the docket in RAI-8930 response we updated.

MEMBER MARCH-LEUBA: Well so how long does it take to de-borate?

MR. INFANGER: As I said, I didn't prepare that information.

MEMBER MARCH-LEUBA: You don't know.

MR. INFANGER: Well --

MEMBER MARCH-LEUBA: But you --

MR. INFANGER: NuScale knows. I didn't bring that information to this presentation.

MEMBER MARCH-LEUBA: Okay. I'm talking to the staff now --

MR. INFANGER: You can probably look back at some --

MEMBER MARCH-LEUBA: I'm talking to the staff now, you obviously since this information apparently exists, you obviously have reviewed it during the audit. And you will be able to tell me what this time is. I mean nowhere in the FSAR says that the chamber de-borates after RRB is open.

VICE CHAIR REMPE: Could I ask what tool NuScale used to do these detailed calculations to determine when it de-borates? Because I saw some information in the SER indicating they'd reviewed the NuScale calculations. But I'm just curious about the level of detail and what the analytical tool was used?

CHAIR SUNSERI: And while you're thinking about that question, this is Matt. I have one, maybe a similar, but slightly different.

Once the ECCS valves open up and you flood the containment, or you establish the level in containment and you couple the core through the core barrel to the water in the containment, through the containment liner, to the ultimate heat sink, when does that conduction rate of cooling diminish the -- be equal to decay heat removal such that you're not steaming the reactor anymore? I guess, or does it ever get to that condition?

MR. INFANGER: This type of information would have to be presented in a closed session. We did not prepare a closed presentation for this meeting. Staff is going to be addressing these in their review of the ACR. And at that time, if there's questions, we could -- we could chime in.

MEMBER MARCH-LEUBA: Yeah. Well let's -- in the open session, what do you claim? Your claim is that the -- after the level drops below the orifices, the downcomer does not de-borate, or it does de-borate? If your claim that the one goes slowly --

MR. INFANGER: There's no mechanism --

MEMBER MARCH-LEUBA: Go ahead.

MR. INFANGER: There's no mechanism to get the un-borated water from the downcomer into the reactor.

MEMBER MARCH-LEUBA: So it will eventually de-borate. We might be arguing about how long it takes.

MR. INFANGER: Yeah. And at that point then it becomes an operational concern. And we've got -- we have CO items to develop procedures that will -- that are required to look at low boron concentration in the containment and the downcomer. So those procedures --

MEMBER MARCH-LEUBA: Have you ever rated -- since we are doing a risk informed evaluation, have you calculated the risk that this dangerous condition poses to the reactor by, you know, by what the calculation claims? Or things that we don't know like oscillations, sensibilities, depressurization? Have you ever rated that risk?

MR. INFANGER: The physical phenomena that we're addressing in design basis space are due to analytical simplifications that make the condition difficult to calculating mixing in the actual condition. And that's why we did, we did modifications that are, prevent the condition from happening in the 72 hour time frame that we're required to evaluate for Chapter 15.

MEMBER MARCH-LEUBA: Well you're just speaking on the record.

MR. INFANGER: It definite -- it one -- but once it --

MEMBER MARCH-LEUBA: You are speaking on the record.

MR. INFANGER: But once you've gone to Chapter 19, if you use the Chapter 19 methodology, we don't believe that there is a mechanism that would lead to this, the operation of that.

MEMBER MARCH-LEUBA: Is it a model for relief? Is it a religious belief? Or do we have a documentation that you have analyzed every possible actuation error? Have you agreement? I mean it's -- does that document exist that we can look at it?

CHAIR SUNSERI: Hey --

MEMBER MARCH-LEUBA: Am I supposed to believe you?

CHAIR SUNSERI: So let me ask a question here and jump in here. I think we're all anxious for the answers to these questions. And I think we may be just getting a little ahead of ourselves. Why don't we let the Applicant go through the information they want to present.

Listen to what they have to say. And then, you know, before this is all over, we'll have the chance to ask our questions either in open session or closed session, depending on where it's appropriate to do so.

We're kind of stuck -- I think we're stuck right here at this point in time, to be honest. And I think we can -- we would do ourselves better to move forward, hear what they have to say, and then --

MR. MELTON: Hello, Matt? Matt, this is Mike Melton with NuScale. Can you hear me?

CHAIR SUNSERI: Yes. Yes, Mike.

MR. MELTON: Yeah. So I would appreciate it if we could stay on the purpose of the presentation. We would be happy to address some of the comments in the closed session. But that really is the staff's presentation and their time to talk about the FSARs.

So if Paul could stay on track, we'd appreciate it. We absolutely disagree with the wording dangerous. And I think at the end of the slides and the discussions, we should get to that point. We do not see any core damage period, after all the work we've done.

And we'll be happy to bring the ACRS and Dr. Leuba up to speed as necessary as we go through this process. But for now, I was thinking --

MEMBER DIMITRIJEVIC: May I also --

MR. MELTON: If we could stay on track with our presentation and go forward.

MEMBER DIMITRIJEVIC: Yes. But in your presentation, you should really define to us what scenarios you have looked. Because so far we have a very general discussion. But not really the definition of all initiated three to that state.

And water that's receiving this scenario and sequences leading to this state. Any in what time we will get in the situation we have to worry about something? So far, we have a general discussion. But it's not translated to, at least in my opinion, it's not translated to Chapter 19 scenarios.

MR. MELTON I appreciate that. I think we will get there. We are presenting the differences from the June 3rd and 4th meeting where we had extensive discussions with the ACRS, and the final changes that we made in that time period.

And during that time, we have been involved in detailed and challenging conversations through the audit with the staff. They will present their findings as is pretty much the bulk of this meeting. So what we want to do is bring the ACRS up to date on our status and our changes that got us to this point.

MEMBER MARCH-LEUBA: But I need to intervene here a little while. Sorry to not get along. But this is going to be a long meeting. In the June meeting, we were told that when you turned CFDS after the breaking downcomer, after activating the ECCS. It would not possibly cause any core damage, because there was some time constant thing.

And you confessed that that was just an opinion. And there was no calculation behind it. So have you done a -- am I to understand what you're saying now that you have calculated what happens when you turn CFDS after downcomer regulation?

Is that being documented? And is there a document you can give me the number so I can go into the reading room and read it? Or you have not? This could be --

MR. INFANGER: Yeah. I've got --

MEMBER MARCH-LEUBA: Exactly what we're doing for this presentation. What has been done since June to now?

MR. INFANGER: Yeah. We did a calculation. And if Ken Amone (phonetic) is on the line, he was the engineer for CRA that just did that evaluation. If you could just, Ken if you could just give a brief summary of what we did. This is a -- again, this is a public call, so we cannot get into the proprietary details.

MEMBER MARCH-LEUBA: I'm willing to wait until the closed session as long as you tell me the document information now exists, and has been documented. Because in June, it had not.

MR. MELTON: We -- this is Mike. We have completed the calculations.

MEMBER MARCH-LEUBA: Okay. So where --

MEMBER KIRCHNER: Jose, this is Walt. I'm sorry everyone, I was dropped off the Skype there for quite a bit. So thank you, Mr. Chairman for intervening. Let's let the Applicant go through the slides they have to present, and then ask our questions.

I think, Jose, you've got your point on the table. And let's hear from them at this point. And then either we'll take it up in closed session or at the end of their presentation. So Paul, please go forward.

MR. INFANGER: Can you hear me? I think I've had some microphone problems here.

MEMBER KIRCHNER: Your audio is a little garbled for some reason.

MR. INFANGER: Okay. It was -- okay, is that any better?

MEMBER KIRCHNER: Somewhat. Okay, go ahead.

MR. INFANGER: Okay. The purpose of this presentation is to inform of additional work since the June 3rd and 4th meeting of ACRS. And implement some design changes to the topic reports and the staff changes.

MEMBER MARCH-LEUBA: Sorry Paul, you are really garbled. I can barely understand it. But it's really bad.

MR. INFANGER: I'm going to hang up and call back in. It will just take a minute.

MEMBER MARCH-LEUBA: Okay.

MS. NORRIS: This is Rebecca Norris. While he's reconnecting, just so everyone knows, we are on slide four, about to go to slide five.

(Pause.)

MR. INFANGER: Okay. I've called back in. Is there -- am I any clearer?

MEMBER KIRCHNER: That's much better. Yes. The Court Reporter could not work with the previous audio. So go ahead Paul.

MR. INFANGER: All right. One more time. Okay, so again, this is just an update to the June 3 and 4. There is new technical information as we'll talk about shortly. The -- in this time period since the last meeting, we've continued on with the boron distribution audit.

That audit had initiated on March 9th. And we've had daily meetings between NuScale and the staff. In the mornings we would basically meet with the staff, tell them what information we put in the electronic reading room, or we would take requests from the staff for additional documentation. And schedule any technical calls that were needed. We had numerous technical calls, often three or four a week that lasted several hours a day.

We documented 21 submittals that described design change information, provided analysis, and the DCA changes. And on June 19th we submitted final DCA changes for this boron redistribution issue. It was a complete submittal with all parts of the DCA. And then we exited the audit on June 26th, just a couple of weeks ago.

So this is very similar to what we presented on June 3rd and 4th. The design changes, everyone is pretty well aware of it. We implemented these design changes to prevent the possible boron solution sequences. And the --

MEMBER MARCH-LEUBA: Sorry. Let me stop you right there. Because this is another misleading slide. You introduced some design changes to prevent a subset of the postulated boron distribution sequences. Is that correct?

MR. INFANGER: I think we --

MEMBER MARCH-LEUBA: I mean we still have -- we still have sequences.

MR. INFANGER: We believe the --

MEMBER MARCH-LEUBA: You believe in what?

MR. INFANGER: We believe all of the

sequences we were required to evaluate for Chapter 15.

MEMBER MARCH-LEUBA: Okay. So you did not include any ECCS, forced ECCS actuation de-boration? Correct?

MR. INFANGER: The design changes we implemented we believe prevent those situations.

MEMBER MARCH-LEUBA: But how can you say that? The moment you actuate the ECCS, the water level drops below the orifices, and it's past de-boration. So it does not prevent boron dilution. Both, it prevents some of it.

MR. INFANGER: Well we'll have to get into it in the closed session. But there's no mechanism to get the water from the downcomer into the core. So the --

MEMBER MARCH-LEUBA: And there is a thorough and exhaustive search for all possible scenarios. And you have recommended that?

MR. INFANGER: Those were evaluated in our, by our engineers and by the staff. So we'll go -- they will -- at this point, we're just giving a status. And the staff will explain how we met the criteria for the SER. And then if we have additional questions, we'll address them at that time.

MEMBER MARCH-LEUBA: I just wanted to

point out that this slide -- this slide says the design changes prevent these boron solution sequences. All of them on this slide. But if the sequences --

MEMBER KIRCHNER: But Jose -- Jose, this is their position. And we will have an opportunity to challenge it. So let's continue on at this point and not quibble over the wording of the view graphs. I think your point is well taken.

And I'm certainly prepared to ask that question when we get to the right juncture about whether this prevents all possible boron dilution sequences. So let's continue on. Go ahead Paul.

MR. INFANGER: Okay. The -- in addition to the four three-quarter inch riser holes, we added an ECCS actuation on low RCS pressure. And we lowered the set point for the ECCS actuation on containment level.

For the DCA, we provided additional information for the staff to support their development of their safety evaluation. And some of that information that was needed, the staff wanted more information related to the ECCS actuation signal interlocks.

They wanted that referenced in the ECCS actuation table in Chapter 6. And also in the Chapter

15 analytical limits table. So those now reference the table in Chapter 7, which goes into detailed information about all of the permissives and interlocks associated with the ECCS system.

Probably the single largest change we made, is we added a section in the long term cooling section of 1505 of Chapter 15. We added a description of the riser hole flow path evaluation.

We -- the downcomer boron concentration remains above the critical boron concentration during DHCS cool down for beginning cycle and middle cycle events. And there's minimal impact at the end of cycle due to the low boron concentration in the reactor.

VICE CHAIR REMPE: So it doesn't matter because we have copies of your slide Paul, but I think what's on my screen is slide six. And I think you're getting ready to go to slide eight. Have we lost whoever is running the slides connection?

MR. INFANGER: I just finished slide seven.

MS. NORRIS: This is Rebecca. I am presenting. Mine shows slide eight. Are other people having the same problem? I can cycle the presentation.

MEMBER PETTI: I see slide six.

VICE CHAIR REMPE: That's what I see too. I think you need to reset.

MS. NORRIS: I'm sorry.

VICE CHAIR REMPE: It's not a big deal. We've got our own copies. Just keep telling us what slide you're on, Paul.

MR. SNODDERLY: Yeah. Just -- this is Mike Snodderly. Just quickly, if you don't activate your screen once in a while, it will go to sleep.

And that's, I think, the problems that Paul and Rebecca are having. So please, just once in a while, move a slide, or -- to keep your system active. Thank you.

MS. NORRIS: Understood. Hopefully you can see it again now.

MR. SNODDERLY: Not yet. It's loading. We can see it. Please proceed. You're on slide eight.

MR. INFANGER: Okay. Okay --

MEMBER KIRCHNER: Paul, was there something you wanted to cover on slide seven? What we see in front of us right now is slide eight.

MR. INFANGER: Oh, well slide seven was the DCA changes. And the -- where we added ECCS actuation information on the interlocks to the Tables in Chapter 6 and Chapter 15. This was information the staff wanted for, related to the instrumentation. And we added a section 1505, added information to that section that describes the -- more details about the riser hole flow path and how we performed that evaluation.

And that presented the information that the boron concentration in the downcomer remains above the critical boron concentration for beginning and middle of life scenarios. And at end of life, there's very little impact because the boron concentration is very low.

MEMBER KIRCHNER: And Paul, for the record, all these -- this is Walt Kirchner. For the record, these calculations of boron concentration were performed how? Were these just the next balance calculations? Or were they RELAP? Or were they computational fluid dynamics calculations?

What was the tool that was used to estimate boron distribution concentration gradients and mixing in the downcomer and lower plenum?

MR. INFANGER: Okay. Ben Bristol is from our -- a supervisor in our engineering for safety analysis.

MEMBER KIRCHNER: I'm not asking for the details now, just the methodology that was used for the public record.

MR. INFANGER: Yeah. I was going to ask Ben to give a brief, nonproprietary description of the -- of how we calculated the downcomer boron.

MR. BRISTOL: Hi. Sure. This is Ben Bristol with NuScale. The -- at the ACRS that -- we would present to the ACRS in June, we performed a simple mass volume-based distribution calculation based on inlet and outlet flow conditions.

MEMBER KIRCHNER: Then a question I will ask in the closed session is: what kind of granularity was used to do those estimates? In other words, what axial noding was employed?

MR. BRISTOL: Well we can go through that.

(Pause.)

MEMBER KIRCHNER: Keep going Paul.

MR. INFANGER: And --

VICE CHAIR REMPE: Another question for -- you can wait until the closed session if you want to, but today we're going to hear about the staff and how they evaluated this issue.

And you've mentioned you're going to be developing some procedures. Are you planning to use a more sophisticated tool in the future to support development of these procedures? And you can answer later if you want to.

MR. INFANGER: Those are going to be in the COL Applicant's -- the design certification does not develop procedures. That will be the Applicant for the combined license.

VICE CHAIR REMPE: So the staff will be needing to evaluate what the Applicant does, and hopefully with more detailed evaluations.

MR. INFANGER: Right. We have a COL item that -- we have a COL item that requires the Applicant to develop procedures, which includes covering this scenario.

VICE CHAIR REMPE: And does it say using more sophisticated tools? I've forgotten what the exact wording of the COL item was.

MR. INFANGER: No. It's not that prescriptive.

VICE CHAIR REMPE: Thank you.

MEMBER MARCH-LEUBA: Okay. While we're talking procedures and tech specs, can you tell me how you measured the boron concentration? What instrumentation is used? That is part of the specification, specifying instrumentation.

MR. INFANGER: We have a -- there is a boron measurement that comes off of the CDCS discharge line. But the detail on the instrumentation is part of the design.

MEMBER MARCH-LEUBA: So it is the PSS, right? Prime something system. And the only thing that was in the drawings.

MR. INFANGER: It's a balanced plant system. It's not interlaced.

MEMBER MARCH-LEUBA: Yes. Correct. Now if that boron concentration, first, when you have a tech spec that says your boron concentration has to be, say, 2,000 for Mode 5. What do you mean?

Do you mean the boron concentration in the core or the downcomer? What does a tech spec mean when it says your boron concentration must be 2,000?

MR. INFANGER: Okay. Well --

MEMBER MARCH-LEUBA: Okay, while you think about that, you obviously cannot mention the boron solution. This boron system, the boron instrument samples off the CDCS let down line. At what elevation does that let down line come into the vessel? And specifically, is it above or below the water level?

MR. INFANGER: It would depend on the, on the level --

MEMBER MARCH-LEUBA: If you get there and your goal --

MR. INFANGER: All right. Well --

MEMBER MARCH-LEUBA: Your arteries are open and you're cold. What I'm going to is, I don't believe the design you're sending for certification has a boron measurement system that you can rely on under these conditions, or at least I haven't seen an analysis that shows it. And that's not efficiency.

MR. INFANGER: Right.

MEMBER MARCH-LEUBA: I mean we are certifying that instrumentation. And we will want to, so but I think we've established that whenever we take readings for operator procedures, set points, tech specs, if the instrumentation doesn't work, you haven't thought very carefully how to do it. However, I'm out.

MR. INFANGER: Okay. Thank you. We will --

MR. MELTON: This is Mike Melton. We will defer those questions. We have thought carefully about everything. And we should be able to address that later after the staff makes their presentations.

MEMBER MARCH-LEUBA: Eagerly await them.

MR. MELTON: Okay.

MR. INFANGER: The next slide is slide eight. Finishing up on the LOCA topical report, the staff had requested additional information about the ECCS actuation on low pressure. The LOCA topical was, the sample calculations were completed before we added the low RCS pressure ECCS actuation. And so we added information to state that the existing calculations were still conservative.

That the -- there would be some scenarios where you would get an earlier ECCS actuation than was done in these LOCA calculations. But the results have been conservative results, because used for MCHFRN for the last liquid level above the top of that fuel.

Most steam spaced breaks will go on the new RCS pressure, low pressure ECCS actuation. And some liquid space breaks. So we added that information to the topical report to -- and stated that it would be information in the topical report, still demonstrated that the methodology was conservative and balanced.

We also added descriptions of the ECCS actuation signal interlocks. The -- again, since the topical report was developed before the new signal, no RCS pressure was added, that is new information. But we also added the interlocks associated with the existing containment level of ECCS actuation for consistency.

And a description of what the interlocks are there for. And those are to prevent ECCS actuation for non-LOCA events and expected operational conditions. So you don't want ECCS going off on -- for non-LOCA events or during other planned reactor operational scenarios.

We also added a discussion of the function and impact of the riser holes too this topical. And the main conclusion on that was that the analyzed flow range remained the same, the minimum and maximum remained the same even with the riser holes.

And slide nine. So that's -- up to slide eight, that describes what we changed since our -- the submittal we had. Right before June, I believe it was on May 20th, we had submitted an update to the DCA and topical reports.

And then since then, the changes that we've made were the ones I just described. So those were new since the last presentation we made to the ACRS. So the other topic we wanted to address in this public presentation was an issue that came up that was still in development when we are making the last presentation. So we didn't have the information to present.

And that was on the General Design Criteria 33. And what GDC-33 does is it has a requirement that the rev coolant makeup system is available to mitigate small RCS breaks with or without AC power.

And NuScale had already submitted with the initial application, an exemption to GDC-33. And primarily because the MPM design does not require additional coolant to maintain adequate core cooling for the duration of design basis events. So we didn't need a makeup system to handle leaks. Because leaks go into the containment and the containment, fluid in the containment is available during ECCS actuation.

So you don't actually lose the coolant, so there was no need for makeup. So as such, the chemical and volume control system, make up system, the system itself and the backup power are not safety related. It's not required. But one of the things that was missing from the initial application really is we did have just some description of the exemption. But we didn't discuss now we actually met the intent of GDC-33, and that's with the ECCS system.

The ECCS actuates automatically for the LOCA spectrum. And you know, LOCA spectrum is defined as any leak greater than the makeup system capacity. And it also actuates for most smaller leaks. And then depending on pool temperature down to, you know, almost single digit amounts of leaks.

And then we did an analysis that was for smaller leaks, we still meet staff goals without needing to provide any makeup.

So slide ten. We've enhanced the basis for our GDC-33 exemption. As said, the original revision four of the DCA only had information in Section 9 of the DCA, which is -- because that's where the acceptance criteria for most plants on the makeup system would be, in Section 9.3.

And since we didn't have -- since we didn't have -- since we just, in that section we just said that we didn't need a make up system to meet the GDC, it was not applicable to the MPM design. And then we didn't credit CVCS. But we didn't have information to support how we did meet the GDC, or at least the intent of the GDC, because we did request an exemption from it, because the wording does specifically call out make up systems.

So we added information to the SR 4.3 basically saying that small leaks with now ECCS, the boron mixturing is maintained by riser holes until the holes are uncovered. And the core concentration remains above the initial boron concentration for 72 hours.

So that information is in with the core description in SR 4.3. And then in Section 6.3 for ECCS, we added information that the ECCS actuation on the set points, or on the 24-hour timer prevents that lose AC power, mitigates most leaks.

And then we evaluated and showed that smaller leaks, that with really cold pool temperatures down around the low tech spec limit, they won't get automatic actuation of ECCS in 72 hours. But that they don't challenge SAFDLs, and no credit is needed for the CDCS make up system.

MEMBER MARCH-LEUBA: Paul, when we're talking about Chapter 6, I don't have it in front of me right now, but I'll paraphrase it. The main thing that it says, on boron and downcomer degradation is prevented after ECCS actuates. And it appears several times, the after ECCS actuates.

What you mean is that you have demonstrated that it doesn't de-borate up to the point of ECCS actuation. But we have established that after ECCS actuation, it will de-borate.

So if we are going to issue a final

version, it would be nice to fix that section says what you really mean. Which is instead of after ECCS actuation, you mean up to the point of ECCS actuation, because that's what you demonstrate.

MR. INFANGER: I think we need to address that in the closed session.

MEMBER MARCH-LEUBA: This is just that. Okay. We will, but I'll bring it up again.

MR. INFANGER: All right.

MEMBER KIRCHNER: Yeah, Paul. This is Walt Kirchner again. Yeah, on your second major bullet, there's two sub-bullets. This is of much interest for us. So we expect that we'll get to hear the calculational evidence to support the two statements there.

I would just note that yes, of course the core concentration remains above the initial concentration. That's not the issue. The issue is, what is the downcomer and lower plenum concentration? Because any perturbation would then allow the possibility of that lower boron concentration to enter the core.

And that is the main concern. Not that the core concentration remains above the initial concentration. That's not a good metric. That's not a good figure of merit in this case. That's not the concern.

So what it says there is good and correct. But there should be a third sub-bullet that says and the, the dilution of the downcomer and lower plenum does not raise the possibility of a reactive, insertion of reactivity on any upset.

And the upset could be any kind of perturbation on the system. Again, you've got two free surfaces here once you've got these conditions. And there are, you know, the operator could turn on the CVCS system to extract water; that's a perturbation. He could, or she could initiate spray.

There are a number of things that could perturb the status quo. So what is of most concern is: what's the concentration profile on the downcomer and the lower plenum in terms of boron?

Not just that the core remains. Probably the core, if there's no perturbations, the core will just have higher and higher boron concentration. End of statement. But we would like to explore that in the closed session. Maybe that's a hint to the staff.

MR. INFANGER: Okay. And that was evaluated by the staff. So we will direct to that.

So I'm going to move on. But I think it's the end of the information about the GDC-33. So the next slide is just, slide 11 is just the summary and conclusions. And that the statement of the design changes preclude boron redistribution for possible design basis and beyond design basis events.

ECCS actuation and low RCS pressure are high containment level. It shows the initial flow was out of the reactor pressure vessel into containment. And it precludes the influx of un-borated water from containment or downcomer. So your initial flow is going to be out. You're going to get mixing. And then the flow is going to be slowly back in.

The riser holes that show boron mixing in the downcomer and core region and for DHRS events, as it cools and shrinks, the RCS level above the riser does not shrink down below where the riser holes are. And the holes remain, the mixing of boron concentration are like a little mini flow between the riser and the downcomer and core.

For the smaller LOCAs and RCS leaks, while the holes continue to be mixing, while the RCS level is above the holes. And they ensure that the core concentration remains above the initial concentration.

And then we provided additional basis in Chapter 4 and Chapter 6 for our justification for our exemption to GDC-33. And explained how we met the intent of GDC-33 using the ECCS system.

And that the riser holes support the boron mixing. And there was no reliance on CDCS make up or operator action. And that SAFDLs continue to be met for all RCS leaks.

MEMBER MARCH-LEUBA: I need to say something, because this slide shows a clear bias or lack of attention to detail. Okay. First bullet, design changes preclude boron released solution for postulating design basis and beyond design basis events. Okay.

If you have an ECCS actuation, is that a design basis event? Because of a small LOCA for example?

MR. INFANGER: No.

MEMBER MARCH-LEUBA: Okay. Does the design change preclude boron redistribution in that case? Does the downcomer go into de-borate after you open the ECCS pump? So that statement is false.

MR. INFANGER: The analysis we've done shows that we do not have unacceptable reactivity events from those scenarios.

MEMBER MARCH-LEUBA: But you don't have to do an analysis. Once you open the ECCS valves, you are draining on the downcomer and the containment either from the water containment or from the steam generators. You're draining the steam water.

As I say, I don't know if it's going to take 10, 100 hours, 1,000 hours. But it -- the boron redistributing is beyond a shadow of a doubt. There is nothing you can do that will convince me that you don't release steam water. And admit you will end up with a completely de-borated containment and downcomer.

So that statement flies --

MR. INFANGER: No. But that water cannot get into the core. There just is no mechanism. And that's what our analysis shows.

MEMBER MARCH-LEUBA: That's not what you say. That -- that number one, that's not what you say in this slide. Number two, I have seen no evidence to support your statement yet. Provide me with some.

MR. INFANGER: We provided that information -- we provided that information to the staff. And they will be discussing --

MEMBER MARCH-LEUBA: I haven't seen it.

MR. INFANGER: -- how that's met. And then we will answer questions at that time in the closed session.

MEMBER MARCH-LEUBA: All right. Now on the other bullet, which says riser holes assure boron mixing in downcomer and core region and then go to the first bullet. To assure core concentration remains above initial concentration, if anything the presence of riser holes will reduce the core concentration, because some boron will leak to the downcomer.

So it has nothing to do with --

MR. INFANGER: You're talking about the concentration that when you're operating the power plant, you have a certain boron concentration. From that point on, the ECCS will concentrate boron in the core. And then you will -- even if these events --

MEMBER MARCH-LEUBA: ECCS won't concentrate boron in the core. The boron in the core will be concentrated by boiling.

MEMBER KIRCHNER: It's boiling is the phenomena that concentrates the core.

MEMBER MARCH-LEUBA: That is right.

MEMBER KIRCHNER: I think that --

MR. INFANGER: Right. It evaporates.

MEMBER MARCH-LEUBA: Okay. I'm just really -- but it looks a lot like there is lack of attention or detail. It's as if you don't understand the process.

I mean it doesn't seem like it. And I'm sorry to say that, but when I see these statements that are false on the face, it shows that you guys don't understand the problem. That is what the impression I get. Because you're making incorrect statements that are false on the face. I mean they're not.

So let's go on now.

MEMBER KIRCHNER: Paul, maybe I can help. I think the word here that is troublesome for Jose and me, is design changes preclude. I think they mitigate. But they don't preclude boron redistribution. The boron is going to redistribute when you have a LOCA event, any of these events.

You're going to get concentration in the hot part of the reactor pressure vessel, i.e., the core, probably the riser. Hopefully it's also mixing down in the lower plenum. I haven't heard anything about that.

The holes don't do it. The holes realize, as Jose actually points out, will diminish the concentration. But this is a good thing, because what you want is to prevent an accumulation of distilled water in the downcomer. That's why the holes are there.

So to support Jose's point, I think the choice of words here are perhaps not what you intend. I think the design changes mitigate the boron dilution like events.

But the boron is going to redistribute in the system. That will be a -- as soon as you're in the down -- as soon as the riser is uncovered, it's going to then result in boron concentration gradients.

That's not in and of itself a bad thing. It's the extended dilution of the downcomer that has -- is of most concern. So your holes there aren't precluding boron redistribution. They're actually doing a positive contribution to minimizing the dilution of the downcomer.

And it begs the question about the elevation of the holes. And we can explore that in the closed session for some of the transients which you already indicate there are transients where the holes are uncovered.

MR. INFANGER: Yeah. Boron redistribution will occur. But it precludes an unacceptable boron redistribution. And that was the intent.

MEMBER KIRCHNER: Yeah, okay.

MEMBER BLEY: Walt, this is Dennis.

MEMBER KIRCHNER: Yes, Dennis?

MEMBER BLEY: I'd like to get a comment on the table before we leave --

MEMBER KIRCHNER: Go ahead.

MEMBER BLEY: -- this session. And it's in support of Jose and a little bit Matt, I want to challenge what you said earlier.

Although operators will follow their procedures most likely, there's a whole host of operating events however that point out there are conditions under which it's difficult for the operators to do what we would hope they'd do.

As Jose points out, we don't have anywhere right now in the FSAR or in the operational chapters that point out there could be a long term boron dilution problem in the downcomer under certain conditions.

Without such a condition being identified here, some years from now, when the procedures are actually written, or we actually have operators, they don't have a low boron distribution in the downcomer alarm, or even an obvious measurement at this time.

And I think for me to be happy with this design cert at this point on this issue, there needs to be a condition or something added into the FSAR that clearly points out that this has to be considered very carefully when developing the procedures.

And this could drop off the table by that time. And operators aren't real good in responding to things that they haven't really thought about or worked on, and have to diagnose on the fly, sometimes without much help.

They might be sitting here and looking at, my God, how did this happen? Uh oh, now we figure it out. So I think without some form of --

MR. INFANGER: We did -- so we did enter that -- we did add that information into the FSAR. Chapter 4 and Chapter 15 both have detailed descriptions about the potential to have un-borated water in the containment and the downcomer.

And Chapter 13 requires procedures that will address all of those operating conditions. So all of that information is in there.

MEMBER MARCH-LEUBA: Oh come on. Come on. It's a phrase opinion at the bottom of a paragraph. At the bottom of a section.

MEMBER BLEY: I certainly agree on that, Jose.

MR. INFANGER: If it's required that -- so for Reg Guide 1.126 that you -- all procedures described in the FSAR are implemented into plant operating procedures. So it's -- there is, you know, a regulatory flow path there that requires all of this information to be in the plant procedures.

MEMBER MARCH-LEUBA: I've waited for you guys to show me the first --

MR. INFANGER: It's only in the --

MEMBER BLEY: How did you not -- and how did that slip through the process? We had a rule that said you ought to catch it.

MEMBER MARCH-LEUBA: Yeah. Yeah, but I got away from the decision. You guys can show me the calculations.

MR. INFANGER: So I'd like to remind the ACRS that we --

MEMBER KIRCHNER: May I intervene here for a moment? Thank you, Dennis. I think Rebecca Norris is pointing to me that Ben would like to make a comment. Let's let Ben, if we can unmute his mic. Go ahead Ben.

MR. BRISTOL: Yeah. Can you hear me?

MEMBER KIRCHNER: A little louder, please.

MR. BRISTOL: This is Ben Bristol with NuScale engineering. Can you hear me?

MEMBER KIRCHNER: Yes. Go ahead Ben.

MEMBER MARCH-LEUBA: Yes.

MR. BRISTOL: Okay. Yeah, I would like to remind the Committee that we spent quite a bit of time in March explicitly discussing the analysis that went into ECCS mode cooling, boron redistribution issues, and their potential for a safety concern from a Chapter 15 perspective.

And we included some discussion of what potential recovery actions could occur, to demonstrate that the systems were -- that we have in the design were sufficient to allow for safe recovery from those conditions.

What was brought up in the June meeting was the specific concern about an inadvertent ECCS actuation. And as Paul mentioned, we have -- we spent some time discussing that. We went back and spent and have done analysis of it. And if it would be useful, after the staff has finished their presentation tomorrow, we can certainly get into the details of our analysis of that.

But I've been a little confused with the conversation, the way the conversation has gone. And the assertion that NuScale hasn't provided analysis and hasn't performed analysis.

We've spent two years working with the staff on the analysis of boron redistribution during

ECCS cooling. And have acknowledged that boron accumulation in the core is good for reactivity and hold down.

We understand that boron solution in the downcomer, if it could sink to the core, would be of concern. And that, we've spent a lot of time looking at and evaluating and ensuring that doesn't exist.

MEMBER MARCH-LEUBA: Yes. But you spent two years studying the boron redistribution and did all the beautiful calculations with moving from the reds to blue and all that. And failed to define the uncontrolled cooling in passive mode. Which turned out to be an air hole.

And it had likely done core damage with a very high frequency is what I understood from NRC. So you just, you spent two years working on it. But you failed to identify the most important event that could happen in NuScale, and we have fixed it now.

So when you tell me that we've been looking at it, and I'm telling you, well, where did you, you can see here is what happens. I would like to see those analyses. Because if you spent two years doing it, then define it.

MR. BRISTOL: Okay. So just to clarify, we spent -- we understood that ECCS phenomenologically and that the way the boiling and condensing works, is a method for boron redistribution.

The NRC asked us about that several years ago. And we've spent a great deal of time quantifying what occurs when boron could be, and there are some simplifications that go into that analysis.

What we -- what we identified back in March was the specific concern prior to ECCS actuation that boron redistribution in the riser and downcomer, if the riser were to uncover, could result in core and surge events that need to be precluded.

And we spent some time in June explaining to the ACRS how the design changes have fixed that issue. But the issue of boron transport and redistribution and the analysis of it had already been presented to the ACRS back in March.

And we spent some -- a great deal of time reviewing that with the staff to ensure that there is no safety concerns, no safety issues for ECCS cooling mode.

MEMBER KIRCHNER: Ben, this is Walt. Yes, we acknowledge we heard and received the presentations on boron redistribution. The issue here is the boron dilution set of events that is of concern.

And you have correctly stated that after your corrective action, I may not be using the right terminology, that you looked at this and made the design changes. That's the holes in the risers, you changed set points, and so on.

So I think what we're looking for in the closed session, is again, the confirmation that in the event where we get shrinkage and/or redistribution such that we're now below the riser holes, within as I said in my opening comments, within a 72 hour envelope, do you de-borate the downcomer such that you could have the possibility or potential for a reactivity insertion event and consequences? And that, I think, right now, is what we're looking for.

And second, we can't leave the -- notwithstanding that you're going to develop operating procedures and such, we have to be convinced of, based on physics, that for example, reactivation of the CVCS system doesn't -- you're not sitting at a cliff, and then all of the sudden the operator operates one of these systems, either in a letdown mode, or a makeup mode, or a spray mode, or a containment drain and fill system, that it doesn't trigger an upset in the system that inserts diluted water into the core.

And the analysis to back that up. That's, I think, as succinctly as I can state it. And then again, you can't have a design where it's at a cliff state. So I would expect that you would put in tech specs at 72 hours, or whatever time, based on your analysis, that the operator intervenes and does such and such.

Because you haven't gotten to the end of the Chapter 15 analysis if the downcomer is sitting there with a de-borated condition.

MR. BRISTOL: I'll repeat. That analysis was provided to the ACRS and presented in March. The accumulation of the boron redistribution presentation that we presented in March includes the calculation of the rate at which the core accumulates boron and the downcomer dilutes boron.

And we evaluated the safety concerns of that condition. And presented that analysis in March. And the staff presented their findings in March.

MEMBER KIRCHNER: Okay. We will explore this with the staff. Members, are there other questions of NuScale at this point?

(No audible response.)

MEMBER KIRCHNER: Using the 15 second rule at this point then, Mike Snodderly just help me here.

MR. SNODDERLY: Yes. Yes, sir.

MEMBER KIRCHNER: Are we going to have --

MR. SNODDERLY: Yes.

MEMBER KIRCHNER: We're going to have a public presentation from the staff. Is that correct?

MR. SNODDERLY: That is correct. And I would like to request that Marieliz Johnson share her screen.

She will be the presenter for the staff. And if we can get started. Thank you.

CHAIR SUNSERI: Walt, this is Matt. While we're doing this transition, I want to take a 10 minute break.

We've been at this for an hour and 15 minutes. It's after lunch. We need to take a 10 minute break.

MEMBER KIRCHNER: Thank you, Matt. Well let's say we'll re --

CHAIR SUNSERI: Let's make it -- we'll reconvene at a quarter after the hour. 3:15 we'll reconvene.

MEMBER KIRCHNER: Okay. Thank you.

MR. SNODDERLY: And thank you, Marieliz. And we'll yes, see you guys at 3:15. And we'll start with Marieliz Johnson from the staff. And also I believe Anna was going to make an opening statement for the staff, Chairman Sunseri.

CHAIR SUNSERI: Understood.

(Whereupon, the above-entitled matter went off the record at 3:04 p.m. and resumed at 3:15 p.m.)

CHAIR SUNSERI: Okay, this is Matt Sunseri, I have 3:15. We will reconvene with a roll call of the Members. Ron Ballinger?

MEMBER BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley?

MEMBER BLEY: Here.

CHAIR SUNSERI: Vesna Dimitrijevic? Walt Kirchner?

MEMBER KIRCHNER: Here.

MEMBER DIMITRIJEVIC: Yes, I'm here sorry. I did not mute the button. I'm here.

CHAIR SUNSERI: Yes no, that's okay. I have that problem myself. Jose March-Leuba?

MEMBER MARCH-LEUBA: Yes, I'm here.

CHAIR SUNSERI: Dave Petti? Dave Petti, are you trying to -- Joy Rempe?

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella?

MEMBER RICCARDELLA: Here.

CHAIR SUNSERI: And myself. So we're just missing Dave. It sounds like he might be having a mic problem.

So we have a quorum, we can continue. Walt, I think the Staff had some introductory remarks they wanted to --

MEMBER KIRCHNER: Yes, I believe so. Would this be Anna Bradford? Who from the Staff is going to start?

MS. BRADFORD: Yes, thank you. This is Anna Bradford.

MEMBER KIRCHNER: Thank you. Go ahead, Anna.

MS. BRADFORD: Good afternoon. As mentioned, my name is Anna Bradford. I'm the director of the Division of New and Renewed Licenses in the Office of Nuclear Reactor Regulation.

I'd like to thank the Committee, as well as the ACRS Staff, for the opportunity to come before you today. And I'd also like to thank our technical project staff that have worked very diligently on the issues that will be discussed. And that have already had some interesting discussions.

In February 2020, NuScale identified a design issue associated with its boron redistribution analysis that required substantive design changes in order to demonstrate that the regulations were met.

And as result, we initiated an audit on March 4th. NuScale submitted their final design changes on May 20th and the Staff completed our audit on June 26th.

Over the course of the last several months the Staff has reviewed some very complex NuScale related design changes, which affected 11 design certification application chapters, five technical reports and two topical reports.

Today we're prepared to present our findings to the Committee. I believe that the Staff's presentational highlight our continuous focus on safety significance and supporting the NRC's mission to protect public health, safety and the environment.

And as you heard earlier, I would also like to note that we have recently received a differing view from a staff member that will be discussed during the closed session.

So thank you again for this opportunity, we look forward to the interaction with all of you today. And with that, I'll turn it back over to Marieliz.

MS. JOHNSON: Good afternoon. Marieliz Johnson. Today we're going to present a focused area, boron redistribution and the applicable design changes of the NuScale design application.

For the agenda we're going to present the NRC Staff review team, background, design changes, discussion by review team and the conclusions. In the next several slides you'll see the Staff, the review team.

A quick background. As Anna mentioned, in February NuScale modified NRC Staff about, of an error of the boron redistribution analysis and informed that they are following the corrective action program.

The Staff started an audit in March 4th with a scheduled letter on May 1st. On May 20 NuScale submitted their final design changes document. On June 3rd the Staff presented the audit status to the ACRS Members. And on June 26th we exited the audit.

The three design changes are the ECCS actuation on high containment water levels at point change, new ECCS actuation on low RCS pressure signal and addition of the riser holes.

Here you see the 11 chapters that were affected by the change. And the technical and topical reports.

Mike, do you have anything to add? Mike Dudek?

MR. DUDEK: I do. Can you hear me?

MS. JOHNSON: Yes.

MR. DUDEK: Okay. So --

MEMBER KIRCHNER: Yes, Mike, we can hear you.

MR. DUDEK: OGC has reviewed and approved seven of the ten chapters that experienced the design change. We are still working towards three chapters going through OGC. Those three chapters would be Chapter 6, Chapter 15 and Chapter 19.

We hope to have those OGC concurrences and legal, non-legal objections soon. And assuredly we aim to have them by the next ACRS date of July 21st. Thanks.

MS. JOHNSON: Now I'm going to turn it over to Yuken Wong so we can start the Staff presentation.

MR. WONG: Can you hear me?

MEMBER KIRCHNER: Yes. Go ahead, Yuken.

MR. WONG: Okay. My name is Yuken Wong from the mechanical engineering and in-serve testing branch. The NRC Staff, with the assistance from Dr. Stephen Hambric revealed the structural integrity and flow induced vibration effects related to the new riser holes.

The four riser holes are small compared to the riser. And the structure properties of the riser are not affected significantly.

The alternating stress due to the turbulent baffling is very slow. Even with a stress concentration due to the riser holes. The alternating stress will not approach the material critic limit.

NuScale calculated the discharging jet loads from the riser holes. And these loads are more than an order of magnitude, lower than the lows already considered in the steam generator tube analysis.

So the jet loads from the rider holes will not significantly affect the steam generator tubes.

The riser holes will not cause state residences. There is constant flow through the riser holes. And the flow eliminates the possibility of a shear layer flow instabilities.

In case the flow cannot suppress the flow instabilities, NuScale calculated the flow instability frequencies and the riser acoustic frequencies. These frequencies are well separated.

The Staff ordered the NuScale calculations and found that NuScale adequately addressed the riser structure integrity and potential flow induced by bringing the gaps of the riser holes.

MEMBER MARCH-LEUBA: Yuken, can I

interrupt you for a moment?

When you say flow instability, you mean a density wave instability in the current riser?

MR. WONG: No. This is the shield layer instability.

MEMBER MARCH-LEUBA: Okay. So it's a LOCA instability, okay.

MR. WONG: Correct. Okay, I'm going to turn over the presentation to Tom Scarborough.

MR. SCARBOROUGH: It tells me now I'm no longer muted, so I don't know if you've heard anything I've said so far.

So, let me start over. So --

MEMBER KIRCHNER: Could you start from the beginning please?

MR. SCARBOROUGH: I sure will. Thank you. Sorry about that. I don't know why it took so long to unmute me.

Okay. Okay, this slide has to do with the main valve itself opening.

MEMBER KIRCHNER: Hold on. Stop. Would you just identify yourself for the court reporter?

MR. SCARBOROUGH: Oh, I'm sorry. This is Tom Scarborough in the mechanical engineering branch.

MEMBER KIRCHNER: Oh, Tom, sorry. My

apologies. Go ahead.

MR. SCARBOROUGH: No problem. No problem. Okay, so early in the audit process NuScale indicated that they might rely on the ECCS main valve self-opening at low differential pressure.

So we looked at that as part of the audit process. So, the self-opening of the emergency core cooling system main valve was part of the initial group of concept testing of the valve system at the Target Rock Facility with pressurized ambient water in 2015.

There were several tests at that time that demonstrated that the main valve spring could open the ECCS main valve under a narrow range of very low differential pressure conditions. Now, the specific differential pressure conditions is proprietary, and we can get into more of that in the closed session if you like.

So the Staff looked at that. And in 10 CFR 50.43(e), that requires that the new reactor design features be demonstrated by testing or a test based analysis.

So, the Staff reviewed that Target Rock test report and determined that based on the repeatability of the test that the report provided a reasonable demonstration that the ECCS main valve spring will reliably open the main valve at very low differential pressure conditions would satisfy 10 CFR 50.43(e). So, that's where we go with that.

Now, we did look at the main valve spring itself. Now, the main valve spring is designed manufactured safety related component, but the function itself is not considered by NuScale to be safety related.

However, the Staff considers it to be important to safety because of its assumed performance to open the main valve at low differential pressure conditions.

So we looked at the design specifications. They specify the function of the main valve spring for low differential pressure operation, so therefore that function will be tested as part of the qualification program under ASME Standard QME-1-2007. As accepted in Revision 3, Reg Guide 1.100. So it will be covered by the design specifications.

Now also in the NuScale FAR in Section 3.9.6, it does specify that the performance assessment testing of the ECCS valve system will include testing to verify that the main valve will open at low differential pressure as either part of the shutdown process or a specific testing activity.

So based on that the Staff was comfortable with the self-opening capability of the main valve with that spring that's installed in the main valve. And that --

MEMBER BLEY: Tom?

MR. SCARBOROUGH: -- completes my presentation. Yes, sir.

MEMBER BLEY: This is Dennis Bley. My understanding from previous meetings was that function has already been tested. Is this further testing you're talking about?

MR. SCARBOROUGH: Yes, actually, the ECCS valve system testing that was conducted at Target Rock after the initial testing, we did look at the initial testing back in the 2018 time frame.

And the testing of the whole system itself, under the initial proof of contact testing, we did not consider that to be sufficient to satisfy 50.43(e). Because it focused on ambient water pressurized, it did not have high temperature water condition.

So from an overall performance of the ECCS valve system, that initial proof concept testing was not sufficient for a 50.43(e) demonstration. Because you didn't have any flashing, you didn't have the sharp changes in differential pressure that would occur under the operation of the ECCS valve system.

So NuScale conducted additional testing, in response to our questions, to demonstrate that 50.43(e) was satisfied using high pressure, high temperature water, and borated water, to show that it would operate properly.

Now, this goes back, the 2015 testing goes back to the ambient pressurized water, where here it's a much more simpler operation. You're just showing that under the conditions of the main valve itself that the small spring installed in the main valve would open the main valve at very low differential pressures. And do a repeatability.

And that's what they showed in that initial proof of concept testing back in 2015. So based on that we went back in time, like they had done initially. And that initial testing we considered to be sufficient to satisfy 50.43(e) for design certification.

Now of course, they still have to conduct design specification qualification testing, which is much more detailed, as part of QME-1. And they still need to do that.

But from a design certification perspective, we considered that initial testing to be sufficient.

MEMBER KIRCHNER: Tom, a question of clarification. This is Walt Kirchner.

Since you point out in your third bullet that the spring is important to safety, I am assuming that the ECCS valves are safety related components.

MR. SCARBOROUGH: Yes, sir. They are completely all safety related. And all the components --

MEMBER KIRCHNER: So what is the distinction you're trying to draw there?

MR. SCARBOROUGH: Oh. Because the function of the spring, the function of that little spring was not considered to be safety related by NuScale. The function of that small spring.

But everything is designed and manufactured, including the small spring, as safety related components under Appendix B. They're all qualified that way.

It was the function. We had this distinction that NuScale had that the function of that small spring was not considered to be safety related. But the staff noted that it is called out in the designed specifications, therefore it will be tested under QME-1 by the requirements of QME-1.

If it's in the design spec it is required by QME-1 to be tested to be qualified. And so they will be required to qualify that function of the spring.

So we're making the distinction that we're calling the function of that small spring to be important to safety under Appendix A to Part 50. And they still will need to be able to test it and quality per QME-1.

MEMBER KIRCHNER: Okay, that may be a conversation for the future but thank you. That helps.

MR. SCARBOROUGH: Okay, thank you. Okay, Marieliz, you can move on if there's no more questions.

MR. TANEJA: So, Slide 12. This is Dinesh Taneja from the I&C engineering branch.

The lowering of the set point for ECCS actuation on the high containment water level, affected Chapter 7 and the set point methodology topical report.

This design change did not require any changes to the containment vessel water level sensors.

The revised analytical range of 240 inches to 264 inches is within the calibrated span of 100 inches. That is from 220 inches to 320 inches.

The calculated total loop uncertainty is bounded by the plus and minus 12 inch nominal set point allowance that is assumed in all applicable analyses. Changes made in Chapter 7 are consistent with the assumption made in our applicable analyses.

Next slide please. So for the new ECCS actuation and low RCS pressure signal, existing wide-end RCS pressure sensors are used.

The safety classification for the sensor is being upgraded to A1. They used to be A2.

Changes made in Chapter 7 and Tier I tables 2.5-2 and 2.5-4 are consistent with the assumptions made in the applicable analyses.

Interlocks are provided to automatically bypass ECCS actuation when T hot is less than 475 degrees Fahrenheit or when containment vessel pressure is less than one psia.

Next slide please. Now I'm Slide 14. The set point methodology technical report is revised to demonstrate that the calculated total loop uncertainty is bounded by the plus and minus 100 psia allowance assumed in applicable analysis.

The advanced sensor technical report has also been revised to include the SFAS actuation function for the wide-end RCS pressure sensors and the related interlock functions.

Next slide please. Slide 15. Digital based sensors are used for the wide-end RCS pressure signals. Therefore, most could perform digital common cause failure assessment to demonstrate coping with the potential failure, potential failure mode of these sensors.

The best estimate D3 coping analysis, defense-in depth and diversity coping analysis, that credits xenon reactivity and all rods end condition, concluded that an earlier ECCS actuation, low RCS pressure, would not be required for any break size or location or LOCA break spectrum.

In these cases, ECCS actuation occurs due to high containment level or low DP across the ECCS valves. The Staff finds that sufficient diversity exists such that ECCS is available to mitigate these small break LOCA events.

This concludes my presentation. Any questions?

MEMBER MARCH-LEUBA: Yes, Dinesh. I apologize, this is Jose. I apologize in advance because I know you don't know the answer to this question, but I need to place the question because you're the I&C guy.

MR. TANEJA: Okay.

MEMBER MARCH-LEUBA: For boron, de-boronization of the downcomer, especially after ECCS actuation, carry has been taken at least orally, because I cannot find much documentation on this, carry has been taken from the boron concentration instrumentation, the boron concentration instrumentation, which will be used by the operator to enforce tech specs and to perform whatever those magic procedures the COL will come up with.

Now, this instrumentation we now know that is samples from the CVCS recirculation line. So CVCS must be running. It must be sucking water from the letdown line. And then that water will be sampled by the PSS and it will provide a concentration for the boron. Which will work very well during normal operation.

But what confidence does the I&C branch have that this instrumentation will work for the intended conditions?

And let me point you out that the CVCS letdown line, I cannot find the saturation, but this drawing show it 224 feet of the RB. So it's likely in the steam space.

Even if it's not in the steam space, for the recirculation to work CVCS has a centrifugal pump that is rated 50 gpm and is rated for more than 2,000 psi of operation. But in these conditions you will probably likely be super prosthetic and that pump will likely cavitate.

So you can tell me, no, I don't know, but my question is, what confidence does the NRC Staff has that the instrumentation that is being created to perform this operator action safely actually works?

MR. TANEJA: Okay. So in Chapter 7 space we evaluated all the pulse accident monitoring instrument, PAM instrumentation in accordance with --

MEMBER MARCH-LEUBA: No, this is the PSS. The PSS, plant sampling system.

MR. TANEJA: Right, right. So, you know, if the action, the credited operator action, it was credited in Chapter 15 space to --

MEMBER MARCH-LEUBA: It's probably in the Chapter 19 space.

MR. TANEJA: Okay. So if it's credited in the Chapter 19 space then we did not evaluate it in Chapter 7, we evaluate any potential operator action that is credited in Chapter 15 space as part of the PAM variables. Post action monitoring variables.

MEMBER MARCH-LEUBA: Yes.

MR. TANEJA: Which are documented in Chapter 7. So for mitigating or dealing with any of the events that are in Chapter 15 space, there are no manual credited operator actions.

MEMBER MARCH-LEUBA: Right.

MR. TANEJA: So therefore the sensors are the parameters that we evaluated. You know, this did not fall into that category --

MEMBER MARCH-LEUBA: Yes, but if --

MR. TANEJA: -- so therefor we did not need it to credit --

MEMBER KIRCHNER: Jose and Dinesh, this is Walt Kirchner. If it's a LOCA, and NuScale can correct me if I'm wrong, you'll get an isolation signal for the containment. This will isolate the CVCS line. You have no sample.

MEMBER MARCH-LEUBA: Yes, but you can always exceed it to get it. I mean, even one more reason why this doesn't work.

But even if the operator went to defeat the isolation and establish recirculation, you can because this is in the steam space.

MR. TANEJA: Well, you know, so the design basis event, you are correct that you are going to get an automatic containment isolation, which will isolate the sampling system.

And if you do need to take a sample, you would have to procedurally, and override the isolation signal to be able to access the sampling system to take a sample. So it really did fall outside of the DCA review in a boundary.

MEMBER MARCH-LEUBA: Now, is this is a wholly now review process? Maybe we need to think about it because if Chapter 19 takes credit for this instrumentation, 19, there has to be some specification that it works.

MEMBER DIMITRIJEVIC: Jose, this Chapter 19 doesn't take credit for this instrumentation. This operator action is not in Chapter 19.

Operator action, about staffing CVS and CVCS, which we've discussed before, they are totally unconcerned about the bottom in this moment. So this sequence, these actions are not put into the PRA. And we will bring that up as soon as we come to the Chapter 19.

MEMBER MARCH-LEUBA: Right. My point is, to my knowledge, by reviewing all of the available, the limited available documentation that is limited, that's available to me, I don't see any evaluation of the risk imposed by this de-boronization. I don't know --

MEMBER DIMITRIJEVIC: No, there is no. there I no scenario, there is no sequence, there is not any even discussion in Chapter 19 of this.

MEMBER MARCH-LEUBA: Right. Right. And in my humble opinion it should. Because we found out, we found out that the thing that the holes now solve, which is the small break, this lower being, small break LOCA, was the limiting core damage frequency by many others among it.

So, I just --

MEMBER DIMITRIJEVIC: The Chapter 19 is coming in the end of this presentation --

MEMBER MARCH-LEUBA: All right.

MEMBER DIMITRIJEVIC: -- so let's bring this up again then.

MEMBER MARCH-LEUBA: All right. But this was I&C. The I&C has, the Staff has not evaluated whether the boron concentration instrumentation works. It's available to the operator if they want to take credit for it whenever they want to take credit for it.

Now --

MEMBER KIRCHNER: Jose? Jose, this is Walt. In the current Chapter 15 scenarios they don't take credit and they don't un-isolate to look at boron concentration.

They have designed and analyzed and feel that they, as Paul has presented, prevent this event. In Chapter 15 space. So therefore there is no need for an instrumentation and sampling line.

MEMBER MARCH-LEUBA: Being Chapter 15 space because you are --

MEMBER KIRCHNER: They're assuming that there is no operator intervention --

MEMBER MARCH-LEUBA: Right.

MEMBER KIRCHNER: -- and that the design of the system and the systems, like ECCS that they rely on, actuation, are sufficient for their Chapter 15 scenarios.

MEMBER MARCH-LEUBA: Because customarily in other reactors we stop that Chapter 15 analysis when one reaches a safe and stable condition. Which for most AOOs is one minute or less. Okay.

And you never ride certain quality, you're on it for the first minute when you reach a safe and stable condition, you stop. My argument is that a de-borated lower plenum with 24 less or 25 hours' worth of positive activity, ready to get into the core at the minimum perturbation, is not a safe and stable condition.

MEMBER KIRCHNER: Yes. And you've stated that. I think they have the point and we will, let's explore that with the Staff when we get to Chapter 15.

MEMBER MARCH-LEUBA: Right. But we have built a foundation to have significant doubts that whenever NuScale wants to take credit for operator actions, the operator will be blind. He won't know where the boron is. Because the boron instrumentation doesn't work.

And this is part of the CVA. Instrumentation is part of the 75 design. Over and out.

MR. TANEJA: Thank you.

MEMBER KIRCHNER: Dinesh, please continue.

MR. TANEJA: I'm done, unless there are any additional questions. No other questions than Slide 16 starts with Chapter 16.

MR. HARBUCK: Good afternoon, this is Craig Harbuck of the technical specifications branch. And I'll be presenting the effects on the technical specifications by these design changes.

The first one, regarding the lowering of the set point for the high containment water level, ECCS actuation, had no effect on the tech specs as the set point for it is not explicitly stated being given as required by the set point program in the set point methodology.

And then for the new ECCS actuation on low RCS pressure, we added a new function and renumbered the subsequent functions. And in Table 331-1.

And for this new function we required four operable channels, as for the other functions in the table, for the most part, that are required to be operable in Mode 1 and Mode 2 when RCS temperature, hot temperature, is above 475 degrees Fahrenheit. And that is the new T6 interlock.

And then we added a condition to go along with this applicability so that if you were in default actions you would exit that applicability.

The other interlock, P1, ensures that unless the pressure, the containment goes above one psia, this function would be blocked.

The existing surveillances for the MPS instrumentation also apply to this function. And all references for these functions and tech specs and bases and additional explanatory information was added to the bases to conform to these changes.

Regarding the addition of the riser hole modification there was added material in the bases for tech spec subsections 331 and 351. And this concludes all the changes that are effective with technical specifications and the bases.

MEMBER KIRCHNER: Members, any questions?

MS. JOHNSON: Alex Siwy?

MS. SIWY: Yeah, I was just waiting. Fifteen second rule, right? This is Alex Siwy, and I'm a technical reviewer in the reactor systems branch. As described on Slide 17, one of the many areas the reactor systems staff reviewed with respect to the design changes is how the rise holes might impact steady state RCS characteristics and DHRS performance as described in Chapter 5.

Now the riser holes are relatively small, so we initially suspected that any effects would also be small. But to confirm that, the staff audited NuScale sensitivity calculations for five non-LOCA events that showed that the rise holes had an insignificant impact on steady state RCS and secondary parameters of interest as well as non-LOCA event progressions and figures of merit. In addition, the staff performed confirmatory calculations of a DHRS cooldown and observed that there were minimal differences when the riser holes were modeled.

MR. CORRADINI: Alex?

MS. SIWY: Yes.

MR. CORRADINI: You used just -- you used the applicant's RELAP calculation and did sensitivities with it, or you did a separate calculation with another tool within the NRC staff?

MS. SIWY: We used -- I believe it was the applicant's NRELAP 5 model.

MR. CORRADINI: And did additional calculations or had them do additional calculations?

MS. SIWY: Yeah, we performed additional calculations ourselves.

MR. CORRADINI: Okay. All right. Thank you.

MS. SIWY: So as a result of --

VICE CHAIR REMPE: Could you verify -- this is Joy. I'm sorry to interrupt you. But in both cases we've asked earlier today, what was the applicant's tools, and verify that they did indeed have RELAP 5 calculations.

MS. SIWY: Yeah. For these analyses, the applicant used NRELAP 5 consistent with their non-LOCA methodology.

VICE CHAIR REMPE: Okay. Thank you.

MS. SIWY: Sure. So as a result of this, the staff finds that the steady state RCS parameters and DHRS performance, as described in DCA Part 2, Tier 2, Chapter 5, would not change substantially if the riser holes were to be added. And therefore, changes to Chapter 5, other than a basic description of the riser holes, are not necessary. Are there any other questions on this slide?

MEMBER MARCH-LEUBA: Yes, Alex. And I apologize because I don't know if this proprietary or not. So I may put you on the spot. But I agree with you because I have seen those numbers, that the impact on the flow -- pressure and flow on these orifices is negligible. Can we say what the number is? Well, it doesn't matter. It is very small. Do you agree that the change in flow is very small?

MS. SIWY: I agree it's very small.

MEMBER MARCH-LEUBA: Yeah, and insignificant, right? Because what I'm going to is -- and we're not supposed to be designing the reactor for them. But if they had also drilled another set of holes at the RRV level, all of this problem would have went away because then we would not be deliberating the lower number. And the impact on operation is minimal. But I'm not designing the reactors for them. Over and out.

MS. SIWY: Okay.

MEMBER RICCARDELLA: I'm sorry, Jose. What level did you say that was in?

MEMBER MARCH-LEUBA: RRV, below the lowest water level that you can reach --

MEMBER RICCARDELLA: Okay.

MEMBER MARCH-LEUBA: -- you have a second set of holes.

MEMBER RICCARDELLA: All right. Thank you. That's all.

MEMBER MARCH-LEUBA: And then you never uncover them.

MS. SIWY: Are there any other questions or comments on this slide?

(No audible response.)

MS. SIWY: Okay. Can we please move to Slide 18? Thank you. The reactor system staff also reviewed several aspects of Chapters 6 and 15 with respect to the design changes and provides this brief summary of areas not substantially affected by the design changes. The first area is DCA Part 2, Tier 2, Section 6.2.1.1 related to containment analyses and the containment response analysis methodology technical report.

This area was not substantially affected because the limiting design basis events and resulting values for peak containment pressure of 994 PSIA and peak containment wall temperature of 526 degrees Fahrenheit were unaffected by the design changes based on NuScale sensitivity study results. In addition, the previously non-limiting cases remaining non-limiting with the design changes considered.

MEMBER KIRCHNER: Alex, this is Walt Kirchner. So your first bullet refers to actually the containment limiting design case, and I believe that is the reactor recirculation valve discharge inadvertent opening. What kind of loads did you see? Or I know we heard earlier from your colleague about structural loads.

Do you see because of these holes any kind of loading -- additional loading as the primary system goes down, in particular, impingement on the steam generator tube bank? I would expect the downcomer to void first, closest to the RRV, and then the pressure wave would kind of back up the downcomer and into the riser core area. So are there any concerns about loads because of the flow through the holes that have been introduced or impingement on the steam generator tubes?

MS. SIWY: I personally have not looked at that, and I'm wondering if any Chapter 3 reviewers might have.

MR. WONG: This is Yuken Wong. NuScale did evaluate the impingement loads, and those loads is about an order of magnitude lower than the loads from fitting and thermal expansion. So those are loads from the riser holes. It will have an insignificant effect on the adjacent steam generator tubes.

MEMBER KIRCHNER: Okay. Thank you.

MS. SIWY: Thanks, Yuken. So the second major area not substantially affected by the design changes is the LOCA and non-LOCA topical reports. The staff audited related NuScale calculations like I had discussed on the previous slide and confirmed that only conforming changes were needed such as the ones that NuScale mentioned already related to updating the LOCA topical report to acknowledge that there is a new ECCS actuation signal on low RCS pressure.

The third major area not substantially affected is basically all Chapter 15 non-LOCA events. As discussed on the previous slide, the riser holes have an insignificant impact on steady state conditions, transient progressions, and non-LOCA figures of merit. In addition, the changed high containment level ECCS actuation set point is not relevant to non-LOCAs because non-LOCA events simply don't accumulate sufficient level in containment to reach the set point. And finally, non-LOCA events are unlikely to actuate ECCS on the new low RCS pressure signal because of the associated interlocks that Dinesh mentioned earlier.

And the final area not substantially affected is the Chapter 15 inadvertent ECCS actuation events. For this event, the staff audited NuScale's qualitative assessment and agrees that the design changes would have an insignificant impact on steady state conditions, the transient progression, and figures of merit, in part, because of the current analysis for this event considers the immediate loss of DC power which results in the earliest possible ECCS actuation when the IAB release pressure is reached. Are there any questions on Slide 18?

(No audible response.)

MS. SIWY: Thanks. I believe the next presenter is Carl Thurston.

MR. THURSTON: Yes, this is Carl Thurston from the reactor systems branch. So I'm going to talk about the effects on the LOCA transient. Primarily, that would be 15.6.5, the loss of coolant accident.

So for the loss of coolant accidents, these are primarily affected by the low pressure signal. Because the low pressure activated a lot -- allowed the ECCS to activate a lot earlier. So steam space and larger liquid space breaks, they also activate a lot earlier on low pressure.

The earlier ECCS actuation and the lowered CNV level setting kind of minimizes condensation and improves boron distribution. And lastly, the minimum collapsed liquid level and CHFR figures of merit are not changed because the limiting case is based on loss of AC power. So those cases are not affected by the new RCS pressure set point.

MEMBER MARCH-LEUBA: Carl, Jose here again.

MR. THURSTON: Yes.

MEMBER MARCH-LEUBA: Your last bullet, what that means is that the -- (Telephonic interference.) -- operation on the CNV high level actuation setting does not change the medium collapse level on TAF. So I --

MR. THURSTON: So --

MEMBER MARCH-LEUBA: -- find that inconsistent because if you open it with the level two feet above TAF, for example, then containment is 15 feet higher than that.

MR. THURSTON: Well, so the limiting case for the top of active fuel is a very small 5 percent injection line break. And the reason that it's limiting is because you can fill up. So even if you have a case and this case does not assume DHRS, so the RCS pressure lags high.

So the level will fill up and then go beyond the new level set point and you have to wait for the IAB. So that way, you discharged the maximum amount from the reactor vessel into containment. And that's how you achieve your minimum level of active fuel.

MEMBER MARCH-LEUBA: Same as it was before the modification. But --

MR. THURSTON: That's correct.

MEMBER MARCH-LEUBA: -- if your level is only literally two feet above TAF, then the containment level is 15, 20 feet higher. When you open the RRV, you're going to have a very large flow going into the downcomer and the downcomer will flush into the core. So you have to ensure that the downcomer is not de-borated below the critical boron concentration.

MR. THURSTON: Right. So for this particular scenario, so DHRS is not on. So you don't have the cold surface for condensing on the steam generator tubes, right?

MEMBER MARCH-LEUBA: Right. But you're condensing on the -

MR. THURSTON: You're condensing in containment. That's right.

MEMBER MARCH-LEUBA: No, no, no. The containment is you have 15 feet higher on containment of cold water. So you have 15 feet of vessel -- primary vessel wall condensing.

MR. THURSTON: That's right. That's right.

MEMBER MARCH-LEUBA: So are we sure that we've done all the analysis to ensure that the CBC, the critical boron concentration, is not reached? Because when your level in the vessel is very low, the volume of downcomer is lower so it doesn't as long time.

MR. THURSTON: That's right. That's right.

MEMBER MARCH-LEUBA: You have run all these cases?

MR. THURSTON: Right. So these cases were evaluated under 8930. And so the limiting case was the RRV break for the 8930 boron distribution analyses. So this did not rise to the level of review for those boron-related calculations.

MEMBER MARCH-LEUBA: This is -- I mean, under this particular -- so it's a 5 percent break of the charging line.

MR. THURSTON: Correct.

MEMBER MARCH-LEUBA: You are going to have a rush of flow coming from containment downcomer. It's going to push whatever is in the downcomer into the core. So we -- has NuScale analyzed this and made sure --

MR. THURSTON: Right. So --

MEMBER MARCH-LEUBA: -- they're not below the CBC?

MR. THURSTON: Right. So I'm saying that this is not the limiting case for boron distribution. So I guess, I mean, we can --

MEMBER MARCH-LEUBA: Seems to me that it may be.

MR. THURSTON: -- probably get back and confirm that. But that is the staff's understanding that this is not the limiting case regarding boron distribution.

MEMBER MARCH-LEUBA: The protocol is I'm relying on your eyes because I don't like to see anything. I mean, I know you very well. We're good friends, and I trust you. And I'm relying on you to look at these things.

MR. THURSTON: Yes.

MEMBER MARCH-LEUBA: This looks to me like it could be the limiting case, and you're telling me you didn't look at it.

MR. THURSTON: No, no. I'm saying that it's not the limiting case. I'm saying that --

MEMBER MARCH-LEUBA: But it looks to me -- my judgment tells me it could be.

MEMBER KIRCHNER: Well, Jose, this is Walt Kirchner. Depending on the rate -- Carl, how long does this blowdown take?

MR. THURSTON: Oh, this is a very long blowdown. So it might --

MEMBER KIRCHNER: It's a long blowdown.

MR. THURSTON: -- take a couple hours. It's a 5 percent break.

MEMBER KIRCHNER: But it's a big enough break that the boron is carried over with the flashing --

MR. THURSTON: So --

MEMBER KIRCHNER: -- of the primary system. But I think the concern that Jose may have voiced is while this water is accumulating, is it still at saturated conditions in the containment vessel? Or has it been cooled --

(Simultaneous speaking.)

MR. THURSTON: Well, it's going to be cooled -- significantly cooler in water in the containment, right, because you're condensing on those walls and those walls are going to be quite cold. And that will be -- as Jose pointed out, it will be raining in the containment.

MEMBER KIRCHNER: Yeah, but now we have a large --

MR. THURSTON: And that level will build up.

MEMBER KIRCHNER: -- a large level of cold fluid. And the cold fluid with the opening of the ECCS valves then goes into the downcomer and into the core. So --

MR. THURSTON: That's right.

MEMBER KIRCHNER: -- have you looked at the moderator temperature feedback effect on the core?

MR. THURSTON: I mean, I don't think we have looked specifically at this -- well, it has been evaluated. So it was evaluated in 8930. And I guess -- I don't know if Becky or Jeff can chime in here to help me out. But this case was not found to be limiting in any of the 8930 analysis we did because for Chapter 15.6.5, we're pretty much only looking at the LOCA figure of merit --

(Simultaneous speaking.)

MR. THURSTON: -- and the other emphasis were done in a different calculation.

MEMBER KIRCHNER: Again, the concern would be an injection of cold moderator into the core.

MR. THURSTON: Yeah, I understand.

MR. SCHMIDT: So this is Jeff Schmidt from the reactor systems branch. So we have looked at that. So we've looked at ECCS actuation, basically keeping it -- and end of cycles are a good example. There's not much boron to redistribute between the core and the downcomer, right?

So when the ECCS actuates, that downcomer water will -- and lower plenum water will enter the core. And that reactivity effect has been looked at as part of, like, the EOC return to power case. Does that answer your question?

MEMBER KIRCHNER: Thank you, Jeff. Yes, as long as you looked at it and analyzed it. And the follow through obviously is that if there's a significant level in the containment, then you'll have a traveling wave, so to speak, of colder and colder water coming through the core until the system equilibrates at equal levels, downcomer and --

(Simultaneous speaking.)

MR. SCHMIDT: Yeah, so we have looked at, I guess, the transient effect of ECCS, and we've also looked at the quasi-static state where you're just in boil up and you have zero ppm coming into the core. I don't know if you recall from the March presentations, I gave a presentation on an NCNTMP (phonetic) -- case. That was run where you had zero ppm coming into the core. And we looked at one saturated --

MEMBER MARCH-LEUBA: Watch out, Jeff. That might be proprietary.

MR. SCHMIDT: Oh, okay. All right. So there was an analysis done of this of zero ppm -- thank you, Jose -- where --

MEMBER MARCH-LEUBA: Jeff, my answer to your previous question is no. We're way past the GDC 27 return to power which is an end of cycle problem. We are now on the de-boration problem which is a beginning of cycle problem. And --

MR. SCHMIDT: Yes, yes. I was trying --

MEMBER MARCH-LEUBA: -- another --

MR. SCHMIDT: -- to answer the moderator temperature effect --

MEMBER MARCH-LEUBA: Yeah.

MR. SCHMIDT: -- not the boration effect, Jose.

MEMBER MARCH-LEUBA: Right, right. But if you remember the presentation we got in June by NuScale where they presented the critical boron concentration, it's not -- doesn't take 100 percent de-boration to get critical. I don't remember if the number is provided. It probably is, but it's not 100 percent. It's much, much lower than that.

So if any rain -- distilled water rain is coming into the downcomer, then with a lower level, it's coming from the vessel wall because the vessel has to be 10, 20 foot of cold water in the containment on the other side. And it doesn't take that much de-boration. Of course, that CBC is a very conservative number, and it assumes that once the worst stack crawl out, which is a very conservative assumption. But everything else is not conservative. This doesn't look good, guys.

MR. SCHMIDT: I guess we can discuss more.

So NuScale, are you referring to just, like, a LOCA transient in the dilution? So they did 1,900 cases where they looked at the new set point. And their figure of merit was downcomer concentration versus critical boron concentration. So that --

MEMBER MARCH-LEUBA: So they have looked at this particular run and say that it's not above the -- below the CBC?

MR. SCHMIDT: That's right.

PARTICIPANT: That's correct.

MR. SCHMIDT: That's correct.

PARTICIPANT: That's correct.

MR. BRISTOL: This is Ben Bristol with NuScale.

MEMBER MARCH-LEUBA: Okay. You have --

(Simultaneous speaking.)

MR. SCHMIDT: Yeah, that's right. Go ahead, Ben.

MEMBER MARCH-LEUBA: It sounds --

(Simultaneous speaking.)

MR. BRISTOL: So there's a unique nuance in the assumptions that are made that the LOCA model was developed very specifically for -- with special conservatisms for calculating minimum level. Carl was kind of alluding to that. The key one here is the treatment of DHR.

For our analysis of boron distribution, we did not apply that same conservative assumption because the DHR system would be actuated and would be expected to be actuated. So there's a unique phenomena where under the LOCA conditions where the IAB will block it and hold out longer than the ECCS signal would be expected to come in. That does not occur under conditions where the DHR is operable.

MEMBER MARCH-LEUBA: Correct. And --

MR. BRISTOL: So the analysis Jeff was -- go ahead.

MEMBER MARCH-LEUBA: And your statement that you have looked at this 5 percent charging line break, you have looked at it assuming DHRS is on?

MR. BRISTOL: Correct.

MEMBER MARCH-LEUBA: Therefore, IAB doesn't block, and everything is fine?

MR. BRISTOL: That's right. And the level --

(Simultaneous speaking.)

MR. BRISTOL: -- still comes in when we expect it to.

MR. CORRADINI: So this is Corradini. I want to make sure since Ben jumped in, wasn't this the

March presentation we heard in detail in closed session?

MEMBER MARCH-LEUBA: No.

MR. CORRADINI: I'm asking Ben.

MR. BRISTOL: No, this was analysis that we performed in June -- in support of the June meetings.

MR. CORRADINI: But then I'm going back to the March presentations. I thought those focused on boron distribution under ECCS actuation conditions. Am I misremembering?

MR. THURSTON: No, we did present this case in the March meetings.

MR. CORRADINI: Okay. I thought so. Thank you.

MEMBER MARCH-LEUBA: Well, I mean, I'm sorry to be the bad guy, I don't get that warm feeling about what is it that we've done. And I, myself, haven't seen any of this. I don't want to see it again, but I'd like to see a summary before you're asking me to decide what you've done is acceptable. At least summarize what you plan.

MR. THURSTON: Yeah. So I think the staff can take action, Jose, to give back to the ACRS. Becky, you want to chime in? And I think we should take an action to confirm. So this case was evaluated by NuScale, and it's a part of the recent audit that we completed. And we can take an action to get back to the ACRS with confirmation.

MEMBER MARCH-LEUBA: Tonight? We're running out of time.

MS. PATTON: This is Becky Patton. I mean, yeah, we can, Carl. I mean, I think we've documented a lot of this within the SER. But if -- we have a closed session tomorrow. So if you want to provide more embellishment, I think we certainly could.

MEMBER MARCH-LEUBA: What I would like is that you give me sufficient reason to believe that you have covered all -- you cross all the t's, dot all the i's, or at least most of them. I mean, right now, with what I have, the SER is orders of magnitude better than the SAR. The SAR has absolutely no information. It just says, trust us. We looked at it. It looks good.

The SER at least contains some information, but it still doesn't have all the details. And this is very delicate, these calculations. Whether you reach the CBC, the critical boron concentration, or not, depends on minutes. If

DHR is running or not running or you're condensing on the wall or you're not condensing on the wall, the details matter. Okay. I said enough. Thank you.

MEMBER KIRCHNER: Carl, please go on.

MR. THURSTON: Yes, so this is actually my last slide.

VICE CHAIR REMPE: Can I interrupt for just a minute too? When you talk about you've documented it and I don't have the specific location, but Chapter 6, there were occurrences by the staff that you did the calculations and after ECCS actuation and you had confidence that the SAFDLs were fine - (Telephonic interference.) And then you kind of -- and I don't remember now whether it was Chapter 15 or 6.

But you said you extrapolated that to seven days or used it to infer to seven days. What would be good to know is exactly what type of calculations were the basis for those kind of statements in Chapter 6 -- (Telephonic interference.) -- what I'm saying?

MEMBER KIRCHNER: Joy, your signal audio is cutting in and out. You might want to just quickly restate what you're requesting.

VICE CHAIR REMPE: Okay. I can see red bars which is a bad thing. Can you hear at all?

MEMBER KIRCHNER: I can hear you, but you're breaking in and out.

VICE CHAIR REMPE: I'm in the mountains of Sun Valley, and this is -- (Telephonic interference.) -- because it's been fine today and I can hear you all. What I'm trying to get to is -- I'll say it again. If it doesn't work, I'll try later, send an email.

But in Chapter 6, staff has said in the safety evaluation -- the draft safety evaluation report, the staff says, we audited calculations that looked at the plant response after ECCS actuation and things were great. The SAFDLs weren't exceeded, et cetera. And somewhere I recall also seeing about it was evaluated out to 72 hours. And then the staff inferred out to seven days. Can you hear enough of what I said? Or did it -- (Telephonic interference.) -- now. So is it getting better and you can understand me? Or do I need to repeat myself?

MR. SCHMIDT: So this is Jeff Schmidt from reactor systems here. I think I heard you. I think the extrapolation out to seven days was more of the decay heat removal system that I recall.

VICE CHAIR REMPE: Okay. So what about the fact that you looked at the calculations? After

ECCS actuation, things were great and the SAFDLs weren't exceeded.

MR. SCHMIDT: That only goes --

VICE CHAIR REMPE: What type of calculations --

MR. SCHMIDT: -- I think, to 72 hours that I recall.

VICE CHAIR REMPE: Okay. And what type of calculations did you look at, NRELAP calculations or hand calculations, because it was just --

MR. SCHMIDT: Yeah, so those were RELAP calculations.

VICE CHAIR REMPE: -- I couldn't figure out what you're looking at. We were talking at the same time. Please say it again.

MR. SCHMIDT: I'm sorry. It was the leakage cases I think that you're referring to in 6.3 were NRELAP. The hand calculation determines the riser hole flow under DHRS operation. But it does -- part of that is used to determine the riser hole flows in that NRELAP calculation.

As we'll discuss in the closed portion, the NRELAP calculation has a slightly higher hole flow rate. So what NuScale did is they kind of renormalized it. So it's a combination really of

NRELAP -- it's primarily NRELAP with a renormalization for a riser hole flow.

VICE CHAIR REMPE: Okay. Thank you. It would be good to see something like this documented with a little more detail because I'm struggling with the fact that the staff -- the additional calculations you have are very detailed that we saw, the official ones. I've not really got a good feel for what NuScale did. But now we've got differences of opinions on staff calculations, and it's kind of puzzling. Usually, the staff reviews what NuScale does. We're not struggling with differences just on staff calculations.

MR. SCHMIDT: I'm not sure I understood that, but I think I -- like I said, it's the applicant's NRELAP that was audited. But they used some information for their -- so some of the time period during these LOCAs, right, especially the small break LOCAs, the riser holes remain covered. So that hole flow rate during when they are covered still comes from the hand calculation of the extended DHRS. I don't know if that's any clearer, but --

VICE CHAIR REMPE: Well, I thought -- (Telephonic interference.) -- looked at, and I think some of this was in the actual SER where they said, after ECCS actuation, there's cases that have the riser holes becoming covered. But you did some audit reviews and you decided it -- (Telephonic interference.) And Jose -- (Telephonic interference.) -- that's what really the staff looked at.

They don't have any NuScale calculations -- (Telephonic interference.) -- particular quote because Section 6.3 and I highlighted it. And it's going to take me a while to find the exact words. But if there were some calculations after, that NuScale did -- (Telephonic interference.) -- after the riser holes were covered. And they determined that the SAFDLs weren't -- (Telephonic interference.) -- see the specific calculation results. And I don't think -- (Telephonic interference.) -- before because why would have done -- (Telephonic interference.) -- riser holes uncovered?

MR. SCHMIDT: I guess I didn't catch all of that. I'm sorry. You were cutting in and out again.

MEMBER MARCH-LEUBA: Joy, this is Jose. The court reporter is saying he cannot transcribe you. You really are cutting off. Would you mind if we continue and you reboot or restart the Skype –

VICE CHAIR REMPE: I don't think that --

MEMBER MARCH-LEUBA: -- because the court reporter cannot hear you.

VICE CHAIR REMPE: Okay. I don't think that'll help. It's the internet connection, Jose. But I can try.

(Simultaneous speaking.)

MR. SCHMIDT: The staff does cover this in a later slide. We might be able to get to it then.

MEMBER KIRCHNER: Joy --

VICE CHAIR REMPE: The other thing is, Jose --

(Simultaneous speaking.)

MEMBER KIRCHNER: -- phone line.

VICE CHAIR REMPE: Pardon? Oh, call in on the phone line. Okay.

MEMBER KIRCHNER: You might not cut out so much.

VICE CHAIR REMPE: Okay. Thanks. Go ahead.

MR. THURSTON: Yes. So that's the conclusion of staff's review for Slide 19.

MR. SCHMIDT: Okay. This is Jeff Schmidt from the reactor systems. I got the next couple slides. Again, as we've talked, the applicant added riser holes to limit the downcomer dilution during decay heat removal cooldown.

The RCS water level may drop below the riser following reactor trip depending on the initial RCS conditions. Those are mostly hot full power when you have towards the lower end of the pressurizer range. NRELAP and the staff's TRACE model showed riser uncovery between five and six hours under nominal conditions assuming no operator action.

The concern was that the ECCS valves could open either on the loss of AC power at 24 hours or the main valve like Tom talked about on the low differential pressure, that spring he was referring to earlier, causing a potential in-surge of diluted water into the downcomer. And this is DHRS operation, and there are times when ECC -- (Telephonic interference.)

MEMBER KIRCHNER: Jeff, I think we lost your audio.

MR. SCHMIDT: Yeah, somebody muted it. I'm sorry. I don't know what happened there. I didn't touch anything. Okay. So I'm not sure where I left off. The second bullet? Can anybody hear me?

MEMBER BLEY: I can hear you, Jeff.

MEMBER KIRCHNER: Yeah, Jeff, we can hear you. Start with you mentioned the riser uncovery and under DHRS operation under nominal conditions, no action by the operators, takes five to six hours. And then you were transitioning into it.

MR. SCHMIDT: So again, the issue is under DHRS cooldown, the ECCS valves could open either a loss of AC power at 24 hours or on the main valve low differential pressure causing a potential in-surge of diluted downcomer water into the core. So the applicant performed a series of hand calculations to determine the riser hole size and elevation to maintain the downcomer boron concentration. Above the critical boron concentration for times and cycle, when significant, downcomer dilution is possible. Next slide.

The applicant performed -- evaluated two different primary to secondary side heat transfer modes, depending on the relationship of primary to secondary side. This kind of bound the problem. The conductive cooling as it was referred to is where the secondary side is below the primary side level. And heat is transferred primarily through the riser wall.

And then the other extreme is the boiling condensing mode where heat is primarily removed from condensing steam on the exposed steam generator tubes when the secondary side level is above the primary side level. Each transfer mode has different condensation rates and thermohydraulic phenomena that determine the riser hole flow rates. The staff audited the applicant's hand calculations to ensure the conservative condensation and riser hole flow rates were sufficient to prevent significant downcomer dilution. Next slide.

CHAIR SUNSERI: Hey, this is Matt. I noticed that there's quite a few guests that have their microphones open. So that may be causing a bogging down of our system. If you're not talking, please mute your microphone, please. Thank you.

MR. SCHMIDT: And let me ask. I can't see the bottom corner of my slides because there is a showing of people that are muted. Does anybody know how to get rid of that?

MEMBER KIRCHNER: Jeff, just for your information, we're seeing you blocking your slide. But don't worry about it. Just talk through it if you think --

CHAIR SUNSERI: But you can do that by going up to the top right-hand corner of your screen, the little arrow with the guy in it and click, content view.

MR. SCHMIDT: Okay. Because I'm not

controlling my slides, so I -- all right. So I think it's resolved. I can see my slides now. The NRELAP and TRACE models show pressure and temperature decreasing during cooldown consistent with convective heat transfer.

Both NRELAP and TRACE show a liquid discharge over the riser for approximately one and a half to two hours after riser uncovery. The applicant's hand calculation conservatively assumes no boron containing liquid discharge over the riser during that time frame. The applicant assumes state point values for the decay heat, RCS pressure, steam generator pressure, and for the convective case, a riser to downcomer temperature difference as a function of time.

This was all part of their hand calculation to determine condensation rates and the hole flow rates. Staff compared the assumed state point values and found them either reasonable or conservative compared to the applicant's NRELAP 5 and the staff's NRELAP 5 and the TRACE confirmatory cases. Staff audited the applicant's hand calculated condensation rate both the convective and boiling heat transfer mode and found them to be conservative. Next slide, please.

For the convective heat transfer mode, the staff confirmed the applicant's hand calculation of through-wall heat transfer was conservative. Staff compared the riser to downcomer temperature difference after the liquid discharge over the riser and found that temperatures were consistent with the staff's NRELAP 5 and TRACE confirmatory runs. When decay heat is high, again, liquid discharge prevents a direct comparison to the assumed state point calculations, at least for the riser to downcomer temperature differential I should say. Staff reviewed the methodology associated with the riser and downcomer level determination and found it to be reasonable.

VICE CHAIR REMPE: So Jeff, this is Joy.

MR. SCHMIDT: Yeah.

VICE CHAIR REMPE: Is it still cutting in and out or is it --

MR. SCHMIDT: Oh, I can hear you now.

VICE CHAIR REMPE: Good, okay. What I was trying to ask earlier was that in Chapter 6, there are places where the staff indicates -- and I think it's Section 6.3 -- that after ECCS actuation, there are some cases they looked at where the riser holes became uncovered. But the ECCS was adequate to ensure that the SAFDLs weren't exceeded or there weren't any problems. Were those calculations NRELAP calculations, or were they the combined hand calculations, NRELAP baseline type of thing? And has ACRS really seen those calculations?

MR. SCHMIDT: I don't think -- so the staff audited those calculations and a NuScale calculation. I don't -- I mean, when you say, has ACRS seen those calculations, no. They're probably in the audit report.

VICE CHAIR REMPE: Which I'm not sure we had. But they were NRELAP calculations. They weren't hand calculations. What can you --

MR. SCHMIDT: They were NRELAP calculations. They were just informed by the riser hole flow rate hand calculation. But they were predominately -- think of them as NRELAP calculations.

VICE CHAIR REMPE: Okay. Yeah, I think that right now, as you said in the open session earlier, we're to discern between something the staff has produced versus a difference of opinion. If we could see more of what NuScale did, maybe it would -- (Telephonic interference.) -- inform us on what to believe.

MR. SCHMIDT: Right. So yeah, I understand, and that's probably -- would have to probably come out in the audit report of what we looked at. Or we'd have to go back and modify RSE.

VICE CHAIR REMPE: Yeah, I'd be interested to see a little more detail of what -- (Telephonic interference.) But anyway, that's just my -- (Telephonic interference.)

MR. SCHMIDT: Okay. Yeah, so I guess I just want to leave you with was that I think -- I don't remember the exact number. I want to say 60 NRELAP cases. And NuScale can probably correct me on the number. There's a table in their calculation that has a whole list of a variety of conditions that they ran.

VICE CHAIR REMPE: More information would be helpful. Thank you.

MR. SCHMIDT: Okay. And I think we can get probably into some of those details in the closed session if you want.

VICE CHAIR REMPE: More information today would be helpful.

MR. SCHMIDT: Okay, sure. Let's see. Staff -- let's see. I think I covered that. I think we're on the next slide. Next slide, please. Is anybody hearing me? All right. This is the connective heat transfer mode continued.

Staff reviewed the loss form factor and found the values and the hand calculations to be conservative. This was obviously to determine the pressure across the holes. Staff audited the applicant's energy balance verification as part of their hand calc check and agrees within the framework of the hand calculation a conservative riser hole mass flow rate was determined.

In other words, the total of the energy loss from condensation through-wall and riser hole flow rate energy was less than the assumed decay heat energy. Staff compared the applicant's hand calculated riser hole mass flow rate with the applicant's NRELAP cases that was part of the audit and the staff's TRACE confirmatory cases and found the applicant's hand calculated values to be reasonable. Next slide.

So the other bound of the heat transfer mode is the boiling condensing heat transfer mode. In this case, it's two phase level swell on the riser that determines the pressure differential and the flow across the holes. The applicant performed analysis through 72 hours using a quasi-steady state analysis method, very similar to the conductive case for a generic event progression.

Calculation included conservatisms intended to underestimate riser void fraction and overestimate the condensation rate. And during the closed session, we'll get into the details of that, including the staff's hand calculations. NRC staff reviewed the applicant's methodology, audited supporting calculations, and performed confirmatory calculations.

A review of draft scenarios with no reactor coolant leakage, i.e., no LOCA cases or I should say leakage cases, not LOCA cases, below the definition of LOCA. Staff found the applicant's method and results acceptable for the conditions reviewed in the application. Next slide.

So the idea, as we've talked about during this, is to maintain the downcomer concentration above the critical concentration. So the last part of this exercise is to determine the downcomer concentration. So as part of this, it's assumed to be in a quasi-steady state with the core and net flow as equal to the riser hole flow and the condensation rate.

The applicant uses a wave front model to transport boron from the riser to the downcomer and back to the core. Staff finds the wave front model conservative as the model maximizes boron transfer out of and minimizes boron transport into the downcomer and effectively ignoring any potential recirculation mixing. The staff's riser hole design acceptance criteria is to maintain downcomer concentration greater than at critical, including the effects of xenon with the highest worth control rod remaining out of the core at BOC and MOC conditions for 72 hours.

The staff grades the applicant's acceptance criteria as conservative as maintaining a downcomer concentration above the critical value, ensures shutdown should occur when the ECCS valves open at times in life when significant, downcomer dilution is possible. At EOC, as I was referring to a little earlier, there's a negligible downcomer dilution between the core and the riser. Obviously, as you go to zero, there's zero differential between the riser and the downcomer.

And the staff looked at the downcomer with a surge in between if you were to open up on the timer at 24 hours and after 72 hours didn't cause a return to power greater than that evaluated already in the return to power analysis at 15.0.6. And that really is the -- we found that the ECCS cooldown is already in DCA 15.0.6 was still the limiting case. Next slide. Turning this over to Josh.

MR. BORROMEO: Yeah, so this is Josh Borromeo from the nuclear systems performance branch. I'm going to be talking about GDC 33. So NuScale evaluated boron redistribution and the design changes with respect to the exemption for GDC 33. And GDC 33 requires a system to supply RCS makeup for protection against RCS leaks and small breaks.

So specifically, NuScale evaluated the RCS leaks below the 50.46 LOCA spectrum which is within the capacity of their CVCS. However, to justify the exemption, NuScale assumed only using safety-related systems, so not using CVCS and no operator actions. So the approach that NuScale took was very similar to the extended DHRS.

So this kind of gets back to the discussion that we were having before. So the way I like to think about these RCS leakage cases -- and this is the analysis in 6.3 that I think was discussed previously. These are essentially extended DHRS cases and specifically the boiling condensing heat transfer mode that Jeff just talked about but with the addition of an RCS leak.

So it's a combination of -- so what NuScale did was a combination of RELAP calcs and hand calcs to figure out the two phase level in the reactor. So does that clear up kind of what NuScale did whenever they analyze these cases, like, what codes they used, what method they used?

MEMBER MARCH-LEUBA: Yeah, I have no problem with this GDC 33 evaluation.

MR. BORROMEO: Okay. So the staff evaluated the approach in two ways. So they took a look in cases where ECCS actuates while holes are covered and then when ECCS actuates after the holes are uncovered. And I think in the SE, I think there's some confusion similar to what we were talking about during the NuScale presentation about there was an evaluation after ECCS actuates. Well, really it was, what happens at the time of ECCS actuation? So there wasn't a calculation beyond ECCS actuation, right? It essentially stopped there.

VICE CHAIR REMPE: So there was no -- just say it again -- NRELAP calculation beyond the time when ECCS actuation occurred?

MR. BORROMEO: Correct.

VICE CHAIR REMPE: So --

MEMBER MARCH-LEUBA: Sorry, Joy. Go ahead.

VICE CHAIR REMPE: No, you go ahead.

MEMBER MARCH-LEUBA: Yeah, you and I have been emailing on this topic for the last week. I kept telling her that the intent of the SER was to say that there will not be any boron issue at the time of ECCS actuation which could be a very big problem because then you have the rush of water coming in. But the SER says after ECCS actuation which means for two weeks after ECCS actuation. If you guys are still changing the SER, I would recommend that you look at the language and replace after ECCS actuation without the time of actuation.

MR. BORROMEO: Understood.

VICE CHAIR REMPE: And I agree with that. That's what I was trying to ask because I still had hope that there were some calculations you looked at beyond, and there were none. And that's what I'm trying to get to.

MR. BORROMEO: Right. There was no calculations completed for RELAP beyond, right? But there was -- NuScale did evaluate what would happen if you lost the riser hole.

VICE CHAIR REMPE: So then -- and they did that with hand -- a simple analytical model, right?

MR. BORROMEO: Well, I mean, I'll characterize it as they took a look at the results at the time of ECCS actuation and then made a conclusion off of that. And then I think probably tomorrow we can get in the details of what the staff observed with respect to their calculations as well as what we observed in our own confirmatory calcs using RELAP and TRACE.

VICE CHAIR REMPE: So that's where I was -- the point I was trying to make -- been trying to make all day today is here we are where the staff has done a lot of calculations that are more detailed than the applicant. And there's some questions amongst the staff on what's been done. Jeepers, it would've been nice if the -- (Telephonic interference.) -- had done some more detailed calculations.

MR. BORROMEO: Well, I mean, I don't know if I would totally agree that they just didn't look at this at all. I mean, they did a lot of cases at various initial conditions, right? And we took some of the limiting ones, and we're trying to find other cases where it could be worse. So I think we took what NuScale did and kind of extrapolated on a few cases where we thought there might be some issues. But what I think the applicant did wasn't insufficient, I'll say.

VICE CHAIR REMPE: Because of the calculations the staff did, you have confidence. Then we're trying to decide on whether we have confidence. And usually, the applicant would have to take the lead, and then the staff does confirmatory analysis. But anyway, I think I tried to make the point as best I could.

MR. BORROMEO: Understood, understood. So the other points I want to emphasize is the majority of cases that we saw and what the staff expects is that ECCS is going to go off prior to these holes being uncovered, right? So they're going to hit the ECCS RCS low pressure set point, or they're going to come open on the ECCS valve design feature that Tom talked about earlier that open below EP, right? So that's what we -- for the majority of cases, that's what we expect to happen.

Now there was some uncertainty about the calculations that NuScale did with respect to, for example, a two phase level. And because the ECCS valves are this -- this dP function for them to open is not safety-related, there was some uncertainty there. So we took a look at scenarios where if you lost the riser hole, what would happen if ECCS would actuate after that?

And in order for that to happen, you really need a specific set of conditions and design failures for this to occur. So it's not likely that you would get to a situation where you lost the riser hole before ECCS actuates. But the NuScale evaluation showed that core boron concentration would remain above the initial RCS boron concentration and the staff performed confirmatory studies to help us to come to a regulatory determination on that. So overall, the staff has reasonable assurance that the underlying purpose of GDC 33 is met without reliance on non-safety-related systems or operator actions.

MEMBER PETTI: I have a question or a request because I'm losing the thread here a little bit. This idea that NuScale didn't do any calculations after ECCS actuation, if you go back and pull the March 2020 subcommittee slides, there's a whole bunch of analysis of what's going on with boron after ECCS actuation. So I just need to have the whole picture painted because we're jumping around so much, and I don't know if that's NuScale or Ben can do that when we get into closed session either today or tomorrow or the staff. But to kind of lay out here's the phase space and this is covered here and this was covered here so that we get a sense of completeness because I think some of us are forgetting stuff that was presented in the past.

MR. BORROMEO: Sure. So I was speaking related to the evaluation that NuScale did with respect to GDC 33. So maybe Jeff or someone else can speak to what they did for 8930.

MR. SCHMIDT: Yes, this is Jeff Schmidt from reactor systems again. Yeah, so the March, I guess, ACRS presentation covered what the -- when you had significant boron -- well, it covered a couple things, and one was that EOC return to power. And the other was when you have significant boron concentration, what would happen to the core and downcomer concentrations out to 72 hours and there was an evaluation out to seven days?

So that is correct is that, that was covered in March. What we're trying to cover in these slides here today is relative to the design changes, right? We didn't go back -- all the way back to March and redo all this --

MR. CORRADINI: So Jeff --

MR. BORROMEO: -- as far as the presentation goes. So --

MR. CORRADINI: Jeff, this is Corradini. I'm kind of with Member Petti on this. The March analysis is not affected by the riser hole because upon actuation, the riser holes are uncovered. So all the March analysis still is applicable.

MR. SCHMIDT: That's right. That's right.

MR. CORRADINI: So that's, I think, part of the big --

MR. SCHMIDT: So what this --

MR. CORRADINI: -- picture that was lost in all the back and forth that we've been going through all this afternoon. And it's my understanding at least in the closed session -- so that's all I'll say -- is that NuScale and staff went through this in great detail and we're satisfied with how ECCS performs out to a few days. I'll just use the word, a few days, because your next slide is where I have some major questions.

MR. SCHMIDT: Okay. All right. Well, let's get to the next slide then if we're done with this one.

MR. NOLAN: Hi, this is Ryan Nolan, and I'm going to close out the reactor systems presentation for the open session and briefly discuss operator recovery actions and their role within the NuScale design basis review. Clearly, boron distribution within the core must be carefully considered when exiting extended DHRS and ECCS cooling modes. The NuScale Chapter 15 safety analysis does not rely on operator actions to satisfy the pertinent regulatory criteria.

So consideration of operation actions to recover a module following an event is outside the scope of the staff's design basis review. Multiple operator errors of commission for -- or common caused failures are considered beyond design basis and they are addressed as part of Chapter 19. This is sort of laid out in -- this is laid out in 15.0, sort of the ground rules of how we do the Chapter 16 reviews for passive designs. Is there a question?

MEMBER BLEY: Yeah, there is. This is Dennis Bley. That makes sense from the usual point of view which is that after this initial period, things have reached a stable condition, and recovery means putting the plant back together again. If you leave hands off this one, you can eventually get into some trouble. And I think you're extending the normal rules into a case where 50 years ago when we were setting all this up, it wouldn't have applied because you weren't really stable yet. That's all.

MR. SCHMIDT: So this is Jeff Schmidt from the reactor systems. So I'm not sure I understood the statement because we get to this core concentration downcomer dilution state. And I guess we consider that a safe, stable state.

MR. CORRADINI: But I think, Jeff -- this is Corradini. I'm kind of with Member Bley. You're getting to a point now where at some point, you're going to have to recover. And there's got to be some sort of point at which the design and the operator has to start recovering. And this would seem to be the appropriate point.

And just from a precedent standpoint, AP1000-ESBWR also at three days had to take on actions to essentially get back to a safe and stable state. Even though they were safe and stable at high pressure, they still then went through a cooldown discussion that staff required.

MR. NOLAN: Right, right. But that analysis was within the scope of Chapter 19. That was not within the Chapter 19 safety analysis.

MR. CORRADINI: That's not my memory, but -- unless I misunderstood Member Bley's point. This is the point where you essentially extend out how things evolve, and you've got to find at least a path back to recovery. And it seems to me this would be the point to identify it. To say that it's outside the scope of the design certification strikes me as kind of not -- well, at least personally, that doesn't seem acceptable. You want to technically show there's a way to get back to essentially a recovered condition because you don't want to keep this condition going on for extended periods of time.

MR. NOLAN: These are -- I guess I'm not familiar with ESBWR. But these are low temperature/pressure conditions, right? I think we've all assumed we're on ECCS here, right?

MR. CORRADINI: Right.

MR. NOLAN: Right. So you can sit on ECCS for quite a period of time.

MEMBER MARCH-LEUBA: Yeah, I probably should let Mike and Dennis make my point. But if you have 20 to 25 dollars' worth of positive activity parked in the lower plenum waiting for any perturbation to put it inside the core, that's not a safe and stable condition. It's not.

MR. SCHMIDT: I understand your concern.

MR. CORRADINI: But let me just -- let me say my concern a little bit differently. I don't particularly buy into a lot of what we've been discussing here. But it just strikes me from good engineering practice there's got to be a point with which you require the owner operator, once they've come to a safe and stable state to get to a recovered condition.

And I don't think letting ECCS go on interminably is an acceptable condition. You've got to come back to it, and it's got to be at some defined time. I'm picking three days because -- and I'll use AP1000 as the example is they were safe and stable, but that at a high pressure, low temperature condition with their containment. And staff basically said, that's good.

But what's better is to come back to essentially a lower pressure. So in their case, pressure was the thing that was required to essentially be mitigated. In this case, it strikes me it's concentration of boron in different locations at different values. And if you continue to do this, it just exacerbates the situation.

MR. SCHMIDT: Yeah, and I think that they do have to recover at some point. I'm not sure what that point is. I mean, it could be beyond obviously the 72-hour coping period of Chapter 15, right?

MR. CORRADINI: But to me, again, I'm just speaking for myself as an individual consultant to the committee. It just strikes me that this is the appropriate time to put in a tech spec requirement that there ought to be operating procedures in places, that at three days into a DBA event or something similar to the DBA event there should be recovery actions identified.

MR. SCHMIDT: Yeah, I think at the design certification state, and maybe other people can jump in here, is that those procedures and demonstration that those procedures can recover you are just at a COL or a later stage than the DCA. I can understand why others would think differently.

MEMBER MARCH-LEUBA: I have thought about this a lot. You guys know I've been thinking about this a lot. If you have a non-repairable break of the CVCS charging line, I just don't see how you're going to recover. The --

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: -- to get out of this is to put borated water inside the core and riser. Every other source of water into the core and containment is in the downcomer which will create a reactivity event. So it is mandatory. I think it's absolutely mandatory to tell me there is one recovery procedure that may work. If there is two or three or four, the COL can choose the one they want. But show me there is one. And when you have a non-repairable break of the charging line of the CVCS, I don't see how you do it.

MR. SCHMIDT: Yeah, I understand your concern, and I think some of that will be addressed a little bit in the Chapter 19 where I think they looked at more of the recovery -- possible recovery aspects.

MEMBER MARCH-LEUBA: Let's not wait. Tell me if you're charging line for CVCS is not working, how are you going to take that core into Mode 4 so you can support it to the refueling station and fix it? Tell me.

MR. SCHMIDT: I honestly can't answer that question because I was not involved in any of the recovery aspect.

MEMBER MARCH-LEUBA: I've been thinking very hard about it. I don't see a way to do it other than, I mean --

MR. SCHMIDT: I guess my response was if you can't do it, then the COL -- if they can't come up with a procedure to do this, then the COL will have to take a departure from the DCA.

MEMBER MARCH-LEUBA: What do you mean departure? You should not buy this reactor because it doesn't work.

MR. SCHMIDT: I'm not the purchaser of it, but --

MEMBER MARCH-LEUBA: Yeah, but it is -- I think it's so clear. Show me. Number one, evaluate what all the possible states of your reactor are. This is a DCA condition. Evaluate what all the possible errors are, and evaluate the risk that this reactor poses to the public –

(Simultaneous speaking.)

MR. SCHMIDT: And I think that is addressed somewhat in Chapter 19, the 19 slides. So maybe we should come back to this after the Chapter 19 slides.

MEMBER KIRCHNER: This is Walt Kirchner. My Skype has dropped me multiple times now. So I missed your discussion on this, but I did want to loop back to this as well. I just want to concur with Jose.

I also wanted to ask you, Jeff, what's the figure of merit with how much margin on this? For example, in -- (Telephonic interference.) -- it was stated that the critical -- the boron concentration in the downcomer is above the critical boron concentration for the core. How much? How much margin?

MR. SCHMIDT: So --

(Simultaneous speaking.)

MR. SCHMIDT: -- nuclear reliability factors --

MEMBER KIRCHNER: Right.

MR. SCHMIDT: -- as part of that. I don't think there's -- so there is some margin, and I think either NuScale or us can provide it in the closed session of what the margin is.

MEMBER KIRCHNER: Okay. I would like to explore that. Some margin doesn't mean a very sanguine situation.

MR. SCHMIDT: Yeah, we can go through the specifics.

MEMBER KIRCHNER: In two hours, you don't want to find out that it's 73 hours the thing actually can go critical.

MR. SCHMIDT: Oh, no. So if you compare, like, the -- I think if we're talking -- I guess let's make sure what we're talking about. Are you talking about the extended decay heat removal cooldown and the riser hole function?

MEMBER KIRCHNER: I don't care what scenario it is. Whatever the concentration is in the downcomer versus the critical boron concentration for the core is the figure of merit that I have in mind, plus significant margin to account for significant uncertainties.

MR. SCHMIDT: So there is margin. And like I said, we can go through those. I probably can't say the values --

MEMBER KIRCHNER: Okay. Well --

(Simultaneous speaking.)

MR. SCHMIDT: -- in the open discussion. But there are --

(Simultaneous speaking.)

MR. SCHMIDT: -- 4 hours and 72 hours. There is margin between the critical boron concentration and the downcomer diluted concentration. And those are values -- I guess you got to put it in context, and we'll get into that more in the -- (Telephonic interference.) -- slides. But that's with conservative riser holes. That's what conservative.

MEMBER KIRCHNER: I know that.

MR. SCHMIDT: Condensation --

MEMBER KIRCHNER: Assumptions on mixing, et cetera. So yes, we can do that. But I also want to go back to Member Bley's comment and then our consultant, Mike Corradini. It just seems to me that you're not completing Chapter 15 analyses if you can't show that with a hands off this reactor under an extended, for example, cooldown condensation mode that does not return to critical.

MR. SCHMIDT: Well, okay, so for boron -- with significant boron concentrations, as we went through in March, it shows it doesn't return to critical, that the final concentration in 72 hours is greater than the initial. Hence, you're not critical. This riser hole design, for example, shows that you have margin to criticality.

And again, the point was if you're on decay heat removal system and you actuate ECCS either at the 24-hour time or at the low dP that you don't introduce a de-borated slug into the core. And that's a function of assuming conservative condensation rates, low riser hole flow rates, and margin between the critical and the de-borated state. So I think we have shown in all these modes that you have, basically, either a subcritical core or you return to power at end of cycle as we discussed in March. And that return to power is benign and your SAFDLs are met.

MEMBER BLEY: This is Dennis again. I just want to throw in a few last little things here. I still think we don't have many other accidents that end in a state that where a simple operator action along the way could throw you in to something much worse than you're in already. That's why I think it ought to be addressed at this stage.

I don't find anything anywhere I can look in the SAR or the SER, I think, that's as explicit as your two big bullets. NuScale told us earlier that Chapter 4 has a statement about it and Chapter 13. I don't find anything in 13. The notes in Chapter 4 are really benign. You'd have to have been through all this discussion to know what they were talking about.

MR. SCHMIDT: Yeah, and I think a very similar note is in 15.04 about the post-recovery actions and --

MEMBER BLEY: Since you refer --

(Simultaneous speaking.)

MR. SCHMIDT: -- potential for a diluted situation.

MEMBER BLEY: Since you refer often to Chapter 19 as covering this, maybe you'll stay around when we get to Chapter 19 because --

MEMBER DIMITRIJEVIC: That's not covered in Chapter 19. That is not -- any of those recovery actions are not mentioned in Chapter 19.

MR. SCHMIDT: Well, I think some of the consequences were evaluated by research and a white paper with regard to action by PRA.

MEMBER DIMITRIJEVIC: Okay. But that white paper is not FSAR, so --

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: We got the white paper yesterday. We got a copy of that white paper yesterday, and I glanced at it. It's a good white paper. I wish we had it a little earlier because I haven't been able to read it in detail.

MEMBER PETTI: So the note came up on my machine. Ben Bristol would like to say something.

MR. BRISTOL: Can you hear me?

MEMBER PETTI: We can.

MR. BRISTOL: Yeah, this is Ben Bristol with NuScale. So a couple of points. Unfortunately at this point in the design, it's not responsible for us to start speculating on what potential recovery actions would be. We do have some high level descriptions of the system capabilities that we can provide in the closed session that will help address the concern that have been stated about the ability to recover, particularly with certain failure modes. So we can get into that in a little bit more detail tomorrow.

I think the other point that's important is that I think all of the thermohydraulic members understand that the idea that a gradient -- a significant gradient between the lower plenum of the core could be sustained. It's just not physically possible. It's a simplification that we use in Chapter 15 to address uncertainties, right?

It's not a realistic condition. Identification of the facts themselves would cause the lower plenum and the downcomer with the convective currents that exist under extended ECCS conditions that have much better mixing than we would postulate or try to defend in Chapter 15. So there's differences -- important differences in the assumptions that we use in Chapter 15 and the actual plant conditions.

MEMBER MARCH-LEUBA: Ben, for the record, whenever I've talked about this, you might look on the record and say I've always said if all the planets align, you can have a terrifying event. But unless -- as a reviewer, I'm asked by Congress actually to judge the quality of your submittal. Unless I have a calculation that shows me otherwise, I have to assume all the planets align because that's what could possibly happen.

And I am with you that if you try to design a nuclear weapon, you have to work real hard to make it go boom. Okay? In a reactor, it's impossible. But unless we have some calculations, hand calculations, bounding calculations, preferably detailed calculations, we cannot say what will happen. What position do you put me in?

I don't think all these terrible events that I keep describing are possible or likely. They're possible. They're not likely. But unless you give me some calculations, some arguments, what do you want me to do? Okay. Over and out.

MR. BRISTOL: I appreciate that.

CHAIR SUNSERI: This is Matt. I'm going to intervene here. Walt just dropped off again. He's asked me to chair while he's getting back on. I think the issue has been discussed. We're at a transition slide. If I'm looking ahead a little bit, we're going into Chapter 19 is the next slide, right? Am I correct on this?

MR. SCHMIDT: Yes, that's correct.

CHAIR SUNSERI: Okay. So what I'd like to do at this point, we've been at this over an hour or so now. Maybe it's been two hours. So I think we need to take a 15 or 20-minute break here, get ready for Chapter 19, and come back into session on Chapter 19. And then we can have -- if this is where the recovery is discussed, the white paper, all that stuff, we can pick up the discussion there. So let's take a recess here until 5:20. We'll resume at 5:20.

(Whereupon, the above-entitled matter went off the record at 5:05 p.m. and resumed at 5:21 p.m.)

CHAIR SUNSERI: Okay, so 5:21, let's go ahead with the roll call. Ron Ballinger?

MEMBER BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley?

MEMBER BLEY: Yes.

CHAIR SUNSERI: Whoa, everybody, please, if you're not speaking, please put your microphones on mute. Vesna Dimitrijevic?

MEMBER DIMITRIJEVIC: I'm here.

CHAIR SUNSERI: Walt Kirchner?

MEMBER KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba?

MEMBER MARCH-LEUBA: Present.

CHAIR SUNSERI: David Petti?

MEMBER PETTI: Here.

CHAIR SUNSERI: Joy Rempe?

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella?

MEMBER RICCARDELLA: I'm here.

CHAIR SUNSERI: Okay, so we're all here,

we're all back from break. And I guess, we were strategizing how the rest of today's going to go and I'm going to take a second here, Walt, if you don't mind, just outline what I think the rest of the week looks like. Because I think it's important for people's planning on this.

So, as you know, we have a couple of sessions here where we're having presentations on, open and closed presentations. We have two topics for the week, one is the EPRI report on TRISO, and the other is the NuScale series. NuScale is the most important thing we have on our agenda right now but we can't ignore the other work that we have as well.

So, we obviously want to get the level of information that the Committee needs to make an informed decision on its outcomes of this DCA.

I'm just surmising from the level of detail that we're getting into in the discussion of these things that we may not have enough time allocated as far as the briefings go. So, I would say that we had time also allocated for report preparation this week with the idea that we would work on the boron dilution letter and try to advance it, and work on our final letter and try to advance that.

I have no expectations that we would

complete either one of those letters this week and, therefore, that would be the goal of our follow-on week, the week of July 21st. So, I anticipate what's going to happen is as we go finish our formal presentations and we go into report preparation, we will be discussing in high-level detail and fine detail all the information that we're hearing this week.

Normally staff, and normally the Applicant, observes during our report preparation and we occasionally ask factual comments or questions of them, or clarifying remarks. So, I anticipate there may be a lot more of that kind of open discussion to help us as we deliberate on our reports. And so therefore, I'm asking Staff and the Applicant to look carefully at our schedule where we have time allocated for report preparation. And I'm going to make a bold request here and ask that you make yourselves available during those timeframes to support our deliberations and any questions we might have as we contemplate what's going to be in our letters.

So, that's the request. At this time, for today, we're going to work through the open session presentation and then we will take a recess after that. We'll ask for public comments on the open session and then we will resume tomorrow morning by starting with an open session, just to open the record and let everybody know where we are and where we're going. And then we will quickly close this session and pick it up where we're leaving off today. Walt, are you comfortable with that?

MEMBER KIRCHNER: Yes, Matt. Maybe one clarification so we don't tie up too many people. I'm thinking of NuScale in particular and also the Staff, who are working on the NuScale SER. And that is, I thought we agreed that we would do the TRISO letter tomorrow afternoon?

CHAIR SUNSERI: Yes, that's good clarification. So, at 2:30 p.m. I believe it is -- let me check the agenda here -- yes, 2:30 p.m. tomorrow afternoon we start our report preparation. And we will lead that off with the TRISO letter, so we'll do the TRISO letter report tomorrow afternoon starting at 2:30 p.m. And that will probably take I'm guessing two hours maybe.

MEMBER PETTI: How long is this P&P going to be?

CHAIR SUNSERI: I'm sorry, Dave, you're really muffled, I couldn't understand that.

MEMBER PETTI: How long is the P&P going

to take on Friday?

CHAIR SUNSERI: Two hours.

MEMBER PETTI: The rest of the time we'll devote to NuScale?

CHAIR SUNSERI: Yes, so after we finish with TRISO and with the exception of the P&P on Friday morning, we have all the rest of time, half the day on Saturday, to devote to NuScale.

MR. DUDEK: Mr. Sunseri, this is Michael Dudek, Branch Chief. Can you maybe get the times to Mike Snodderly so that we can distribute those via email to us so we know exactly who needs to tie in and when?

MR. SNODDERLY: I will, I have it, I'll do it.

CHAIR SUNSERI: Yes, that's a fair request and to the extent that we can predict where we will be, we can give that information to you.

MEMBER RICCARDELLA: Matt, would it maybe be advisable to postpone TRISO to a Friday and have the whole day tomorrow for NuScale?

CHAIR SUNSERI: I'm thinking. I don't know how long -- I guess the problem is it's hard to predict where we're going to be on what the end state on NuScale looks like. So, I guess my thinking on this was we'll get all the barriers out of the way, if I can use that terminology, and I don't mean that TRISO is a barrier but it's an activity that needs to get done.

So, I'm thinking if we get that up and down tomorrow, then that just leaves us to run all out on NuScale. And I think we also may need to take a little break from NuScale after we get through all the presentations tomorrow anyway, just to think about what we heard.

MEMBER RICCARDELLA: Okay, just a suggestion.

CHAIR SUNSERI: But it's a good one. So, let me turn it around on the membership, what is the membership's preference? I'm just trying to lead us through it here.

MEMBER BALLINGER: This is Ron.

With respect to TRISO, the discussion that we've been having so far, at least that I've been listening to, is very intense and requires -- you would have to have some serious concentration on what's going on. And I'm wondering whether the TRISO discussion is simply, for lack of a better word, a nuisance in the continuity of the discussion.

So, on the one hand, you're right, we may need sort of a break, if you will -- sorry about my bell. But on the other hand, there may just not be a logical point to have the break.

MEMBER KIRCHNER: This is Walt. Ron and Pete and Matt, when we, working with Mike Snodderly earlier this week, strategized on schedule. We do have a preliminary, for lack of the right word, draft of a boron dilution letter that is not ready to be shown at this point to go into a public letter-writing session. And our thinking was that both Jose and myself, and perhaps we can conscript one other Member, could work on that offline to have a majority to do the TRISO. We need a break to do that is what I'm saying.

And so giving us at least the earlier part of Thursday evening, because our presence is needed for a quorum for the TRISO work letter report, we could reflect on the presentations and the discussions. And then modify that letter accordingly, perhaps even, with the Chairman's permission, during the recuse from P&P and have something, then, that we could actually use for the purposes of the letter writing activity, which would probably then be Friday.

Anyway, that was the reason we thought that we needed the break, so that we could work on that letter draft for the Committee.

CHAIR SUNSERI: I'm trying to look at the roster here and figure out what the quorum looks like. Can you restate what that sequence would look like in your mind? Because we have two Members that are going to be recused from TRISO, that puts us down to seven, of which we would need four to carry on business to get through the TRISO report.

MEMBER KIRCHNER: Not to be too much of a parliamentarian, but the bylaws, there's some ambiguity. But in general, I think major decisions, and certainly a letter report from the Committee I think falls in that category, should have a majority, and that suggests six.

So, I think you need Jose and myself.

CHAIR SUNSERI: The bylaws allow, the bylaws specifically say that Members that are recused are removed from the majority for the purpose of forming a quorum. So, legally, I mean --

MEMBER KIRCHNER: Yes, that's the quorum part and not the major decision, but okay.

CHAIR SUNSERI: It's the major decision part.

VICE CHAIR REMPE: Matt?

CHAIR SUNSERI: Yes?

VICE CHAIR REMPE: At the beginning of this discussion, I could swear you said you didn't expect to get either the NuScale full letter or this boron dilution letter done during this meeting.

Is that what I thought I heard or did I just mishear part of it?

CHAIR SUNSERI: No, you heard that. There's only two parts to the thing. Really, if you think about our normal course of business, we would be having a Subcommittee meeting right now to get this new information. And then 30 days from now we would be writing a letter based on reflection and the Subcommittee Chair putting together a draft. So, we're trying to put together a letter at the same time we're getting the initial information.

So, with that, unless the information was just perfect and we understood everything quite well, it might have been possible to get a letter out but I did not have that expectation.

VICE CHAIR REMPE: So, might I suggest in light of that comment that whatever Walt and Jose have, and they have looked at the draft, go ahead and read it after we finish the presentations. Then go to the TRISO file and update it. But we may not be able to finish this meeting and that's why I'm kind of --

what you can get done this week done, and then let's progress as far as we can with TRISO.

But getting the Member discussion after the draft is read might be a worthwhile thing and it might influence -- since this is happening so real time, perhaps the Staff at NuScale may -- let's just see where the chips fall.

MEMBER KIRCHNER: Joy, this is Walt. I just do not feel that we should use the current draft letter that we have at this point. I think Jose and I need an opportunity to go through it one more time before we put it in front and do that in an open public session.

MEMBER MARCH-LEUBA: My thought was an adjustment because I wrote a very negative letter based on the available information at the time. I'm hoping to get some good information tomorrow and I can change it. But you have to see my letter.

VICE CHAIR REMPE: So, then, okay, we do the presentations, then we do the TRISO and you guys tinker with it tomorrow night. And then you want to read it after P&P. Is that the schedule that you would prefer?

MEMBER MARCH-LEUBA: My goal is for Walt, me, and maybe Dave, or somebody, Mike, write the conclusions tomorrow night. So, the Committee has a buy-in of what the conclusions are and then we can write the pros on the letter afterwards. But the Committee has to have a bylaw of conclusions.

Right now --

(Simultaneous speaking.)

CHAIR SUNSERI: Yes, so that's what we talked about. When we finish with presentations, we ask Members for what are the main points and that's essentially what you're talking about. So, it just sounds like to me the logical sequence is we'll just continue on like we're doing today, we'll get into the closed session today. We will end with the open session today, we will pick up the closed sessions tomorrow, we will get through the closed sessions and then do the TRISO letter tomorrow afternoon.

And then whatever break you guys need, if you need to miss P&P or whatever, as long as we have a quorum with the P&P, we can then pick up the letter-reading Friday after P&P. Does that sound reasonable?

MEMBER KIRCHNER: That works for me, Mr. Chairman, thank you.

MEMBER PETTI: And I'm definitely willing to help on the NuScale letter.

CHAIR SUNSERI: Yes.

VICE CHAIR REMPE: So, if we're not going to finish it, we still are planning to go through Saturday even though we aren't going to try and finish the letter is what I'm still trying to understand?

CHAIR SUNSERI: Right. It is absolutely critical. Let me back up. While my expectation wasn't that we would produce a letter, my expectation is that this Committee would be as some kind of consensus point on what the content of these letters, what the conclusion of these letters, are going to be so that we could have any chance of finishing them on the week of the 21st.

MEMBER KIRCHNER: It seems to me the way we have it scheduled, we're going to end up with a dead space tomorrow afternoon. We have 2:30 p.m. until 6:00 p.m. and for letter-writing, that's not going to take us that long to do the TRISO letter. And I'm hearing that we won't be ready to even start looking at the boron dilution letter tomorrow afternoon.

CHAIR SUNSERI: So, from 2:30 p.m. you want to start until however long it takes to finish the TRISO letter. If we finish in two hours, that would be 4:30 p.m. and so, you're right, that would actually work to our benefit because we could recess at that time while whoever could go off and start working on the draft letter and be ready for Friday.

MEMBER RICCARDELLA: Okay, and there's a chance we might not get finished with all the presentations by before lunch.

CHAIR SUNSERI: We have about six hours tomorrow.

MEMBER RICCARDELLA: Okay.

VICE CHAIR REMPE: Anna Bradford's going to need Civil Staff support on Saturday.

(Simultaneous speaking.)

CHAIR SUNSERI: I can't hear you, there's some ringing noise going on.

VICE CHAIR REMPE: There's a note in messaging from Anna Bradford wanting to know if the Committee needs Staff support on Saturday.

CHAIR SUNSERI: Oh, let's put it this way, right now I'm asking our Staff to be able to support us on Saturday. I don't know where we will be but if we all want to be successful on this, we need to be lining it up. If we end up cancel it on Friday afternoon to meet for it, then so be it but I found it easier -- at least my judgment is it's easier to turn it off than it is to turn it on, and we may need it.

MR. MOORE: So, this is Scott. The ACRS

Staff is prepared to support Saturday. I think Anna's asking will the NRC Staff need to support Saturday?

And I think, Anna, in answer to your question, you heard Chairman Sunseri say that for the letter-writing, this will be slightly different than normal letter-writing. There may be more interaction between the Committee Members and the Staff and the Applicant. So, I think that's about as much as I can answer at this point.

CHAIR SUNSERI: That's a good summary of what I was saying. Well said, better than me.

MS. BRADFORD: Thank you, this is Anna Bradford. I just want to confirm what I thought I was hearing, which was that the letter-writing may continue into Saturday. It might be kind of an interactive letter-writing session. There might be some questions that we might want to be wanting to answer.

MR. MOORE: That's correct.

VICE CHAIR REMPE: Thank you.

MEMBER MARCH-LEUBA: Hey Matt, since I'm the troublemaker, let me make a statement here so everybody knows what's involves. To date, including today, I've seen no evidence whatsoever that after the down-come of de-borates, when you go into ECCS cooling mode, restarting CFDS or reversing flow on the led-down line on CVCS will not cause a reactivity event.

Unless you guys provide some information tomorrow that I am wrong, I don't see how we get out of this. So, you have all night? You have 18, 16 hours to work on it? But tomorrow, please convince me that when the downcomer and lower plenum is completely de-borated and you restart CFDS, or reverse floor on the let-down line of the CVCS does not bring those $25 worth of reactivity into the core.

Okay? This is important. I mean, the scheduling is important but taking it apart is more important. To date, I have not seen any evidence whatsoever that is the case. Over and out.

CHAIR SUNSERI: Thank you. Any further comments?

VICE CHAIR REMPE: Is this a good time to ask my question? Dave, I think you need to mute unless you have a question.

CHAIR SUNSERI: It's hard to tell if there's five or six people who have their mics on.

VICE CHAIR REMPE: Anyhow, before we broke I had a question that's pertinent to Jose's comment but it's a question for Ben Bristol. Because I still get the feeling that different impressions from what

I hear from NuScale when I keep asking this question. Ben just told us we have several upper-level candidate actions that we believe will avoid this surge of undiluted water.

What's the basis for those high-level decisions? Could Ben elaborate? Do they have calculations that support this? I thought I heard earlier today NuScale saying, no, that's the COL Applicant's job. Does NuScale have anything in house and what is it? Is it hand calculation or some NRELAP calculations?

Do they do a CFD analysis?

MR. BRISTOL: This is Ben Bristol. Can you hear me?

VICE CHAIR REMPE: Yes.

MR. BRISTOL: Okay, sure. I think we can bring some more details on that tomorrow. I think maybe an important characterization is coming into this meeting, NuScale was in a support role of the Staff and their SER, and so that's why we were not planning on presenting any new technical information.

However, I think we've heard the feedback and we understand the concern, and I think we can characterize the design's capabilities better. Obviously, that's proprietary information and since we have a generic DCA design where we're mostly focused on safety systems, some of the details need to be pretty high level because we don't have all of the final design systems mapped out yet.

But, yes, we have done several, we have been working nonstop on this situation since the February timeframe when the issue was initially identified. And we have quantified it and characterized it all number of different ways, up to an including descriptions of the operators capabilities, what they would have, what they would see for different event progressions, different event scenarios.

And I think it is important to consider that what we feel is the combining of deterministic one-directional mixing assumptions that we use in Chapter 15 and the actual realistic conditions, where we know that the lower plenum will not be at zero boron connection, and in all likelihood, the downcomer will not be in the unsafe position that has been characterized throughout the day. But we can certainly follow up tomorrow with some more details on the plant capabilities and what operators could do in the very unlikely event that we ended up in this condition for an extended period of time.

VICE CHAIR REMPE: So, I have a follow-on question. With all this additional information that you say you have, is that what the Staff reviewed during their audit?

MR. BRISTOL: We do not believe that information is relevant for the DCA --

(Simultaneous speaking.)

VICE CHAIR REMPE: Did the Staff do an audit --

(Simultaneous speaking.)

MR. BRISTOL: Pull up the DCA.

VICE CHAIR REMPE: So you said you have information but the Staff's never reviewed it?

MR. BRISTOL: Again, as we've discussed at the ACRS several times over the course of this discussion, the specifics of procedures related to bringing a module out of post-transient, where we've established safe and stable conditions is not developed at the DCA stage. So, no, the Staff has not reviewed the credentials that we have with the design.

VICE CHAIR REMPE: Thank you.

CHAIR SUNSERI: This is Matt. I'm not trying to be provocative or anything with this comment, but I just think we're talking past each other and let me just say this. We're not interested in the procedures. We understand the process, the COA application, the procedure, details step by step, we understand the design. What we're talking about is a strategy.

What strategy would the people use to develop the procedures that provides a fail-safe way of getting out of the situation? So, we're not asking for you to tell us the step-by-step procedure. I don't know if that helps or not but I think we just keep stirring the water up here when we say procedures and outside of scope. That's not what we're asking for. We're asking for the how, not the details. Does that make any sense?

MR. BRISTOL: Yes, I understand, and I think if you get a chance to review some of the information that was provided in March, we did actually spend a little bit of time describing some of the plant capabilities from that perspective.

CHAIR SUNSERI: And that's good. We get a ton of information and as Dave Petti said, it doesn't always come together in the right sequence. And so it will be helpful when you talk about this tomorrow just laying out a substantial step-by-step holistic way of bringing this along, bringing us along so that we understand better. Thank you.

MR. BRISTOL: Understood.

CHAIR SUNSERI: So, anything else? Let's go on with Chapter 19 then. Walt, you back on?

MEMBER KIRCHNER: Yes, I'm back on. So, let's go ahead to Chapter 19, please. Who's up from the Staff for this one?

MR. NAKANISHI: Good afternoon, this is Tony Nakanishi with PRA licensing. So, I'd like to discuss the Staff review associated with the boron --

(Simultaneous speaking.)

Can you hear me?

MEMBER KIRCHNER: Once again, we have to ask people who are not speakers or presenters to turn off your mic, please. Go ahead, Tony.

MR. NAKANISHI: Okay, good afternoon. So, I'd like to spend the next few slides discussing the Staff review associated with the boron redistribution issues. From a Chapter 19 PRA perspective, I think it's important to note that since we've been talking about this --

OPERATOR: The presenter has allowed participants to unmute themselves. You can now unmute yourself by pressing Star-6.

MR. NAKANISHI: I hope you can hear me now but what I was saying was that it's important to shift the mindset from a design basis perspective to how we look at things in the Chapter 19 perspective. We look at scenarios from a realistic standpoint and the figure of merit we're looking at is core damage.

So, with that, I also wanted to acknowledge Marie Pohida and Alissa Neuhausen from the DRA Staff that's integral to this part of the review, as well as the Office of Research provided substantial support. Dr. Peter Yarsky --

I keep getting muted for some reason. Can you hear me?

MEMBER KIRCHNER: Yes, we can hear you.

VICE CHAIR REMPE: After Peter's last name you cut out.

MR. NAKANISHI: Okay, yes, so I just want to acknowledge Research's support that provided a lot of confidence in our review. I would expect that Pete and others may be chiming in to contribute to this discussion.

So, just at the outset, I just want to review the objective of the Chapter 19 review, which is to ensure that the design is properly reflected in the PRA and the boron redistribution issues are properly addressed, such as that any risk-significant scenarios are properly captured.

So, next slide, please. So, as was

mentioned before, we had significant interactions with the Applicant through the audit process to look at the underlying calculations, analyses, that support the PRA. And clearly, the thermohydraulic analyses were a key focus for the Staff. In particular, we wanted to make sure we understood that the sequence progression with the new design change such that the potential for increased ECCS actuation and subsequent incomplete ECCS actuations are addressed. We also looked at the interlock conditions.

We wanted to make sure that certain scenarios that relied upon the interlock to bypass ECCS actuation, we looked at that to make sure that if an interlock were to fail, for example, the potential for, again, incomplete ECCS actuations are addressed.

And I also want to emphasize the Staff's review focused on the reactivity insertion aspects in light of the boron redistribution and the design changes associated with those phenomena.

Next slide, please. So, what I'd like to do is go through some specific scenarios that the Staff focused on that we thought were relevant to the boron redistribution issues and the design changes. And so the Applicant found and the Staff agrees that with the new design changes, certain non-LOCA scenarios now result in ECCS actuation on the new low RCS pressure signal.

So, whenever there's significant coolant introduced into the containment and whenever the reactor coolant system temperature remains high, close to saturation, that leads to an ECCS actuation. So, we're looking at RSV cycling scenarios as well as non-LOCA ATWS scenarios. And so those specific sequences appear in a lot of these entries so there is some impact with respect to how the PRA was modeled. And the Staff did confirm that those event trees were properly updated.

Next slide, please. So, in the previous slide, I mentioned that the non-LOCA ATWS scenarios now are assumed to actuate ECCS. And so, essentially, non-LOCA ATWS scenarios become a LOCA ATWS, if you will, and so with that comes the potential for incomplete ECCS actuation. And one of the potential actions taken to mitigate the inventory loss from ECCS failure is a manual actuation of CVCS. So, we wanted to make sure that the CVCS injection does not introduce reactivity insertion.

And so the Applicant responded to our question with some assessment that the scenario is likely not going to collapse enough voids in the riser to introduce core flow from the downcomer. But the Staff wanted to do a little more independent assessment and we were able to confirm the Applicant's conclusion that it's probably unlikely that there would be sufficient void collapse to introduce a large amount of reactivity.

Essentially, if the injection rate is significantly larger than the vapor generation rate, you may get into the potential of flow incursion. But the Staff assessment, and this is where we received significant support and insights from the Office of Research, that the CVCS injection flow is likely not sufficient to cause a flow incursion.

Next slide, please. So, another area we focused on is --

MEMBER BLEY: I'm sorry, can I press you on that a little bit?

MR. NAKANISHI: Sure.

MEMBER BLEY: It's relatively unlikely that a pump's going to fail but we model pumps and look at that small chance of failure. When you say relatively unlikely, what does that mean?

MR. NAKANISHI: So, this is getting into specific reactor coolant system conditions that would require or lead to that kind of scenario. So, it's more of a phenomenological condition and since we're talking about ATWS conditions, basically, you would be at a fairly high heat generation condition. And in those situations, it's really unlikely to have those kinds of conditions, basically during an ATWS condition. So, I'm not sure if that addresses the question.

MEMBER BLEY: I think what you're telling me is they left all of this stuff out of the PRA model because it's relatively unlikely but we have a lot of other things in the PRA model that are relatively unlikely to me. And we run them through the analysis to see which ones show up. Here, you can get rid of most of the PRA by saying things are relatively unlikely and, therefore, we aren't going to model them.

MEMBER DIMITRIJEVIC: What they're trying to say, this failure is in PRA. For example, if you look in the general transient event tree, you will see that even the ATWS, so favorite two trip, they model success, if ECCS fails and the CVS success leads to success, okay. There is a couple of those different scenarios.

I'm trying to find the sequence numbers, which supposedly have the thermohydraulic support for them, as identified in the table in 0.16. So, I assume that this thermohydraulic support after this update actually considers the bottom situation. Is that a true statement or not in order to credit success?

MR. NAKANISHI: Yes, that's correct. So, previous to this discussion of boron redistribution, we really focused on more of the inventory loss aspect that could lead to core damage. And now we're sort of revisiting the success criteria analyses to look at the reactivity aspects.

But to get back to Dr. Bley's point that basically, the assessment, we believe, supports, essentially, the condition, again, for an ATWS condition. It's the vapor generation rate would be too high relative to the injection rate. And so based on analysis, and you know, maybe Pete, if you're around, you might be able to elaborate on that.

MR. YARSKY: Yes, this is Peter Yarsky from the Research Staff, and what we mean by highly unlikely here is a constellation of thermohydraulic conditions that would have to exist in the reactor cooling system that are somewhat self-inconsistent.

So, as Tony's mentioning, you have to postulate that you had an ATWS event and a failure of

ECCS and a LOCA. But somehow you get into a condition of very low vapor generation rate and low pressure. And so we see that and under that specific set of thermohydraulic conditions, you have an unknotted core that somehow with ECCS failure gets to very low pressure and low steaming rate, if those stars align and you have that particular constellation, then injection of CVCS at both CVCS pumps running can produce enough condensation in the riser that you would have a flow incursion that could have the potential reactivity consequence.

But getting to a condition where you have ECCS failure plus ATWS plus low pressure plus low steaming rate, we don't really see a clear path for how you develop and evolve to that specific condition.

MEMBER BLEY: So, these are much less likely than, at least, what relatively unlikely means to me? These are --

MR. YARSKY: Yes, we're going to do an exhaustive calculation of every possible plant evolution but you do have this inconsistency in your assumptions, that you have all rods on so you have power if ECCS fails here at high pressure. But if you can somehow get to low pressure and low power from there; we did some hand calculations to show that specific set of thermohydraulic conditions, this might present a problem.

But it's not clear how you get to that set of thermohydraulic conditions because it's kind of inconsistent with the assumptions that are built into the event sequence.

MEMBER BLEY: It is, and using the event sequence to show these inconsistencies is a pretty reasonable way to say they're --

(Simultaneous speaking.)

MR. YARSKY: Right, and so we just say it's highly unlikely.

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: I want to point out again that there is nothing in event tree presenting this event and nothing is discussed even in analyses. There is a sequence which leads to success. There is nothing there talking that this injection is small and this is a boron injection, there is nothing even mentioning boron. Boron is not even brought in the discussion on the sequences.

So, if the PRA is extensive now, there is absolutely not anything which points to what you are telling us in the discussion. Currently, we have this event tree which leads to success, period. Nothing impacts, nothing in the event tree, nothing in sequences, nothing either points to that except that there is this TH number, which I don't know that is documented and where it was discussed.

But instead of reviewing the PRA, they will have to assume that this is a very unlikely event because there is not any event to begin, unlikely or not unlikely with high lucidity or small incentive is not present in the PRA.

MR. NAKANISHI: So, NuScale's PRA estimates a fairly low core damage frequency. So, we wanted to make sure was that there aren't any sequences out there that can all of the sudden become a core damage. And so some of these sequences you might think as fairly low likelihood and it may be, but relative to the NuScale risk profile, we wanted to make sure we cover these scenarios.

And so, really, that was the focus of this review, was to look at these scenarios and see if they are indeed a success. And what we attempted to do was NuScale did update their FSAR. Now, there's always some judgment as to how much we would want in the FSAR, but there are some key assumptions that were updated, additional design features, associated with the holes and things like that, had been updated, the event trees had been updated.

The Staff FSAR attempts to talk to some of these scenarios. So, there could always be more but we think it's adequate.

MEMBER DIMITRIJEVIC: You mean more than nothing? Because there is absolutely nothing, everything about this assumption which is discussed.

MR. NAKANISHI: So, the particular CVCS aspect, yes, I don't think is in the FSAR. I believe we touch on it in the Staff safety evaluation and the audit report, I believe, hasn't been provided to the Committee but we expect to provide additional information in the audit report.

MR. SNODDERLY: This is Mike Snodderly from the ACRS Staff. The Committee has not been given the audit report, it has not been finalized by the Staff.

MR. NAKANISHI: That's right. We're moving in parallel with a lot of things.

MEMBER BLEY: Expect to see that before our meeting in two weeks.

MR. NAKANISHI: Pardon?

MEMBER BLEY: We'd like to see that audit report in two weeks from now.

MR. NAKANISHI: I guess, yes, maybe DNRL

could provide some feedback on that.

MS. JOHNSON: We're working to have that before that. We'll try our best.

MEMBER BLEY: Okay.

MR. NAKANISHI: Okay, so, if I could move on to the LOCA ATWS scenarios, and then again, this is another example where previously, LOCAs assumed a doubled-ended guillotine break because that's the most challenging from an inventory perspective. But, as we have been discussing, the smaller breaks and liquid line breaks can lead to a more challenging scenario or consequence from a boron redistribution standpoint.

So, we asked the question about what happens if you have a LOCA with the ATWS and ECCS actuates. So, the Applicant provided a comprehensive analysis of break spectrums, break locations, and if we could go to the next slide, Marie?

So, what the Applicant did was they ran NRELAP 5 with a 1D kinetics option as well as the NRELAP boron tracking model. They've updated some modelizations to provide some additional information on how the plant would respond.

Now, we noted that while the analysis provided reasonable results, we also recognize that we really haven't done the code review that we would typically do for Chapter 15, for example. And so we wanted to have additional assurance with respect to the conclusions that are being reached that there's no core damage.

So, NuScale provided a more integrated analysis, supplemented the NRELAP calculations with a hand calculation using the Fuchs Norheim method. We believe it's a conservative approach, assuming instantaneous reactivity insertion of the boron reactivity or boron dilution. And we found that looking at the energy deposition in the fuel, there's reasonable margin to the core coolability criteria. So, we are confident that the LOCA ATWS scenarios with boron dilution will not lead to core damage.

MEMBER KIRCHNER: Tony, this is Walt Kirchner. Did you use RG1236 as the criteria for determining core coolability? So, Draft Guide 1327.

(Simultaneous speaking.)

MR. NAKANISHI: So, what we used was the SRP 4.2 as a 230 calorie per gram limit. There's significant margin, we believe, to that but that was the criteria we used.

MEMBER DIMITRIJEVIC: In the sensitivity analysis, what type of sensitivity analyses were those? Based on the size of LOCA actuation of ECCS?

Or what type of sensitivity?

MR. NAKANISHI: Yes, so I believe it was varying the amount of dilution. In this case I don't know exactly what they did but we think it provides confidence to the uncertainty, the potential uncertainty, due to the fact that we didn't do a detailed KILD review.

MEMBER DIMITRIJEVIC: This is also just depending on the time of ECCS actuation, right? You didn't analyze anything after ECCS actuation?

MR. NAKANISHI: Right, so this is up to the ECCS actuation. So, the ECCS actuation will trigger, basically, an influx of downcomer liquid right into the core. So, that was the issue that we looked at here, but relative to your question about post, we're going to have a slide on that. We'll talk about that a little more too.

MEMBER KIRCHNER: Tony, again for clarification, this is Walt Kirchner. On your first bullet, the boron tracking model, which has not been reviewed and approved by the Staff -- actually, I guess this is a question I should have asked earlier.

For the Chapter 15 analysis, was the boron tracking model reviewed and approved by the Staff? Or is that part of the audit report? I'd assume you would use the same tracking model, that's why I'm asking this.

MR. NAKANISHI: So, we're not using the same tracking model. And Reactor Systems, Jeff or somebody, can correct me but for Chapter 15, they had a different method for addressing boron redistribution, including hand calculation.

For Chapter 19, they basically used the NRELAP calculation. They've updated the nodalization in the downcomer and the riser to be able to address some two-dimensional effects. And we think it's a good approach, although, from a Staff standpoint, we didn't do a detailed review. We really didn't have time to do a detailed review and because of that, we asked NuScale to supplement that potential modeling uncertainty with additional technical basis.

MEMBER KIRCHNER: What I'm drawing from this is, kind of the wave-front conservative approach for Chapter 15, this is more a best-estimate approach? It sounds like they went to more nodalization as well.

MR. NAKANISHI: That's correct.

MEMBER KIRCHNER: Is that a fair characterization?

MR. NAKANISHI: Yes.

MEMBER KIRCHNER: Thank you.

MEMBER PETTI: Was the nodalization done to try to capture some multi-dimensionality that wasn't in the Chapter 15 analysis?

MR. NAKANISHI: The nodalization, essentially, created a two-dimensional component in the riser and the downcomer.

MEMBER PETTI: Okay, great, thanks.

MR. NAKANISHI: Okay, next slide, please?

MEMBER DIMITRIJEVIC: Let me actually stop you because this may not be a bad place to actually how see how much of those actual scenarios we look in. Because LOCA is very simple, it only has four scenarios to look in, right? The event tree has only four sequences leading to success and those sequences activate the reactor trip and the successful, ECCS successful, that's the first one. Or the other two trips successful, ECCS fails, CVCS successful. Right?

MR. NAKANISHI: That's right.

MEMBER DIMITRIJEVIC: So, we assume every reactor trip is successful and we don't have to worry about reactivity, right? That's what you said?

Then if we have reactor trip fail, we again have ECCS successful and that's the sequence which was analyzed. That's Sequence Number 4, right? Reactor trip fail, ECCS successful.

MR. NAKANISHI: Right, so --

MEMBER DIMITRIJEVIC: And then there is another sequence which is if ECCS fails, CVCS successful, but you said the CVCS can never add reactivity to worry about for boron in LOCA.

MR. NAKANISHI: I think that's correct, yes.

MEMBER DIMITRIJEVIC: Okay, so the only sequence you guys are concentrating on is the reactor trip fail, ECCS successful, right?

However, is this ever mentioned in Chapter 19? Is anything about this, what you have on those two slides, can this be found anywhere in Chapter 19?

MR. NAKANISHI: So, the issue here, we wanted to make sure that the break spectrum was addressed. Smaller breaks are more likely than the double-ended guillotine, and also, the smaller breaks can lead to increased dilution.

So, we wanted to cover that and I believe Chapter 19, the FSAR, has some additional information to indicate, and I believe it's in the success criteria table, this topic.

MEMBER DIMITRIJEVIC: No, I'm at the six-criteria table, its only change is related to the number of sequences. The thermohydraulic simulation number, but nothing else.

There is no discussion. If you can point to me the spectrum of the break, the sensitivity analyses, whatever you told us is in Chapter 19, I will appreciate that.

MR. NAKANISHI: Yes, so there isn't going to be that level of detail in the FSAR. So, we do discuss this to some extent in the FSER and again, we plan to provide additional information in the audit report.

MEMBER DIMITRIJEVIC: I pointed this out in our June meeting that issue was never addressed in Chapter 19.

It was never discussed, and therefore, any recoveries or any uncertainties or any sensitivities are not present there?

MR. NAKANISHI: Right, so a lot of this is reviewing what the Staff did during the audit and some information will have to be in the audit report as opposed to the FSAR.

Okay, next slide, please.

MR. CORRADINI: This is Corradini, I think what Vesna's asking, though, in the original PRA calculations and analysis was were these events considered?

Or, essentially, considered too unlikely to even analyze?

MR. NAKANISHI: So, these events were considered but they were looking at it more from the inventory loss perspective.

So, the reactivity aspect wasn't explicit before.

MEMBER DIMITRIJEVIC: Was boron dilution events not considered an original?

And the only thing that has changed between the original PRA and this PRA is that we have a change in the actuation of ECCS system and we have it as a whole. So, they didn't rely on that but it's still just inventory loss, not boron dilution.

So, boron dilution I can say it's not considered in Chapter 19. It may be considered in your audit or the simulation but we cannot see that from Chapter 19.

MR. NAKANISHI: Right, so where we're headed with this is, basically, boron redistribution is not going to be a risk-significant scenario.

That's the conclusion that we're trying to support through these discussions.

So, yes, based on the Staff review, including a review of potential reactivity insertion mechanisms that Research assisted us with, we believe we have reasonable assurance that boron distribution and dilution will not lead to a risk-significant scenario.

In other words, not a core damage event.

MEMBER MARCH-LEUBA: Tony, this is Jose. I know that we will fix it and I know that one of my heroes, Peter, is the one that wrote the report.

I am still waiting to get some details about why Peter thinks that a $1 per minute reactivity ramp that goes all the way to $29 of insertion activity is acceptable in the core.

How come anybody can say that if you put $29 worth of positive reactivity into the core, even if the ramp is very slow, that you don't melt that core?

I'm hoping to get the answers tomorrow.

MR. YARSKY: I could maybe take a stab at giving a short answer to the question.

MEMBER MARCH-LEUBA: Okay.

MR. YARSKY: So, when we developed the white paper, we wanted to have a better phenomenological understanding of the processes that could potentially move diluted water into the core.

And one of the things we looked at was

that because the riser wall will have a conduction heat transfer pathway to the downcomer, what will occur inside the portion of the vessel that's inside the riser wall itself, there will be an internal recirculation flow pattern that will develop.

And that internal recirculation flow pattern is going to mix the core inventory with the upper riser.

So, you have a mixing --

MEMBER MARCH-LEUBA: Peter, you are repeating my theory to me.

You probably have read my white paper where it explains that, I just have not seen that theory validated with any analysis, hand calculations, or even place of paper.

MR. YARSKY: So, what we did, Jose, was we calculated what that mixing time is using TRACE results and that mixing time is about 40 seconds.

MEMBER MARCH-LEUBA: Fantastic. Where is that calculation?

MR. YARSKY: The flow calculation should be in the white paper that you received this week. So, you can take a look at it in there.

MEMBER MARCH-LEUBA: By this week you mean yesterday afternoon?

MR. YARSKY: If you got it, you would have gotten it this week so it's been very recent.

MEMBER MARCH-LEUBA: Yes, it was yesterday afternoon and I had all these things to look at.

MR. YARSKY: Of course, I'm sure. So, the short answer is we looked at a lot of different possible phenomena or mechanisms that could move the diluted water into the core.

But when we looked at that, if the process is slow, and by slow we mean relative to that mixing time, what would happen is if you're putting in the water -- whatever the mixing time is, if it's slow relative to that mixing time, that positive reactivity that's being inserted because the water's diluted, even if you're ramping it up, it starts to be erased by the process of mixing in the high concentration of boron from the top of the riser.

(Simultaneous speaking.)

-- sustainable if you have mixing.

MEMBER MARCH-LEUBA: Let's stipulate that I agree with you.

But number one, I have not seen a single place for written information -- indeed, all the ACRS Members are falling asleep now because they don't know what we're talking about.

And the only place I've seen it written is when I wrote --

(Simultaneous speaking.)

MEMBER KIRCHNER: We actually are very attentive and I know exactly what you're talking about, and I have questions.

VICE CHAIR REMPE: I also have questions.

(Simultaneous speaking.)

-- certainty in a calculation like that, Peter, and TRACE and the validation basis but we can talk about that tomorrow.

MEMBER MARCH-LEUBA: TRACE cannot possibly calculate that.

What Pete is saying is that the front of light water that's coming in the bottom of the core miraculously gets transferred to the upper plenum without creating heating in the core.

And then it mixes with the upper plenum and, therefore, the core never dilutes. And I agree with him, I wrote that on my paper to the Staff but I haven't seen it anywhere.

The front of diluted water comes into to bottom of the core and gets transferred to the upper plenum without going through the core.

MEMBER KIRCHNER: That's not likely.

(Simultaneous speaking.)

-- analyses and there's substantial mixing at the lower entrance to the core, and we should take that up tomorrow because --

(Simultaneous speaking.)

-- great technical detail.

MEMBER MARCH-LEUBA: I think we should wait for tomorrow, I agree 100 percent, and I believe that Pete, as usual, is right but you cannot rely on that. And especially if it's a function of the power level.

If you have high power, you will have a lot of convective currents. If you have very low power, three, four, five weeks after shutdown, how many convective powers do you have?

I don't know, let's talk about it tomorrow in detail.

MEMBER PETTI: Can I ask a question and comment? I think it would help if all of the Members go back and look at the last 20 Subcommittee slides, where ECCS actuation and boron redistribution was discussed.

If people have questions tonight, it would be worth reading Peter's white paper again because a lot of information is in there. I think it'll just mean more to today's discussion, as it does to me.

And third, I am not an expert but if this is Chapter 19, not Chapter 15, then the burden of proof is different.

It's a best estimate calculation, not a Chapter 15 calculation, because it seems like that should play into other things in the discussion.

MEMBER KIRCHNER: David, that was my earlier point when I drew out Tony about this. This is a best estimate now calculation that's being used.

MR. NAKANISHI: Should I move on?

MEMBER KIRCHNER: Yes, Tony, please proceed.

MR. NAKANISHI: So, another scenario we looked at was an isolated CVCS injection line break outside of containment and this is a potential risk-significant scenario because it's a bypass scenario if there is core damage.

And because of the new ECCS actuation design, basically, the ECCS actuates earlier than before, which could lead to greater inventory loss. And so if we revise thermal hydraulic analysis showed that additional -- so, previously, DHRS wasn't needed for this scenario.

But now an additional at least one train of DHRS is required to essentially reduce the RPV pressure to reduce the rate of coolant loss from the RPV. And that will allow the operator reaction to inject containment flooding and drain system to prevent core damage.

So, here, we wanted to make sure that the DHRS effectiveness is appropriate for the scenario of concern. DHRS by design is really intended for non-LOCA conditions, but this is a LOCA condition and the steam generator would be uncovered.

So, the Staff went back and we wanted to make sure there's enough -- so, the experimental basis is sort of sparse but we discussed this with the cognizant NRELAP experts in house and with contractors.

And we believe that there's enough physics to be able to credit DHRS in this condition. So, this was a scenario that we focused on. Next --

MEMBER DIMITRIJEVIC: Your concern here is core uncovering, not the boron? Where you concentrate it, do you have enough time to prevent the core uncovering, is that your statement?

MR. NAKANISHI: That's correct. So, this has nothing to do with boron redistribution, it's a function of the ECCS design change.

MEMBER KIRCHNER: These are just the thermohydraulic figures of merit, not boron?

MR. NAKANISHI: Correct.

MEMBER DIMITRIJEVIC: Right, but you did not consider the consent broadly the couple times that you may have extended the ECCS operation.

Here, with operator for the small break operator starting, does CFDS later after that to make up for losses? Would that be the issue at the bottom?

MR. NAKANISHI: Right, so we'll touch on that I believe in the next I think two more slides.

But this action, initiate containment flooding and drain system, is a very short-term response to an un-isolated CVCS line break outside of containment.

So, this action here is really not the same. It's really to address the inventory loss issue.

Next slide, please.

So, the other scenario we looked at, and again, this is a pure thermohydraulic issue, but the NuScale design is such that if you have a LOCA inside a containment but say you failed to isolate the containment, if you succeed with ECCS actuation, the inventory loss will be sufficiently low that you'll achieve success.

In other words, no core damage. So, in light of earlier ECCS actuation, we wanted to make sure that assumption is still valid. And so we asked for additional information relative to how much coolant mass loss do you get.

And the Applicant did additional sensitivity studies during the timings and we agree that the ECCS actuation, or the new ECCS actuation still prevents core damage for this scenario.

Next slide, please. So, this is getting to, and we talked about this a little bit already, but this is post-event recovery scenario and we have ATWS indicated here.

But really, the assessment we've done applies to whether the reactor failed to scram or whether the reactor was successful in tripping. So, first of all, I think it's very reasonable to assume that any adverse maneuvers would be properly governed by plant-specific procedures.

But here we wanted to focus on the consequence and so suppose that either a CVCS is used or a CFDS is used, after some time, after ECCS actuates and the operator would initiate containment flooding and drain system, or CVCS.

And basically, based on Research's assessment of the reactivity insertion rate, and comparing that to -- we have here a thermal time constant and that's probably on the order of a few seconds.

But it was also mentioned that there's also the mixing time. Basically, the time to add a dollar of reactivity based on the geometry of the module and the amount of initial reactivity in the downcomer.

So, where we're ending up with this is we don't think it's a fast enough event to cause core damage.

MEMBER MARCH-LEUBA: I'm sorry, this is exactly what I was trying to get to, and hopefully, we'll get into the proprietary information tomorrow with more details.

But there is, by any estimate, at least $20, maybe $29, of positive reactivity in the lower plenum.

I don't care how much load you put it in or how thermal exhibiting you are with the core, if you put $29 worth of positive reactivity into the core, there is no way that core doesn't melt.

MR. NAKANISHI: So, the other

consideration here is the pressure. The low pressure conditions that we're in here would affect the density feedback.

MEMBER MARCH-LEUBA: I was going to ask you what void, reactivity, or density feedback you used on your estimation?

Because my estimation in my brain -- it's not even hand calculations, I'm just thinking -- come out to be positive. Have you calculated the void reactivity feedback under these conditions?

MR. NAKANISHI: So, maybe Pete could expand? Yes, how about it, Pete, would you like chime in on that?

MR. YARSKY: This is Dr. Peter Yarsky from the Research Staff. The first item I think I'd like to address is the idea of ramping in all of the reactivity from the downcomer.

And while, Jose, I absolutely agree with you, if you could put all of the $29 into the reactor core, surely it would lead to core damage.

But the idea is inside the core you have a reservoir of highly, highly concentrated boric acid that's contributing a huge amount of negative reactivity.

So, if you add the water from the

downcomer very slowly and it mixes with the highly concentrated boric acid water in the core, it kind of erases that reactivity insertion as you're going.

So, it doesn't ramp up, there's sort of this mixing phenomena that as you're adding that reactivity, it's kind of removing it by restoring the high concentration of boron to that liquid as it's being inserted.

So, there's kind of like the insertion ramp that you're describing, but there's also a process where that reactivity is being removed by putting the boron back into the core.

MEMBER MARCH-LEUBA: Okay, so what you're saying --

MR. YARSKY: There's one mechanism above the ramping and then if that makes sense, I can move on to talk about the void feedback?

MEMBER MARCH-LEUBA: First, let's talk about the mixing.

I 99 percent agree with you that if especially the core is hot, surely after shutdown there will be significant convective coolants in the core that will mix it.

But I have not seen any single calculation that tells me how does it mix or whether does it mix.

In the absence of those calculations, I have to assume it moves as a front, which is what everybody else had been assuming until five minutes ago.

So, you say it doesn't move as a front --

MR. CORRADINI: Jose, I think the wave-front model was for Chapter 15 calculations, not for PRA calculations, if I remember how the Applicant presented it.

Maybe I'm misremembering.

MEMBER MARCH-LEUBA: Michael, have you ever seen a calculation of convective currents in the core that mix the diluted water with the highly borated water?

Do you have any idea?

MR. CORRADINI: I've read Pete's white paper, if that's what you mean.

MEMBER MARCH-LEUBA: So, yesterday he postulated there might be some mixing and let me --

(Simultaneous speaking.)

-- I agree 100 percent, I agree with Pete 100 percent. And indeed, I wrote a white paper for the Staff saying that, that that's what probably happens, but I have no idea if it happens.

Just because I believe it happens, it's not what happens.

MEMBER PETTI: Jose, I thought there was some calculations behind the discussion in the white paper, but it is a 40-page white paper and I could be wrong as I remember other areas.

MEMBER MARCH-LEUBA: Let's ask Pete, what calculations are behind it?

MR. YARSKY: So, the Research Staff, to support I forget which Chapter of the review but it's part of the NuScale Reactor Systems Research Plan, performed a number of LOCA calculations.

And we were able to farm those long-term calculations to look up the internal recirculation flow patterns.

MEMBER MARCH-LEUBA: And those were calculated using what?

MR. YARSKY: TRACE, TRACE calculations.

MEMBER MARCH-LEUBA: There is TRACE calculations? You were using the three-vessel component?

MR. YARSKY: Yes, it's actually, I'm fairly certain, a vessel in vessel in vessel model, where we have a vessel representing the containment vessel representing most of the RCS, and then another vessel representing just the riser.

MEMBER MARCH-LEUBA: Pete, let me

stipulate.

I agree with you that this is the likely thing to happen but if this was an Applicant or a Licensee sending into to you for review, would you accept this calculation?

MR. YARSKY: I think it's important to recognize the difference between the Chapter 15 acceptance criteria for methodology and what is used for the beyond design basis events, where you rely on much more heavily on just best estimate without considerations of the uncertainties.

Here, I think the physical process of the internal recirculation is so key to the progression of the event. I think it's overly conservative to ignore it.

MEMBER MARCH-LEUBA: I agree with you 100 percent, I just don't see any definitive calculation I can put my hand on heart and say, yes, this is right.

I think there will be internal calculations, I think it will mix, and yet, I think the likelihood that the water will be transferred to the upper core, the upper riser, and mixed there.

It won't mix in the core, it'll mix in the riser. But we need more than my gut feeling.

MR. YARSKY: Well, the other thing I would mention is that we're looking at an ATWS case here. So, if you're inserting reactivity less than a dollar you are going to have a power increase, right?

We don't see this as being something that will challenge core coolability, so long as you stay covered and you're not in a prompt critical excursion. But that is going to further promote mixing.

So, the thing that's driving your event to where you would be worried about the reactivity insertion, that exact same thing, if it's slow, is going to promote that mixing.

MEMBER MARCH-LEUBA: And we go back to the boron reactivity coefficient. I've been working it in my head and I'm convinced the boron reactivity coefficient is positive.

MR. YARSKY: so, this is the other item I think is worth spending at least a couple minutes to discuss.

So, while under the highly borated conditions that you would have in the core, if the physical process of the feedback was thermal expansion, like it is when you're at high pressure, then, Jose, it certainly does look like the moderator feedback would be positive.

But under these conditions, you have to look at a post-ECCS actuation, right? Because if you don't have a LOCA with ECCS actuation, it's not really a mechanism to move the de-borated water --

MEMBER MARCH-LEUBA: You're likely depressurized.

MR. YARSKY: So, you're at low pressure?

(Simultaneous speaking.)

So, now that you're at low pressure though, the physical mechanism of density feedback changes.

It's no longer really being driven at all by thermal expansion, it's being driven by void formation.

MEMBER KIRCHNER: And I believe now it will turn negative.

MR. YARSKY: Yes, so when you're in this void formation regime, what will happen is as you heat up the coolant, you'll form bubbles and what happens is, essentially, the hydrogen leaves the core and all the boron stays where it is.

MEMBER MARCH-LEUBA: No. As you form voids, you push the boron out of the core and keep the hydrogen.

MR. YARSKY: If you have a situation where you're flashing but so long as the average flow rate is still upwards, you're not reversing --

(Simultaneous speaking.)

-- the boron doesn't leave.

MEMBER MARCH-LEUBA: There isn't a flow rate of risers and coolers. Is all the easy flow just sufficient to compensate for the --

MR. YARSKY: Some kind of preservation that was like a flashing event, then the void formation would push inventory out of the core. You'd have the reverse flow.

MEMBER MARCH-LEUBA: No, there won't be any reverse flow, it will be all --

(Simultaneous speaking.)

MR. YARSKY: -- any reverse flow. And so because there's no reverse flow, the boron doesn't leave.

MEMBER KIRCHNER: Might I interject here? I suspect that this discussion could go on well beyond 7:00 p.m. Eastern Time.

I would propose that we hold that in-depth discussion for the presentation of, I believe, Peter, you are going to present your white paper in closed session tomorrow, is that correct?

MR. YARSKY: No, I don't believe there's

anything in the --

MEMBER KIRCHNER: We'll have the opportunity to question you on the white paper? Let me turn the tables. Is that correct?

Is that part of the Staff's closed presentation?

MEMBER MARCH-LEUBA: No, it's not.

MR. NAKANISHI: So, yes, there was no prepared presentations on the white paper by Dr. Yarsky, but hopefully, he can answer --

MEMBER KIRCHNER: We can question him on the content and the assumptions.

MEMBER PETTI: We can get a PowerPoint from Mike Snodderly.

MEMBER MARCH-LEUBA: Before we close the record, we just had a spirited physics argument between two bright minds, one much brighter than mine.

And there is a disagreement, there is a difference of opinion, and there is no document, there is no record that we can review from the Applicant or the Staff that positions it.

If there is a difference of opinion between two bright minds, then it's a difference of opinion. We have a problem.

MEMBER KIRCHNER: Okay, your statement has been made, Jose. May I go back and just ask Tony, Tony, on the last two bullets, I will just make a statement. You don't have to answer it in real time.

We could also defer this for tomorrow. Quite frankly, the fuel thermal time constant is not an issue, it's the rate of reactivity insertion that is the governing factor.

So, that's not a good figure of merit on the first sub-bullet.

Second one, once again, a fellow Member asked, found very unlikely, I just don't know what to do with something that's been found very unlikely. So, in tomorrow's discussion in closed session, can we address both of these?

Actually, address probably this whole topic?

MEMBER DIMITRIJEVIC: I want to add something also here.

MEMBER KIRCHNER: Go ahead.

MEMBER DIMITRIJEVIC: Okay, I want to make this point very clear. Sometimes I babble and maybe it's not clear. Here it says PRH updating and there it says post-event recovery.

There is no post-event recovery in Chapter 19. There is nothing about boron dilution in the

Chapter 19, only one sentence in the assumption under success criteria which says the host and the exchange of actuation have addressed concerns of the boron redistribution.

That's all, I just want you to know when I say, oh, this is not the Chapter 15, should be in Chapter 19, there is nothing in Chapter 19 on those issue. And therefore, the PRA Chapter 19 is name of the slides but this thing was not discussed.

There is not any possible recovery or anything. So, if we think the dose evaluation should be discussed everywhere in the FSAR, then maybe the Chapter 19 is the place.

We should also discuss that because currently they are not there. That's all I want to point. Saying Chapter 19 has some post-event recovery, that's not true.

MR. NAKANISHI: Right, so what we're trying to do here is to review with the Committee what we've done as part of the audit to look at these scenarios to make sure that these are not core damage events.

And so I guess, again, there's a judgment as to how much we want in the FSAR. We certainly would. I believe we have some discussion, again, in the FSER, or safety evaluation, and we certainly would elaborate on these in the audit report.

And then the other point, Dr. Kirchner's comment about the reactivity insertion rate, what we tried to convey with that bullet is, essentially, if the reactivity insertion time, the time it takes to add a dollar is significantly greater than the fuel thermal time constant, then there would be a feedback mechanism that would curve the reactivity insertion.

And then the second point, what we're really saying there is that we've considered this phenomenon and we think that it's, as Dr. Yarsky pointed out, thermohydraulically, the starts have to align for this to be a concern.

So, essentially, we think there's a basis to screen it out from the risk assessment.

MEMBER MARCH-LEUBA: Tony, I'm sorry to say this but there are so many things wrong with what you just said. If you have $20, $25, $30 worth of positive activity going into the core, I don't care what void activity you calculated, your core is going to melt.

And my evaluation in my head, not even on paper, is that the void reactivity coefficient is positive, which is even worse. It will have a positive excursion.

So, unless you can provide me a calculation that says the void reactivity coefficient is negative, I cannot accept your statement that as long as the $29 worth of activity commences slowly, we will survive it.

There is no way on heaven or earth that a reactor can survive $29 worth of negative reactivity, especially one that has a positive coefficient.

Maybe we can get into the details tomorrow, but this is --

MEMBER KIRCHNER: Jose, let's take that for a note for tomorrow because I could go on to scenarios like such insertion will induce flow oscillations and maybe flow oscillations are good because you have perfect mixing by the time you're done oscillating a few cycles.

But let's take that for tomorrow and where are we, Tony, in your presentation? Are there more slides?

MR. NAKANISHI: We just have one more, which is a conclusion slide.

MEMBER KIRCHNER: Please go onto your conclusion.

MR. NAKANISHI: So, basically, through the interactions with the Applicant, we've looked at potential scenarios that we thought might be important to consider in the PRA.

And we're basically concluding that there's no known risk-significant contributors that are unaccounted for in the PRA, and that we're able to make the safety findings as described in the SRP.

And that concludes my presentation.

MEMBER KIRCHNER: Questions?

At this point, thank you. We have to remember that we have to turn to the public for any comments, so Mike Snodderly, I see we have a sidebar that someone from NuScale wants to make a comment?

Mike Melton, would you go ahead and make your comment and then we'll turn to the public.

MR. MELTON: Yes, sir. Can you hear me well?

MEMBER KIRCHNER: Yes, I can hear you, Mike.

MR. MELTON: Okay, I had to mute and then I get a message that I'm no longer muted and I miss conversation. So, I believe we can talk about this more tomorrow in the closed session.

We haven't spoken up about the $29 of reactivity. We definitely do not agree with that number and we'd be happy to talk about that even more tomorrow.

So, I think there's been a little bit of excitement on that but we actually do not agree with that based on reactivity, and we'll address that tomorrow. The point about post-accident recovery procedures is not within the scope of the DCA.

They are not within the scope of the DCA and I think the NRC has pointed that out as well. So, that part we definitely agree is not within the scope of the DCA.

So, I think in closed session we will have an opportunity to get some of these real details. I just want to be able to say we can have a much more positive spin on this but we're going to need to provide the details to Dr. Leuba to satisfy those concerns.

That's all, and thank you.

MEMBER KIRCHNER: Thank you, Mike. Mike Snodderly, can we turn next for public comments if there are any and ask to see -- I assume right now the public line is open?

MR. DASHIELL: The public line is open for comment.

MEMBER KIRCHNER: Thank you, sir. Okay,

members of the public, if there is anyone out there who wishes to make a comment, please state your name and make your comment.

MS. FIELDS: This is Sarah Fields --

MEMBER KIRCHNER: Go ahead, Sarah.

MS. FIELDS: -- from Utah and I have a few comments to make. I know this is very difficult and complex and time-consuming and tiring for you all, so I do appreciate everyone's efforts.

I had two comments. One has to do with NuScale and their development of a control room staffing topical report, which will accompany their standard design approval.

And they had a meeting with the NRC on May 28th and they had slide presentations. And what NuScale would like to do is have a pathway for any NuScale COL Applicant to reduce the control room staffing to one control room operator and two senior operators.

So, when you're considering the issues having to do with what happens to recovery in case of a boron dilution situation, you might also think about having one operator for all 12 modules and two senior operators in the control room.

I think this topical report does bring up some very serious issues in light of NuScale DCA discussion today.

Also, the NRC with the support of the nuclear industry and the Department of Energy has proposed changes to emergency preparedness rules applicable to small modular reactions and other new reactor technology.

This proposed rule would make it possible to reduce the size of the plume exposure pathway, emergency planning zone to the site boundary, rather than the usual ten-mile zone.

The draft rule is currently open for public comment and the docket number is NRC-2015-0225.

I've asked for an extension of the comment period, which ends July 27th, because I feel that a lot of the discussion related to the NuScale design SMR is relevant to this NRC proposed rule that states that new emergency planning requirements and guidance would adopt a performance-based, technology-inclusive, risk-informed, and consequence-oriented approach.

So, I think that all of the information that is being presented to the ACRS, the ACR discussion, the rulemaking procedure, is relevant to this proposed rulemaking as it affects the risk associated with the NuScale design and others designs.

I'm not quite sure why the NRC, and this is another Department within the NRC, why they are moving forward with this when there are so many unknowns regarding the NuScale design and they're talking about performance-based reactor approach and consequence-oriented approach when at this time we really have no performance to consider and there are many risks and consequences that have yet to be explored.

Oh, also, I'd like to know what the NuScale schedule would be for tomorrow and how a member of the public would be able to access the sessions that are not closed when it comes to the NuScale design, and how a member of the public can find out at what time an open session for the ACR risk review will be started.

Hello?

MEMBER BLEY: Matt, are you going to address that?

CHAIR SUNSERI: Yes, we take the comments, I heard the comments. We're going to talk about our schedule at the end of this session today.

MRS. FIELDS: Yes, but you're going to close the session. Are you going to talk about it now?

CHAIR SUNSERI: Yes, ma'am. I will address the schedule for tomorrow before we leave today, if you can just hang on for a little.

MRS. FIELDS: Before you close the open portion?

CHAIR SUNSERI: Correct.

MRS. FIELDS: Thank you.

MEMBER KIRCHNER: Thank you, Sarah. I apologize, I was disconnected for a bit there. So, was Sarah provided an answer about when the public sessions would reconvene?

CHAIR SUNSERI: Not yet, Walt, I'm going to do that when we get to that point.

MEMBER KIRCHNER: I think, Sarah, if you would hold on, I think the Chairman is going to make an announcement about schedule once we conclude our NuScale discussion this afternoon.

Are there any other comments from members of the public?

CHAIR SUNSERI: Not yet, Walt. I think we might have lost Walt again. Are you there, Walt? Okay, we lost him.

Any other members of the public wishing to make a statement? Okay, hearing none, Mike, can you close the public line?

MR. DASHIELL: The public line is now closed.

CHAIR SUNSERI: Okay, so let me extend my appreciation to everyone during the very long meeting today, in particular members of the public for their patience and endurance to be at this late hour of the afternoon.

And thanks for all the presentations from Staff and NuScale. As you can tell, it's very detailed. We are looking for information to help inform our decision and there's a lot of details necessary to do that.

As far as tomorrow goes, we're going to go into recess now. We're not going to have any more discussions today. Tomorrow morning at 9:30 a.m. we will reconvene in an open session.

We will address any comments or questions from the ACRS Members that can be dealt with in the open session. I anticipate that being a short session and then we will ask for any public comments at that time, and then we will go into closed session.

So, throughout the day, though, there will be the opportunity that we might go back into open session. So, in order to let the public know what we're going to do, our Staff is prepared to go onto the public line and make periodic announcements.

And so, Scott, I don't know if you had a chance to think about that but I would suggest something like every hour on the hour, somebody make an announcement of where we are and if we are going to be anticipating coming back into open session.

MR. MOORE: Yes, Chairman Sunseri, we can do that.

CHAIR SUNSERI: Okay, and then as far as what we know, we know we will go back to open session at 2:30 p.m. tomorrow afternoon with the primary goal of starting the TRISO -- I'm looking at my schedule, hold on a second.

Yes, 2:30 p.m. tomorrow afternoon and we will pick up the letter report on the EPRI TRISO time. And then however long that takes, I don't know, it may take an hour, it may take three, or whatever.

We will then decide at the end of that session what we want to do, if we were going to continue on with NuScale after that or if we are just going to recess for the rest of that day while people go off and think about what they heard from the closed sessions, prepare a draft report that we may be able to put up in a public session should it be developed far enough along to do that.

But that would not be until Friday some time, at the earliest. It would be Friday 11:30 a.m. Friday morning. So, I hope that helps a little bit with the big-picture and I'm sorry that we can't be more detailed in what we're doing.

We're kind of picking our way through this and doing the best job we can of keeping everybody informed. So, let me ask if anyone has any questions about the schedule?

Can everybody still hear me?

MR. MOORE: Yes.

MEMBER KIRCHNER: Yes, Matt, thank you.

CHAIR SUNSERI: Okay, so just in recap then, we will open tomorrow morning at 9:30 a.m. in open session just to reorient ourselves and address any questions that the Members may have after they've slept on the information they've heard today.

We will then have an opportunity for public comment prior to closing that open session, and we will close that open session and go into closed session for approximately four hours.

We'll have a lunch break towards the end of that and then we will go back into open session at 2:30 p.m., unless something changes during the closed session which allows us to go back in open session.

So, then, the Staff is going to be on the public line making hourly announcements on our progress.

Okay, I think I got that out and so any last-minute comments before we close and adjourn for today?

MEMBER KIRCHNER: Yes, Mr. Chairman, this is Walt Kirchner. I just want to thank the NuScale and the NRR Staff and research for their participation today and presentations.

CHAIR SUNSERI: Good, thank you, Walt, and I certainly agree with that. Everybody did a good job. So, at this point in time, we are recessed until 9:30 a.m. Eastern tomorrow morning. Thank you.

(Whereupon, the above-entitled matter went off the record at 7:16 p.m.)

July 1, 2020

Docket No. 52-048

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Submittal of Presentation Materials Entitled "ACRS Full Committee Presentation: NuScale Topic – Boron Redistribution and General Design Criterion 33," PM-0720-70785, Revision 0

The purpose of this submittal is to provide presentation materials to the NRC for use during the upcoming Advisory Committee on Reactor Safeguards (ACRS) NuScale Full Committee Meeting on July 8, 2020. The materials support NuScale's presentation of boron redistribution and General Design Criterion 33.

The enclosure to this letter is the nonproprietary presentation entitled "ACRS Full Committee Presentation: NuScale Topic – Boron Redistribution and General Design Criterion 33," PM-0720-70785, Revision 0.

This letter makes no regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions, please contact John Fields at 541-452-7425 or at JFields@nuscalepower.com.

Sincerely,

Zackary W. Rad
Director, Regulatory Affairs
NuScale Power, LLC

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Enclosure: "ACRS Full Committee Presentation: NuScale Topic – Boron Redistribution and General Design Criterion 33," PM-0720-70785, Revision 0

Enclosure:

"ACRS Full Committee Presentation: NuScale Topic – Boron Redistribution and General Design Criterion 33," PM-0720-70785, Revision 0

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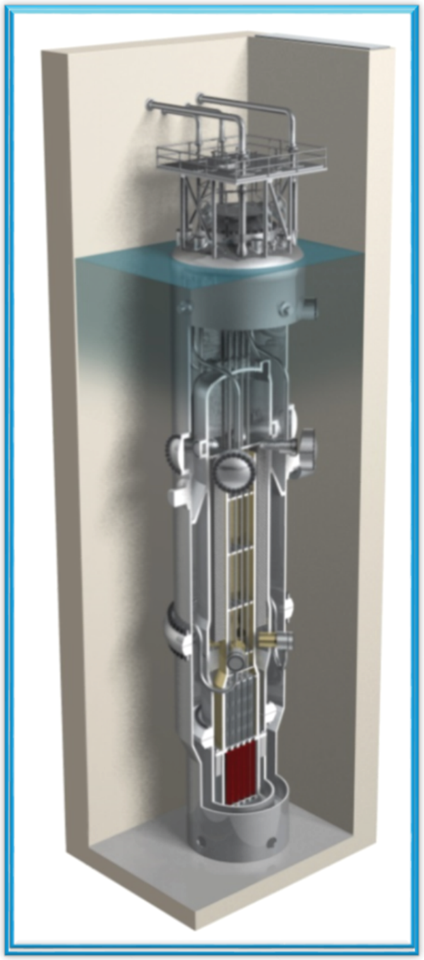


ACRS Full Committee Presentation

NuScale Topic

Boron Redistribution and General Design Criterion 33

July 8, 2020

PM-0720-70785
Revision: 0

Template #: 0000-21727-F01 R6

Presenters

Rebecca Norris
Licensing Supervisor

Paul Infanger
Licensing Specialist

Agenda

- Boron Redistribution Update
- Boron Redistribution Audit
- Summary of Final Design Changes
- DCA Revision 4.1 Boron Redistribution Changes
- LOCA Topical Report Boron Redistribution Changes
- General Design Criterion 33 DCA Changes
- Conclusions

Boron Redistribution Update

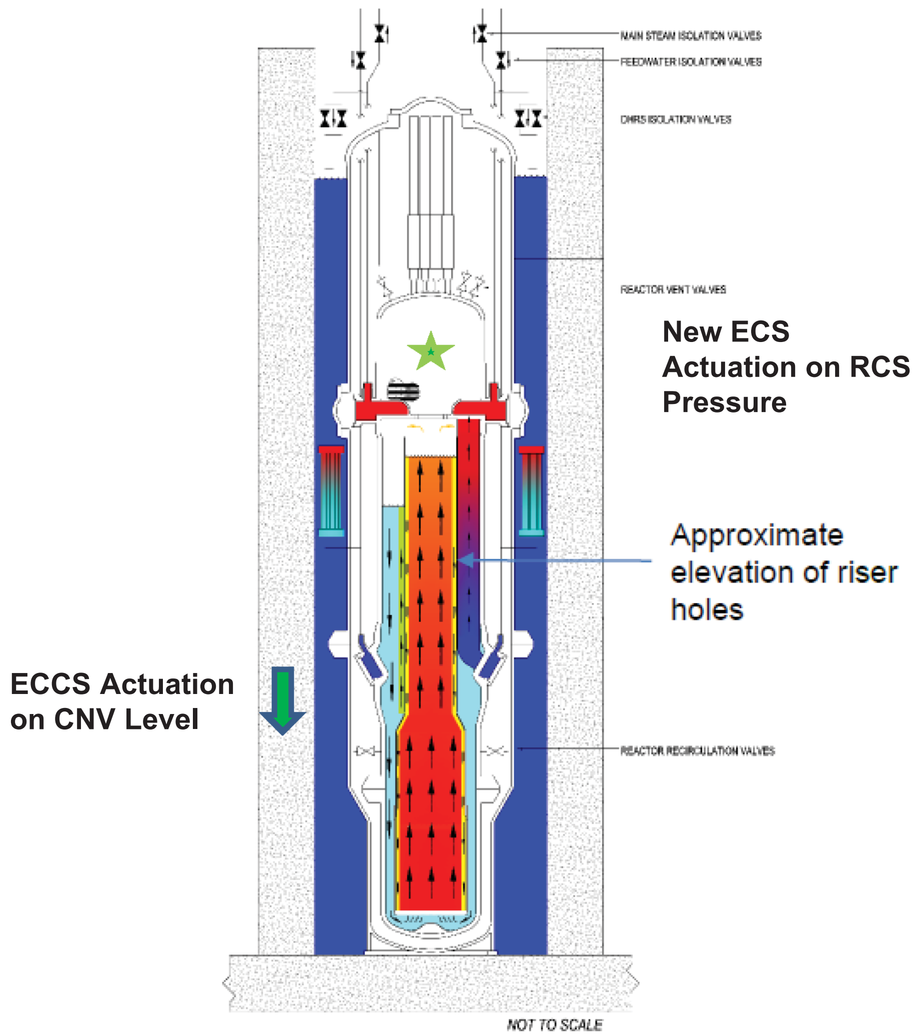
- During ACRS Full Committee meeting June 3 and 4, 2020, scenarios were discussed that could lead to dilution of fluid in reactor pressure vessel (RPV) downcomer
  - under certain conditions, ECCS actuation or restoration of natural circulation flow could transport diluted coolant to the reactor core
  - presented design solutions to prevent or mitigate boron redistribution
- The purpose of this presentation is to inform the ACRS of additional work, since the June 3 and 4, 2020 meeting, required to complete design changes, changes to associated Topical Reports, and FSAR changes

Boron Redistribution Audit

- Audit initiated March 9, 2020
- Daily update meetings between NuScale and NRC staff
- Numerous technical calls
- Docketed twenty-one submittals with design change information, analyses and DCA changes
- DCA Revision 4.1 (complete submittal all Parts) June 19, 2020
- Public Audit Exit Meeting on Boron Redistribution held June 26, 2020

Summary of Final Design Changes

- Design changes to prevent postulated boron dilution sequences
  - Addition of four ¾-inch holes in riser at midpoint of steam generator (SG)
  - Addition of ECCS actuation on Low RCS pressure
  - Lowered ECCS actuation setpoint on containment vessel (CNV) level



DCA Revision 4.1 Boron Redistribution Changes

- DCA Revision 4.1 included boron redistribution FSAR changes made since June 4
  - Table 6.3-1 ECCS Actuation and Table 15.0-7 Analytical Limits
    - Added reference to ECCS actuation signal interlocks in Table 7.1-5
  - Section 15.0.5 Long Term Cooling
    - Added description of riser hole flow path evaluation
    - Downcomer boron concentration remains above critical boron concentration during DHRS Cooldown for beginning of cycle (BOC) and middle of cycle (MOC)
    - Minimal impact at end of cycle (EOC) due to low boron concentration

LOCA Topical Report Boron Redistribution Changes

- LOCA Topical Report changes (submitted June 19, 2020)
  - Added description of ECCS actuation on low RCS pressure
    - Steam space LOCAs and inadvertent RVV opening and some liquid space LOCAs actuate ECCS on low RCS pressure
    - Most liquid space breaks and inadvertent RRV actuate ECCS on CNV Level
    - Earlier ECCS actuation on RCS pressure less limiting for MCHFR and collapsed liquid level above the top of active fuel (TAF)
    - Existing results remain conservative and bounding
  - Added descriptions of ECCS actuation signal interlocks
    - Low RCS pressure interlocked with RCS hot temperature and CNV pressure
    - CNV level ECCS actuation interlocked with RCS hot temperature and pressurizer level
    - Interlocks prevent ECCS actuation for non-LOCA events and expected operational conditions
  - Discussed function and impact of riser holes
    - Minimum and maximum RCS flow unchanged

General Design Criterion 33

- General Design Criterion (GDC) 33 requires that a reactor coolant makeup system be available to mitigate small RCS breaks with or without power available
- NuScale DCA includes an exemption to GDC 33
  - NPM design does not require additional coolant to maintain adequate core cooling for duration of design basis events (DBEs)
  - chemical and volume control system (CVCS) makeup system and backup power are not safety-related
  - ECCS and containment isolation systems credited to meet intent of GDC 33
    - ECCS actuates automatically for LOCA spectrum (greater than makeup system capacity and most smaller leaks)
    - Analysis demonstrates that specified acceptable fuel design limits (SAFDLs) met for small RCS leaks

GDC 33 – DCA Changes

- Basis for GDC 33 Exemption enhanced
  - DCA Revision 4 only included statement in Section 9.3.4 that GDC 33 was not applicable to NPM design and that makeup from CVCS is not credited
- Added basis to FSAR Section 4.3 to support GDC 33 exemption
  - Small leaks with no ECCS, boron mixing maintained by riser holes until holes uncovered
  - Core concentration remains above initial concentration for 72 hours
- Added Basis to FSAR Section 6.3 that intent of GDC 33 is met
  - ECCS actuation on setpoints (or by 24-hour timer for events with a loss of AC) mitigates most leaks
  - Evaluation shows smaller leaks with cold pool temperature do not challenge SAFDLs
  - No credit for CVCS makeup

Summary and Conclusions

- Design changes preclude boron redistribution for postulated design basis and beyond design basis events
  – ECCS actuation on low RCS pressure or high CNV level
    - assures initial flow out of RPV to preclude influx of unborated water from CNV or downcomer
  – Riser holes assure boron mixing in downcomer and core region
    - when DHRS cools and shrinks RCS level below the riser
    - For smaller LOCAs/RCS leaks while RCS level is above holes
    - To assure core concentration remains above initial concentration
  – Basis for GDC 33 added to Chapter 4 and Chapter 6
    - Function of ECCS and riser holes support exemption to GDC 33
    - No reliance on CVCS makeup or operator action
    - SAFDLs met for all RCS leaks

Acronyms

AC – alternating current

ACRS – Advisory Committee on Reactor Safeguards

BOC – beginning of cycle

CNV – containment vessel

CVCS – chemical and volume control system

DCA - Design Certification Application

DHRS – decay heat removal system

ECCS – emergency core cooling system

EOC – end of cycle

FSAR - Final Safety Analysis Report

GDC – General Design Criteria

LOCA – loss-of-coolant accident

MCHFR – minimum critical heat flux ratio

MOC – middle of cycle

NPM – NuScale Power Module

RCS – reactor coolant system

RPV – reactor pressure vessel

RRV – reactor recirculation valve

RVV – reactor vent valve

SAFDL – specified acceptable fuel design limits

SG – steam generator

TAF – top of active fuel

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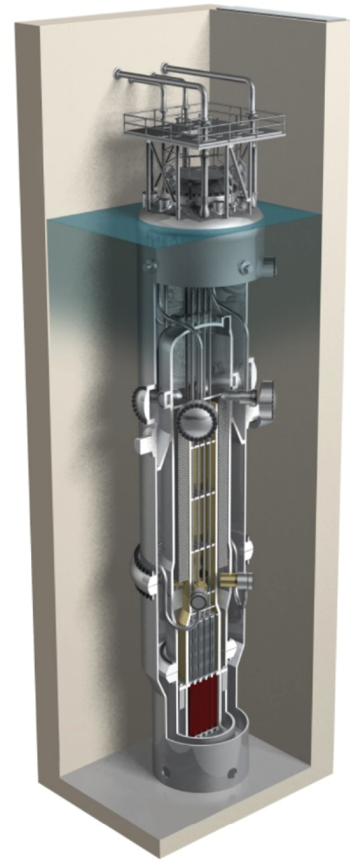

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Protecting People and the Environment

Focus Area: Boron Redistribution/Applicable Design Changes

NuScale Design Certification Application

ACRS Full Committee Meeting
July 8, 2020

Non-Proprietary

Agenda

- NRC Staff Review Team
- Background
- Design Changes
- Discussion by Review Team (Chapter & Design Change)
- Conclusion

NRC Staff Review Team

DEX/EMIB Division of Engineering and External Hazards/Mechanical Engineering and Inservice Testing Branch:
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Yuken Wong
Steve Hambric (consultant)

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Shanlai Lu
Ryan Nolan
Joshua Borromeo (NRR/DSS/SNSB)
Jeffrey Schmidt (NRR/DANU/UART)
Alex Siwy
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Peter Yarsky

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Craig Harbuck

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Bruce Bavol

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Background

- On February 27, 2020, NuScale notified NRC staff of an error in their boron redistribution analysis and informed that they are following their corrective action program.
- Staff started an audit on March 4, 2020
- On May 1, 2020, staff sent a schedule letter (ML20112F455) to NuScale. The purpose of this letter was to communicate the status of the NRC staff's review of the NuScale design certification application given the current schedule and the need for additional design changes.
- On May 20, 2020, NuScale submitted "Second Updates to DCA Rev 4," that includes final design change documents for NRC review (ML20141L787).
- On June 3, 2020, staff presented audit status to ACRS members.

Design Changes

- ECCS actuation on high containment water level setpoint change
- New ECCS actuation on low RCS pressure signal
- Addition of riser holes

Background - Impacted Chapter SERs

- Chapter 3 – Design of Structures, Components, Equipment, and Systems
- Chapter 4 – Reactor
- Chapter 5 – Reactor Coolant System and Connecting Systems
- Chapter 6 – Engineered Safety Features
- Chapter 7 – Instrumentation and Controls
- Chapter 9 – Auxiliary Systems
- Chapter 13 – Conduct of Operations
- Chapter 15 – Transient and Accident Analyses
- Chapter 16 – Technical Specifications
- Chapter 19 – Probabilistic Risk Assessment and Severe Accident Evaluation

Background - Impacted Topical & Technical Reports

Impact – 5 Technical Reports (<u>support various chapters/SERs</u>):

- TR-0616-49121, Setpoint Methodology
- TR-0316-22048, Advanced Sensor
- TR-0516-49084, Containment Response (CRAM)
- TR-0916-51299, Long Term Cooling
- TR-1116-52011, Technical Specifications Regulatory Conformance and Development

Impact – 2 Topical Reports:

- TR-0516-49416, Non-LOCA (“Non-Loss-of-Coolant Accident Analysis Methodology”)
- TR-0516-49422, LOCA (“Loss-of-Coolant Accident Evaluation Model”)

Mechanical-Chapter 3

NRR/DEX/EMIB

<u>#3 - Addition of Riser Holes</u>

- NRC staff reviewed structural integrity and flow-induced vibration (FIV) effects related to the new riser holes.
- Stress concentration due to the riser holes will not significantly affect the alternating stress margin due to turbulent buffeting
- Jet loads from riser holes will not significantly affect the steam generator (SG) tubes
- Riser holes will not cause acoustic resonances
  - Flow through the riser holes eliminates the possibility of shear layer flow instabilities
  - Should an instability occur, flow instability frequencies and upper riser acoustic frequencies are well separated
- Staff determined that NuScale adequately assessed the riser structural integrity and potential FIV effects of the four riser holes.

Mechanical-Chapter 3
NRR/DEX/EMIB

<u>ECCS main valve self-opening</u>

- Target Rock 2015 report describes testing that demonstrates main valve spring will open main valve at low differential pressure.
- Test report provides reasonable demonstration that ECCS main valve spring satisfies 10 CFR 50.43(e).
- ECCS main valve spring is “important to safety” because of assumed performance of spring function.
- Design specifications will include ASME Standard QME-1 qualification.
- FSAR includes Inservice Testing provisions for ECCS main valve spring performance.

I&C-Chapter 3 & 7

NRR/DEX/EICA

#1 - ECCS actuation on high containment water level setpoint change

- Change to CNV water level sensors is not required
- Changes made in Chapter 7 are consistent with assumptions made for Chapter 15 safety analysis:
  - CNV water level analytical limit range (240” – 264”)
  - High CNV level nominal setpoint (252”)
  - ±12” allowance from nominal setpoint
- Setpoint methodology technical report revised to demonstrate:
  - Revised analytical limit range is within the 100” calibrated span (220” – 320”)
  - Calculated total loop uncertainty is bounded by ±12” nominal setpoint allowance

Note: All levels are in terms of module elevation with the global zero elevation at the bottom of the reactor pool

I&C-Chapter 3 & 7

NRR/DEX/EICA

#2 - New ECCS actuation on low RCS pressure signal

- Existing wide range (WR) RCS pressure sensors are used
- Safety classification of WR RCS pressure sensors upgraded to safety class A1 (was A2).
  - FSAR Table 3.2-1 revised accordingly
- Changes made in Chapter 7 and Tier 1 Tables 2.5-2 and 2.5-4 are consistent with assumptions made for Chapter 15 safety analysis:
  - Low WR RCS pressure analytical limit of 800 psia
  - Low WR RCS pressure signal actuation delay time of 2.0 seconds
  - ECCS actuation automatically bypassed when T_{hot} < 475ºF (T-6 interlock) or CNV pressure < 1psia (P-1 interlock)

I&C-Chapter 3 & 7

NRR/DEX/EICA

<u>#2 - New ECCS actuation on low RCS pressure signal</u>

- Setpoint methodology technical report revised to:
  - Add setpoint calculation for low WR RCS pressure protective function
  - Demonstrate that calculated total loop uncertainty is bounded by ±100 psia allowance for nominal setpoint of 900 psia assumed in safety analysis
- Advanced sensor technical report revised to:
  - Add T-6 interlock function for NR RCS hot temperature sensors
  - Add ESFAS actuation function for WR RCS pressure sensors
  - Change safety and risk classification for WR RCS pressure sensors to A1 (was A2)
  - Add P-1 interlock function for NR containment pressure sensors

I&C-Chapter 3 & 7

NRR/DEX/EICA

#2 - New ECCS actuation on low RCS pressure signal

- Digital-based sensors CCF assessment
  - Digital-based sensors are used for low RCS pressure signal
  - Low RCS pressure ECCS actuation signal is implemented primarily to mitigate the possibility of a boron dilution scenario as a result of a small-break LOCA
  - Actuation signal has interlocks T-6 and P-1 to prevent unnecessary ECCS actuation for non-LOCA events
  - Limiting case analyzed for LOCA boron dilution is a smaller break in the LOCA break spectrum that has an ECCS actuation on low RCS pressure
  - This conservative analysis assumes highest worth control rod assembly not inserted and neglects negative reactivity insertion from xenon
  - Best-estimate D3 coping analysis, which credits xenon reactivity and an all-rods-in condition concluded that an earlier ECCS actuation on low RCS pressure would not be required for any break size or location in the LOCA break spectrum
  - In these cases, ECCS actuation occurs due to high CNV level or low DP across the ECCS valves
  - Sufficient diversity exists such that ECCS is available to mitigate these small-break LOCA events

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Tech Spec-Chapter 16

NRR/DSS/STSB

#1 - ECCS actuation on high containment water level setpoint change

- No changes to Function 22.a of MPS instrumentation list in TS Table 3.3.1-1; setpoint not stated in LCO 3.3.1; conforming changes to Bases not needed

#2 - New ECCS actuation on low RCS pressure signal

- Function 23.a added to MPS instrumentation list in TS Table 3.3.1-1 (relabeled Functions 23, 24, and 25 as 24, 25, and 26)
- Requires 4 operable channels in MODE 1 and MODE 2 with RCS Hot Temperature above 475 degrees F (new T-6 interlock);
- Condition N added to provide default required actions to exit applicability
- ECCS actuation at 800 psia RCS pressure is blocked unless containment pressure exceeds 1 psia (new P-1 interlock)
- Existing Surveillances apply
- Updated references to relabeled MPS Functions; conforming changes and additions to Bases

#3 - Addition of riser holes

- Conforming changes and additions to Bases for TS Subsections 3.3.1 and 3.5.1

Rx Systems-Chapter 5
NRR/DSS/SNRB

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#3 - Addition of riser holes

- Staff reviewed the effect of riser holes on steady-state RCS characteristics and DHRS performance
- Staff audited NuScale sensitivity calculations for five non-LOCA events that showed the riser holes had an insignificant impact on:
  - Steady-state RCS and secondary parameters of interest
  - Non-LOCA event progressions and figures of merit
- Staff performed confirmatory calculations of a DHRS cooldown and observed minimal differences with riser holes
- Staff finds that steady-state RCS parameters and DHRS performance described in DCA Part 2, Tier 2, Chapter 5, would not change substantially if riser holes were added
- Therefore, changes to DCA Part 2, Tier 2, Chapter 5, other than a description of the riser holes are not necessary

Rx Systems-Chapter 6 & 15

NRR/DSS/SNRB

Areas Not Substantially Affected by the Design Changes

- DCA Part 2, Tier 2, Section 6.2.1.1, and CRAM technical report
  - Limiting DBEs and resulting values for peak CNV pressure (994 psia) and peak CNV wall temperature (526 °F) unaffected
  - Previously non-limiting cases remain non-limiting with design changes
- LOCA and non-LOCA topical reports
  - Staff audited related NuScale calculations and confirmed only conforming changes needed
- Chapter 15 non-LOCA events
  - As previously discussed, riser holes have an insignificant impact on steady-state, transient progression, and figures of merit
  - Changed high CNV level ECCS actuation setpoint is not relevant to non-LOCAs
  - Unlikely to actuate ECCS on new low RCS pressure signal
- Chapter 15 inadvertent ECCS actuation event (15.6.6)
  - Staff audited NuScale's qualitative assessment and agrees that the design changes would have an insignificant impact on steady-state, transient progression, and figures of merit

Rx Systems-Chapter 6 & 15

NRR/DSS/SNRB

Areas Affected by Design Changes

- LOCA transients
  - These are primarily affected by new low pressure signal and revised (lowered) CNV high level actuation setting
  - Steam space and larger liquid space breaks now actuate earlier on low pressure
  - Earlier ECCS and lowered CNV level setting improves boron redistribution
  - Min Collapsed Level above TAF and Min CHFR figures of merit were unchanged

Rx Systems – Chapter 6 &15
NRR/DSS/SNRB

- The applicant added riser holes to limit downcomer dilution during a DHRS cooldown
  - RCS water level may drop below the riser following a reactor trip depending on initial RCS conditions
  - NRELAP5 and the staff's TRACE model show riser uncovery between 5-6 hours under nominal conditions assuming no operator action
- ECCS valves could open on either a loss of ac power for 24 hours (24-hour timer) or on main valve low differential pressure causing a potential in surge of diluted downcomer water into the core
- The applicant performed a series of hand calculations to determine the riser hole size and elevation to maintain downcomer boron concentration above the critical concentration for times in cycle when significant downcomer dilution is possible

Rx Systems – Chapter 6 &15
NRR/DSS/SNRB

- The applicant evaluated two different primary to secondary side heat transfer modes depending on the relationship of primary to secondary side level
  - Convective cooling where the secondary side level is below the primary side level and heat is primarily transferred through the riser wall
  - Boiling/condensing where heat is primary removed from condensing steam on exposed steam generator tubes when secondary side level is above the primary side level
- Each heat transfer mode has different condensation rates and thermal-hydraulic phenomenon that determine the riser hole flow rates
- The staff audited the applicant’s hand calculation to ensure condensation and riser hole flow rates were sufficient to prevent significant downcomer dilution

Rx Systems – Chapter 6 &15
NRR/DSS/SNRB

- NRELAP5 and TRACE models show pressure and temperature decreasing during a cooldown consistent with convective heat transfer mode
- Both NRELAP5 and TRACE show liquid discharge over the riser for approximately one and half to two hours after riser uncovery
  - The applicant's hand calculation conservatively assumes no boron containing liquid discharge over the riser
- The applicant assumed state point values for the decay heat, RCS pressure, steam generator pressure and, for the convective case, a riser to downcomer temperature difference as a function of time
- Staff compared the assumed state point values and found them either reasonable or conservative compared to the applicant's NRELAP5 and the staff's NRELAP5 and TRACE confirmatory cases.
- Staff audited the applicant's hand calculated condensation rate for both the convective and boiling/condensing heat transfer mode and found them to be conservative

Rx Systems – Chapter 6 &15
NRR/DSS/SNRB

Convective Heat Transfer Mode

- For the convective case, the staff confirmed the applicant's hand calculation of through wall heat transfer was conservative
- The staff compared the riser to downcomer temperature difference, after liquid discharge over the riser, and found the temperatures consistent with staff's NRELAP5 and TRACE confirmatory runs
  - When decay heat is high, liquid discharge prevents a direct comparison of the hand calculated and NRELAP5 and TRACE riser to downcomer temperature difference
- Staff reviewed the methodology associated with the riser and downcomer level determination and found it to be reasonable

Rx Systems – Chapter 6 &15

NRR/DSS/SNRB

Convective Heat Transfer Mode – cont'd

- Staff reviewed the form loss factor and found the value used in the hand calculation to be conservative
- Staff audited the applicant's energy balance verification and agrees, within the framework of the hand calculation, a conservative riser hole mass flow rate
  - The total of condensation, through wall and riser hole flow energy is less than the decay heat
- Staff compared the applicant's hand calculated riser hole mass flow rate with the applicant's NRELAP5 cases and the staff's TRACE confirmatory cases and found the applicant's hand calculated values reasonable

Rx Systems – Chapter 6 &15

NRR/DSS/SNRB

Boiling/Condensing Heat Transfer Mode

- Two-phase level swell in riser during extended decay heat removal system operation would create differential pressure at riser flow holes, driving flow from riser to downcomer
- Applicant performed analysis through 72 hours using a quasi-steady statepoint analysis for a generic event progression
  - Calculation included conservatisms intended to underestimate riser void fraction and overestimate condensation rate
- NRC staff reviewed applicant's methodology, audited supporting calculations, and performed confirmatory calculations
  - Review addressed scenarios with no reactor coolant system leakage
  - NRC staff found applicant's method and results acceptable for the conditions reviewed in the application

Rx Systems – Chapter 6 &15
NRR/DSS/SNRB

Boron Concentration

- The core/riser and downcomer/low plenum is assumed to be quasi-steady state where core inlet flow is equal to riser hole flow and condensation rates
- The applicant uses a wave front model to transport boron from the riser to downcomer and back to the core
  - The staff finds the wave front model conservative as the model maximizes boron transfer out of and minimizes boron transport into the downcomer affectively ignoring any potential recirculation mixing
- The applicant's riser hole design acceptance criterion is to maintain a downcomer boron concentration greater than the critical concentration, including the effects of Xenon, with the highest worth control rod remaining out of the core, at BOC and MOC conditions for 72 hours
  - The staff agrees the applicant's acceptance criterion is conservative as maintaining a downcomer boron concentration above the critical value ensures shutdown should the ECCS valves open at times in life when significant downcomer dilution is possible

Rx Systems – Chapter 6 &15
NRR/DSS/SNRB

Boron Concentration – cont'd

- At EOC negligible downcomer dilution exists such that a downcomer in surge between 24 and 72 hours will not cause a return to power greater than that evaluated in DCA 15.0.6
  - As noted in the staff's safety evaluation Section 15.0.6, a return to power under riser uncovered conditions is not expected for EOC nominal conditions and is bounded by the ECCS cooldown return to power

Rx Systems – Chapter 6 &15

NRR/DSS/SNRB

- NuScale requested exemption from GDC 33
  - GDC 33 requires a system to supply RCS makeup for protection against RCS leaks and small breaks
- NuScale analyzed the design changes following a similar approach as extended DHRS to ensure underlying purpose of GDC 33 was met
- Staff evaluated the analysis with focus on boron dilution and determined the design continues to meet the underlying purpose of the criterion

Rx Systems- Chapter 4 &15 (Recovery)
NRR/DSS/SNRB

- Boron distribution must be considered when exiting extended ECCS or DHRS cooling modes
- Post-event recovery actions are important to capture in the development of operating procedures
  - outside the scope of the design certification review
  - procedures will be developed by the COL applicant or holder at a future licensing stage (COL item 13.5-2)

PRA-Chapter 19

NRR/DRA

<u>New ECCS actuation on low RCS pressure signal</u>

- Earlier ECCS actuation minimizes the potential for boron redistribution for postulated LOCA events.

<u>New riser bypass holes</u>

- Bypass holes provide a flow path from the riser through the downcomer to prolong boron mixing if level drops below top of riser.

- NRELAP PRA model was updated with new design features.

PRA-Chapter 19

PRA audit overview

Staff audited assumptions and/or results of revised T/H analysis for all initiators evaluated in the Level 1 internal events PRA.

- LOCAs, Secondary Line Breaks, SGTRs, ATWS, DHRS cooldown, etc.

Low pressure ECCS interlocks prevent ECCS actuation for Non-LOCA events

- RCS is subcooled in DHRS cooldown events (< 475 ºF) and have no increase in CNV pressure.

PRA-Chapter 19

Non LOCA scenarios

Certain non LOCA scenarios now result in ECCS actuation on the low RCS pressure signal:

- Continuous RSV cycling (e.g. DHRS failure)
- Certain non LOCA ATWS scenarios.

The staff confirmed impacts of additional ECCS challenges with potential for incomplete ECCS actuation are incorporated in the PRA event trees.

PRA-Chapter 19

Non LOCA ATWS scenarios

CVCS credited to prevent core damage given ATWS with ECCS failure.

Staff questioned whether CVCS injection following ECCS failure could cause core damage due to a reactivity insertion.

Comparing the total liquid mass in the core versus the small CVCS coolant injection rate, coolant injection in the riser will not:

- rapidly reduce liquid temperatures in the core region,
- rapidly condense and collapse voids.
- The two redundant safety-related demineralized supply isolation valves would automatically transfer to the highly borated water source (DCA Section 9.3.4.1).

Staff performed an independent evaluation to confirm NuScale's response that core damage does not result from CVCS injection.

PRA-Chapter 19
LOCA ATWS scenarios

Based on TH insights, the PRA assumes that LOCA ATWS does not result in core damage upon ECCS actuation.

Breaks on the smaller end of the LOCA spectrum result in:

- later ECCS actuation
- lower boron concentration in the downcomer from increased condensation and colder RCS conditions.

Applicant evaluated the following for various break sizes:

- high point vent LOCA (steam space)
- CVCS discharge line LOCA (liquid space)

PRA-Chapter 19

LOCA ATWS scenarios (continued)

- Applicant used N-RELAP5 with 1-D neutron kinetics option and the boron tracking model which has not been reviewed and approved by the staff.
- Due to code uncertainty, NuScale provided sensitivity analyses to show the effect of additional dilution in the downcomer prior to ECCS actuation.
- NuScale also provided a hand calculation using the Fuchs-Nordheim method to support the conclusion that LOCA ATWS does not result in core damage due to reactivity insertion.

ECCS actuation may occur when the level in the RPV is well below the RRV elevation.

One train of DHRS is now required to:

- reduce the RPV pressure and rate of coolant loss from the RPV
- allow the operator to initiate CFDS injection to recover level before core damage

PRA-Chapter 19

<u>LOCA Inside CNV with failure of containment isolation</u>

Given an earlier ECCS actuation, the system will reach atmospheric pressure earlier and lose less coolant from the module.

Staff audited documents describing the integrated coolant mass flow out of the containment and sensitivity studies to evaluate the effects of the ECCS actuation timing

PRA-Chapter 19

Post Event Recovery from SBLOCA ATWS

An operator attempting to inappropriately restore water level using either the CVCS or the CFDS could challenge the reactor by adding positive reactivity if diluted water is present in the downcomer.

Either action to inject would likely be precluded by the plant-specific emergency operating procedures (EOPs).

Staff independently calculated the reactivity insertion rate for CFDS and net void shrinkage rates for CVCS riser injection and concluded:

- CFDS slow rate of core refill, time to add 1$ reactivity >> fuel thermal time constant – no core damage.
- Core damage from rapid void collapse following CVCS riser injection evaluated for ATWS with small leak and found very unlikely (must be at very low decay heat without rod insertion, very low pressure with high CVCS flow rates)

PRA-Chapter 19
Conclusions

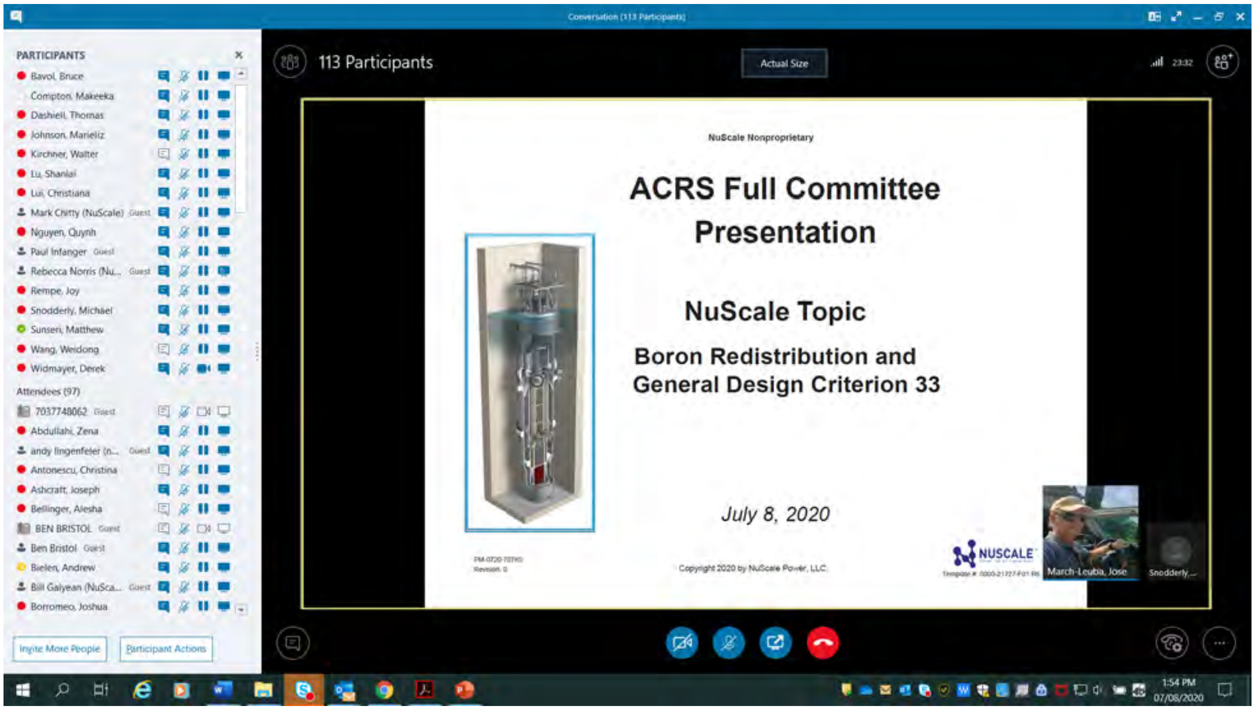
The staff confirmed that NuScale appropriately updated:

- DCA event trees
- DCA Table 19.1-7 on success criteria
- DCA Table 19.1-21: Key Assumptions for the Level 1 Full Power Internal Events

Regarding boron redistribution, the staff confirmed

- There are no known significant risk contributors that are unaccounted for in the PRA.
- DCA Chapter 19 risk results and insights were appropriately updated so that staff could finalize their safety findings consistent with SRP 19.0

Questions?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PARTICIPANTS
Bavol, Bruce
Compton, Makeeka
Dashiell, Thomas
Johnson, Marieliz
Kirchner, Walter
Lu, Shanlai
Lui, Christiana
Mark Chitty (NuScale) Guest
Nguyen, Quynh
Paul Infanger Guest
Rebecca Norris (Nu... Guest
Rempe, Joy
Snodderly, Michael
Sunseri, Matthew
Wang, Weidong
Widmayer, Derek
Attendees (97)
7037748062 Guest
Abdullahi, Zena
andy Ingenfeler (n... Guest
Antonescu, Christina
Ashcraft, Joseph
Bellinger, Alesha
BEN BRISTOL Guest
Ben Bristol Guest
Bielen, Andrew
Bill Galyean (NuSca... Guest
Borromeo, Joshua
Invite More People
Participant Actions
113 Participants
Actual Size
NuScale Nonproprietary
ACRS Full Committee Presentation
NuScale Topic
Boron Redistribution and General Design Criterion 33
July 8, 2020
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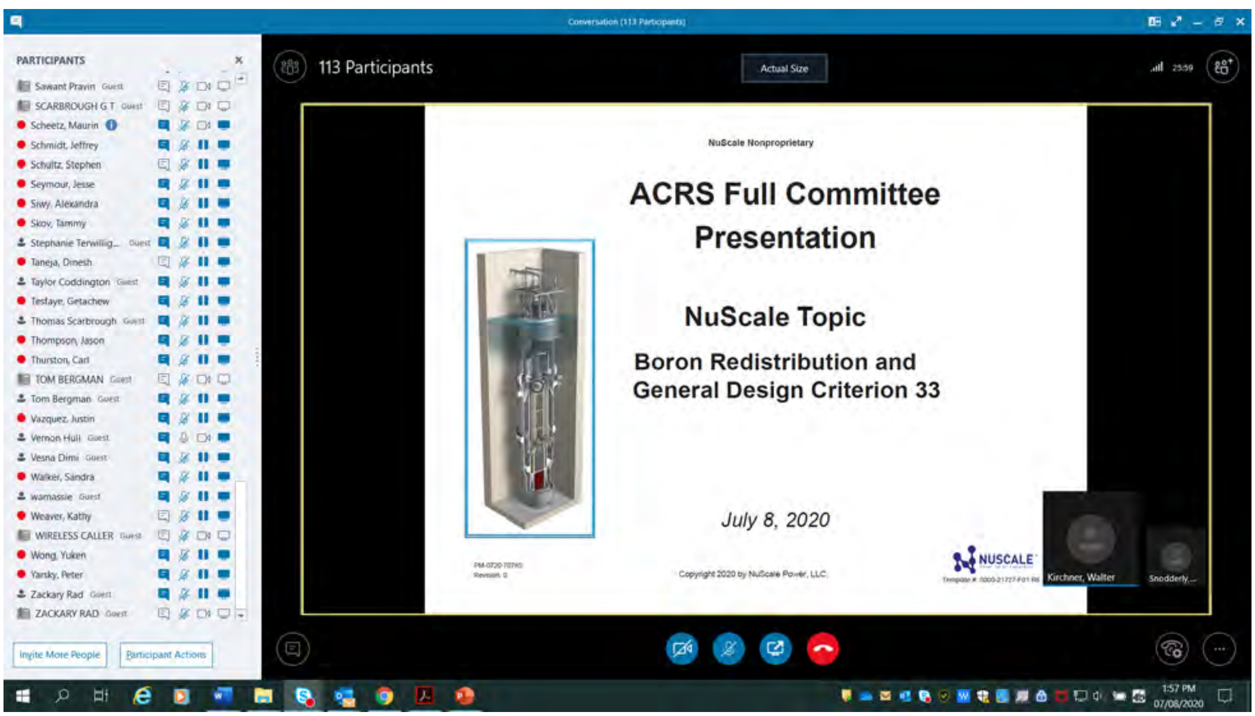
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PARTICIPANTS
Sawant Pravin Guest
SCARBROUGH G T Guest
Scheetz, Maurin
Schmidt, Jeffrey
Schultz, Stephen
Seymour, Jesse
Siwy, Alexandra
Skov, Tammy
Stephanie Terwillig... Guest
Taneja, Dinesh
Taylor Coddington Guest
Tesfaye, Getachew
Thomas Scarbrough Guest
Thompson, Jason
Thurston, Carl
TOM BERGMAN Guest
Tom Bergman Guest
Vazquez, Justin
Vernon Hull Guest
Vesna Dimi Guest
Walker, Sandra
wamassie Guest
Weaver, Kathy
WIRELESS CALLER Guest
Wong, Yuken
Yarsky, Peter
Zackary Rad Guest
ZACKARY RAD Guest
Invite More People
Participant Actions
113 Participants
Actual Size
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ACRS Full Committee Presentation
NuScale Topic
Boron Redistribution and General Design Criterion 33
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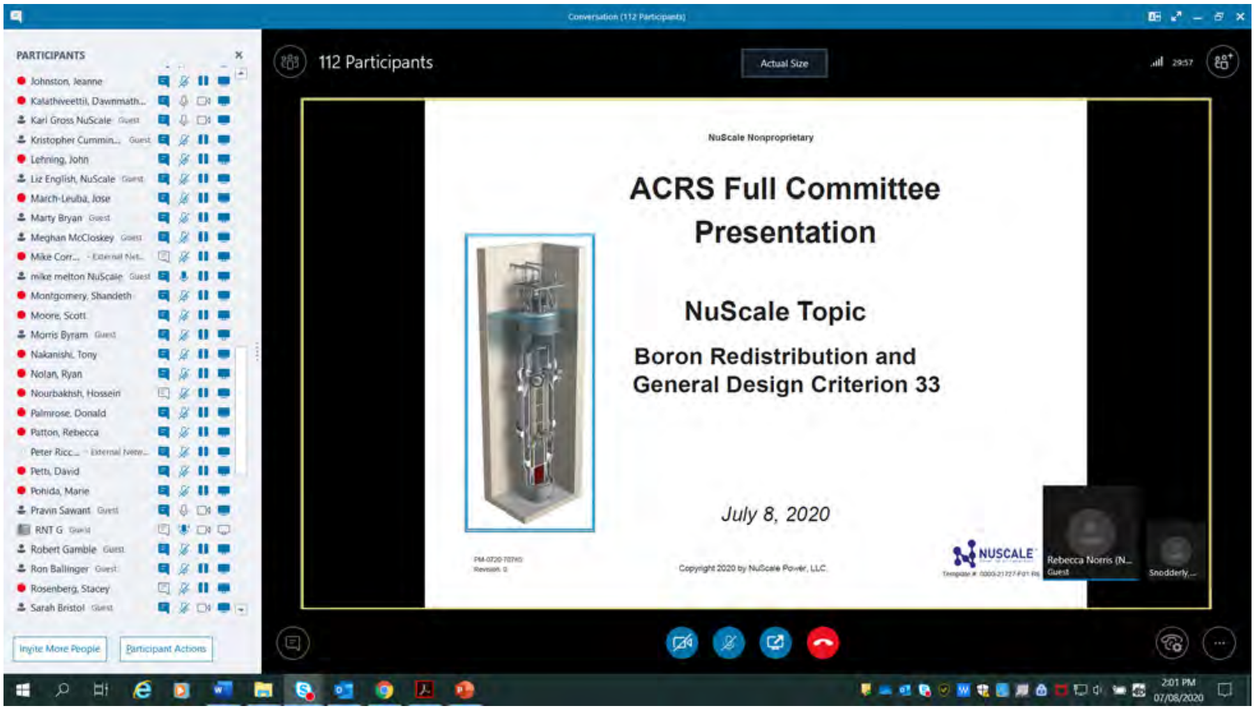
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PARTICIPANTS
Johnston, Jeanne
Kalathiveettil, Dawnmath...
Kari Gross NuScale Guest
Kristopher Cummin... Guest
Lehning, John
Liz English, NuScale Guest
March-Leuba, Jose
Marty Bryan Guest
Meghan McCloskey Guest
Mike Corr... - External Net...
mike melton NuScale Guest
Montgomery, Shandeth
Moore, Scott
Morris Byram Guest
Nakanishi, Tony
Nolan, Ryan
Nourbakhsh, Hossein
Palmrose, Donald
Patton, Rebecca
Peter Ricc... - External Netw...
Petti, David
Pohida, Marie
Pravin Sawant Guest
RNT G Guest
Robert Gamble Guest
Ron Ballinger Guest
Rosenberg, Stacey
Sarah Bristol Guest
Invite More People
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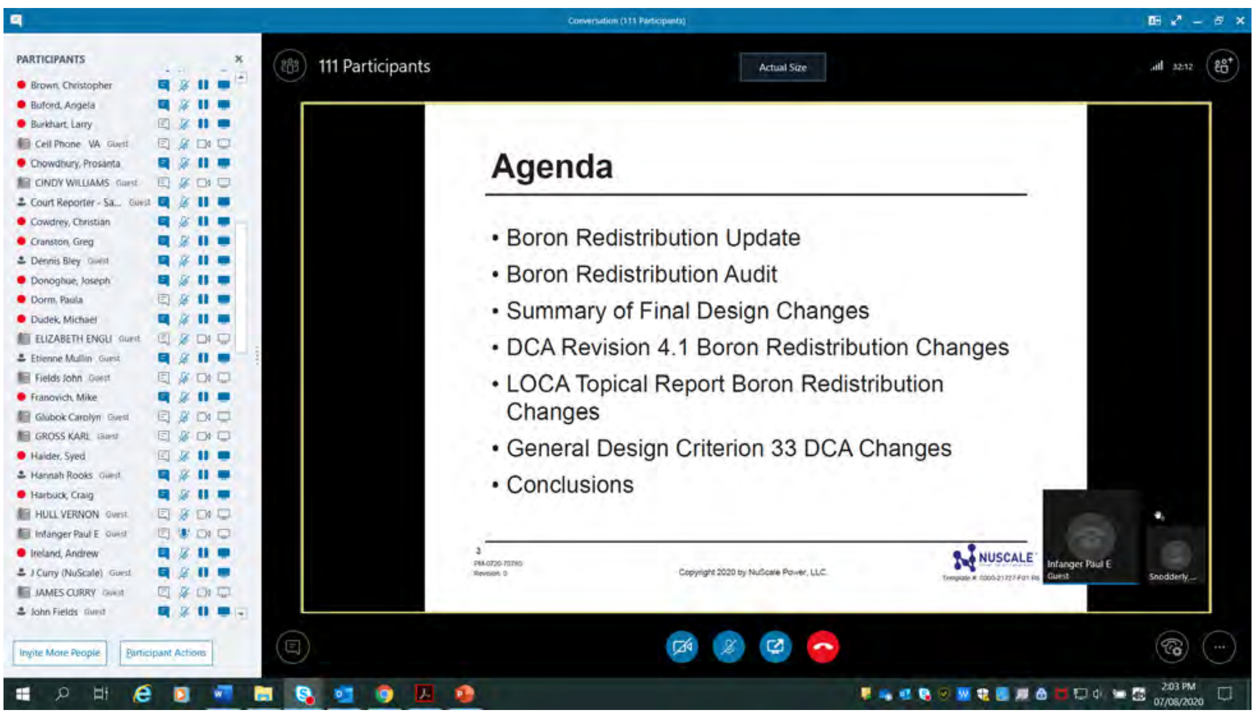
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PARTICIPANTS
Brown, Christopher
Buford, Angela
Burkhart, Larry
Cell Phone VA Guest
Chowdhury, Prosanta
CINDY WILLIAMS Guest
Court Reporter - Sa... Guest
Cowdrey, Christian
Cranston, Greg
Dennis Bley Guest
Donoghue, Joseph
Dorm, Paula
Dudek, Michael
ELIZABETH ENGLI Guest
Etienne Mullin Guest
Fields John Guest
Franovich, Mike
Glubok Carolyn Guest
GROSS KARL Guest
Haider, Syed
Hannah Rooks Guest
Harbuck, Craig
HULL VERNON Guest
Infanger Paul E Guest
Ireland, Andrew
J Curry (NuScale) Guest
JAMES CURRY Guest
John Fields Guest
Invite More People
Participant Actions
111 Participants
Actual Size
Agenda
• Boron Redistribution Update
• Boron Redistribution Audit
• Summary of Final Design Changes
• DCA Revision 4.1 Boron Redistribution Changes
• LOCA Topical Report Boron Redistribution Changes
• General Design Criterion 33 DCA Changes
• Conclusions
3
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Topical Report EPRI-AR-1

Uranium Oxycarbide (UCO) Tristructural Isotropic (TRISO) Coated Particle Fuel Performance

Andrew Sowder, Ph.D., CHP
Senior Technical Executive

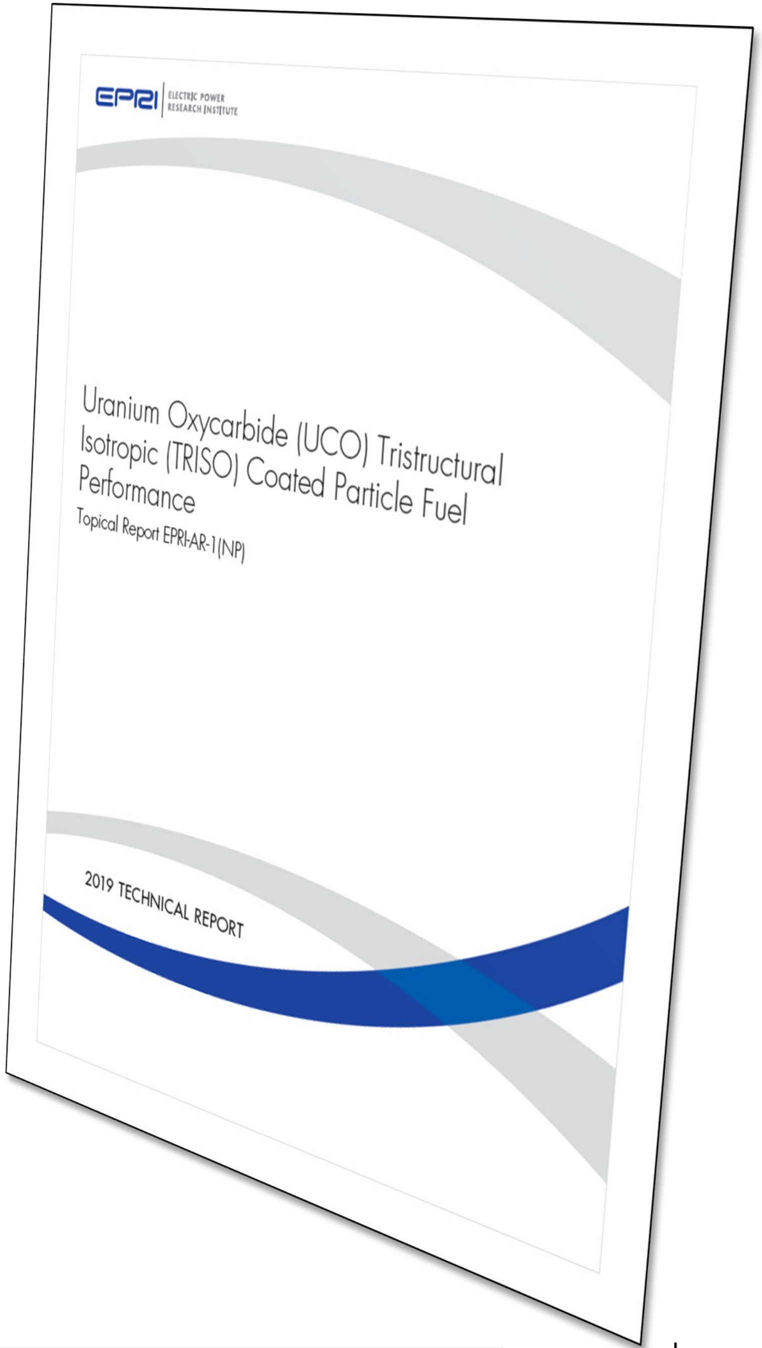
Advisory Committee on Reactor Safeguards
July 8, 2020

TRISO Fuel Topical Report

- Objective:
  Support commercialization of mature advanced nuclear designs to maintain nuclear as a future energy generation option

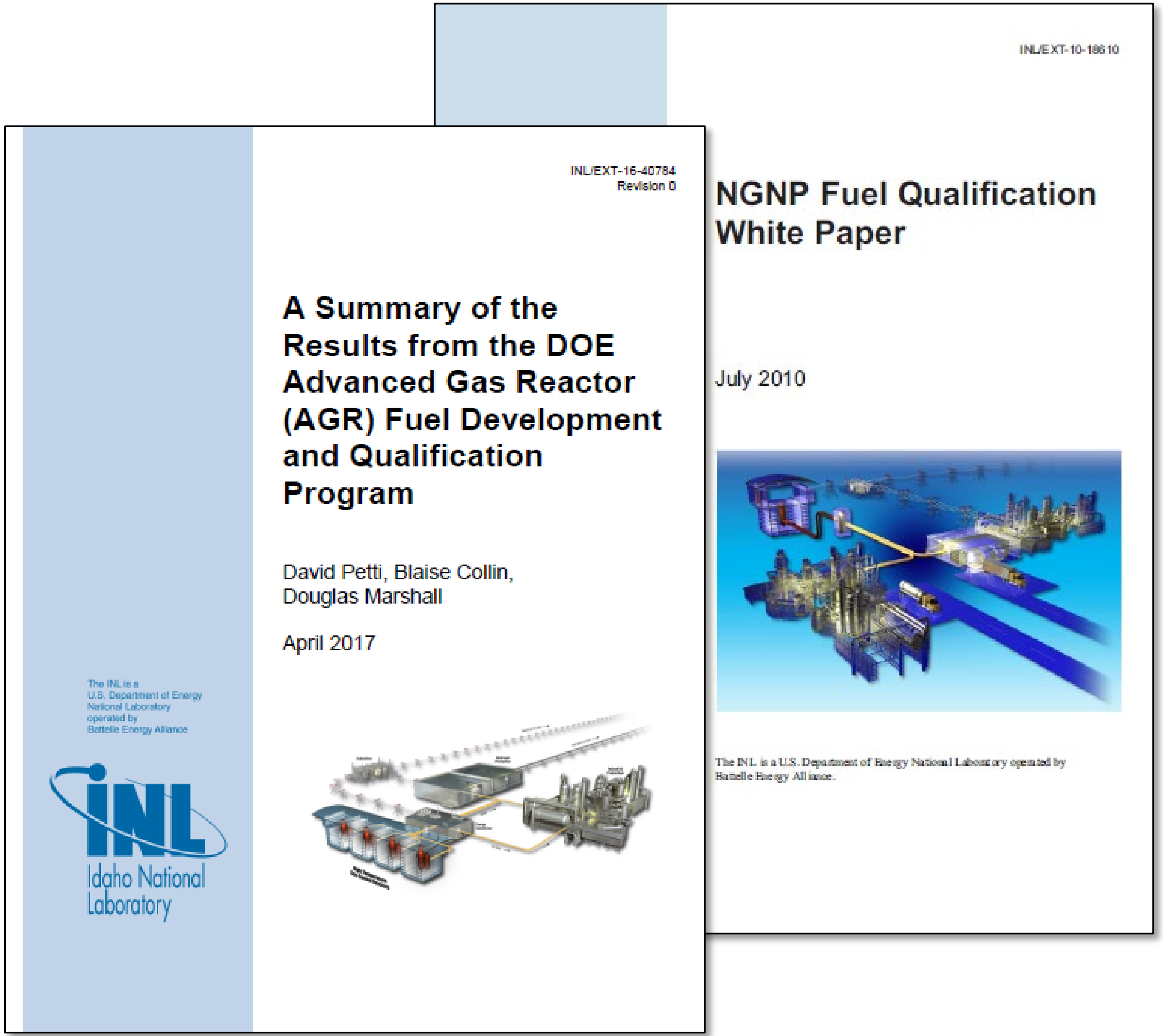
- Scope:
  - U.S. Department of Energy (DOE)-sponsored AGR-1 and AGR-2 fuel campaigns
  - Global context, history, and experience
  - Performance demonstration of TRISO-coated particle fuel with uranium oxycarbide (UCO) kernels
  - Irradiation, post-irradiation examination (PIE), and available post-irradiation safety testing data

- Publicly available report:
  - Uranium Oxycarbide (UCO) Tristructural Isotropic (TRISO) Coated Particle Fuel Performance: Topical Report EPRI-AR-1(NP). EPRI, Palo Alto, CA: May 2019. 3002015750 https://www.epri.com/#/pages/product/3002015750/



U.S. and International Experience

- International experience:
  - High-quality TRISO fuel can be fabricated in a repeatable, consistent manner
  - Fuel performance with very low in-service failures is achievable under anticipated HTGR conditions
- U.S. DOE AGR program:
  - Fabrication of high-quality low-defect fuel is achievable at industrial scale via stable, repeatable processes
  - Demonstration of excellent irradiation performance of a large population of UCO TRISO fuel particles under high-burnup, high-temperature HTGR conditions


INL/EXT-10-18610

NGNP Fuel Qualification White Paper

July 2010

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance.

INL/EXT-16-40784
Revision 0

A Summary of the Results from the DOE Advanced Gas Reactor (AGR) Fuel Development and Qualification Program

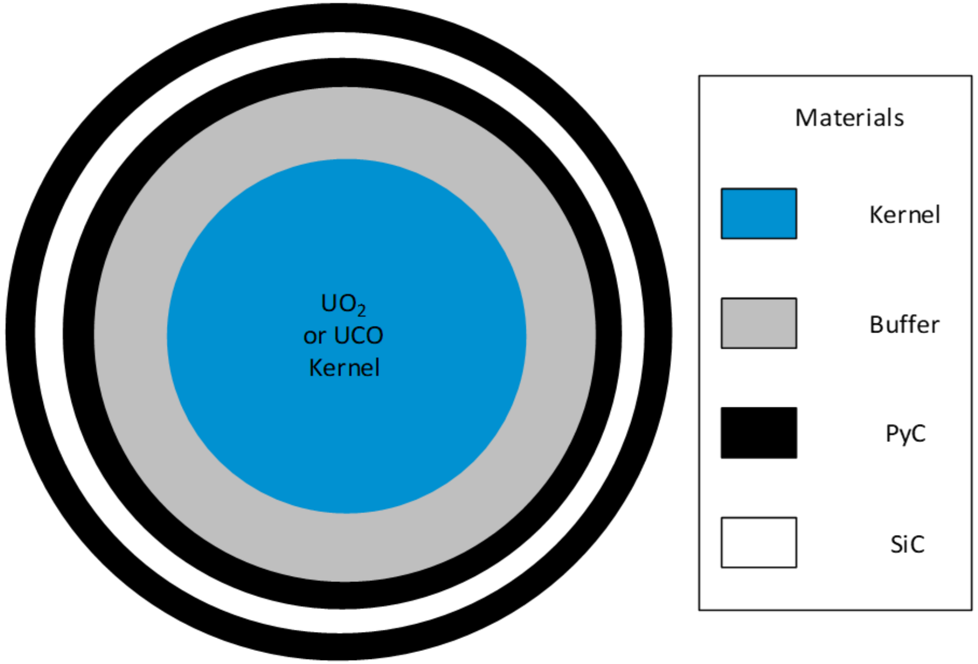
David Petti, Blaise Collin, Douglas Marshall

April 2017

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance

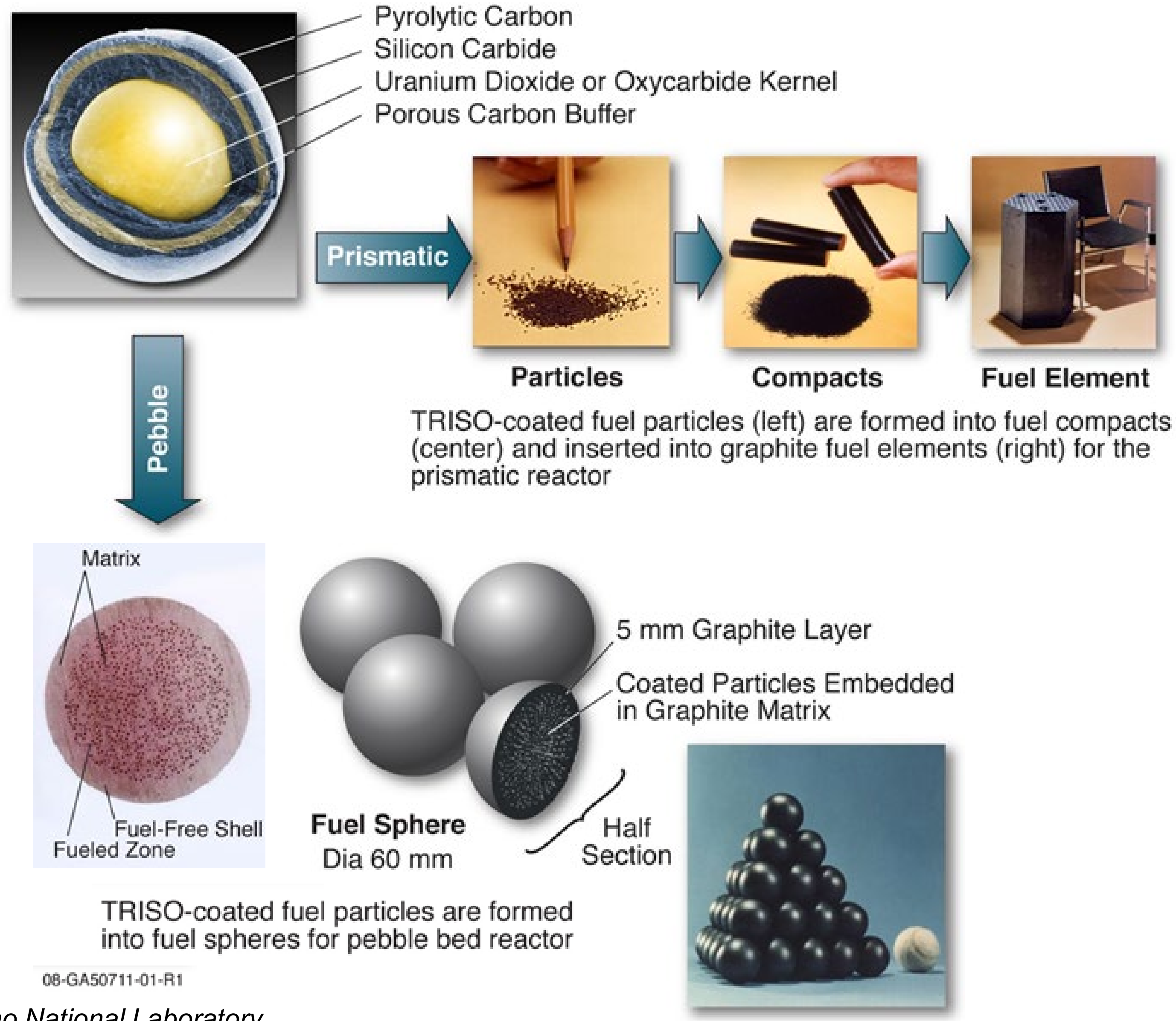
Idaho National Laboratory

TRISO Coated Particles and Fuel Forms



- **International development and use of TRISO fuel has occurred over 60 years**

- **U.S. DOE Advanced Gas Reactor Fuel Development and Qualification (AGR) Program launched in 2002**



Figures courtesy of Idaho National Laboratory

A Model Collaboration and Public-Private Partnership

Independent Reviewers

- independent peer review of draft topical report

INL

- AGR program lead
- report technical content provider
- report technical review
- response to RAIs

HTR TWG

[Framatome, X-energy, StarCore, Kairos Power, BWXT]

- report technical review
- response to RAIs

EPRI

- project management
- coordination of report development, editing, technical review
- topical report submission to NRC
- NRC interface, RAI response coordination

Fuel Supplier (BWXT)

- report drafting and technical editing
- fuel manufacturing and licensing perspective

Product: Topical Report

RAIs

NRC

- regulatory review (off-fee generic activity)
- safety evaluation report issuance

Acronyms

AGR – Advanced Gas Reactor
HTR – High Temperature Reactor
TWG – Technology Working Group
RAI – Request for Additional Information

- DOE and EPRI co-funding
- Industry in-kind support
- NRC off-fee review

Topical Report Contents (sections for NRC review in blue)

- Section 1 - report scope, purpose, content, and structure
- Section 2 - TRISO fuel in the context of past Nuclear Regulatory Commission (NRC) regulatory activities and current regulatory framework
- Section 3 - non-AGR experience base for coated particle fuel technology in the United States and internationally
- Section 4 - basis for the particle design and test conditions used in the AGR program
- Section 5 - brief overview of the AGR program, including the different program elements and the four fuel irradiation campaigns around which the program is structured
- Section 6 - irradiation response of fuel particles in the AGR-1 and AGR-2 campaigns
- Section 7 - follow-on safety test performance and post-irradiation examination data for AGR-1 and AGR-2
- Section 8 - summary of the report, including **conclusions for NRC approval**
- Section 9 - references
- Appendix A - more detail on the U.S. regulatory history related to TRISO fuel
- Appendix B - more detail on the international coated particle fuel experience base
- Appendix C - information from the AGR-1 and AGR-2 fuel specifications

Conclusion 1

Testing of UCO TRISO-coated fuel particles in AGR-1 and AGR-2 constitutes a performance demonstration of these particle designs over a range of normal operating and off-normal accident conditions. Therefore, the testing **provides a foundational basis for use of these particle designs in the fuel elements of TRISO-fueled HTR designs (that is, designs with pebble or prismatic fuel and helium or salt coolant).**

Conclusion 2

The kernels and coatings of the UCO TRISO-coated fuel particles tested in AGR-1 and AGR-2 exhibited property variations and were fabricated under different conditions and at different scales, with remarkably similar excellent irradiation and accident safety performance results. The ranges of those variations in key characteristics of the kernels and coatings are reflected in measured particle layer properties provided in Table 5-5 from AGR-1 and AGR-2. **UCO TRISO-coated fuel particles that satisfy the parameter envelope defined by these measured particle layer properties in Table 5-5 can be relied on to provide satisfactory performance.**

Conclusion 3

Aggregate AGR-1 and AGR-2 fission product release data and fuel failure fractions, as summarized in this report, can be used to support licensing of reactors employing UCO TRISO-coated fuel particles that satisfy the parameter envelope defined by measured particle layer properties in Table 5-5 from AGR-1 and AGR-2.

Together...Shaping the Future of Electricity

U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Clean. Reliable. Nuclear.

Advanced Gas Reactor Fuel Development and Qualification Program: Overview and AGR-1 and AGR-2 Results Summary

Advisory Committee on Reactor Safeguards

July 8, 2020

Paul Demkowicz, Ph.D.

Idaho National Laboratory

AGR Program Technical Director

Advanced Gas Reactor Fuel Development and Qualification Program

Objectives and motivation

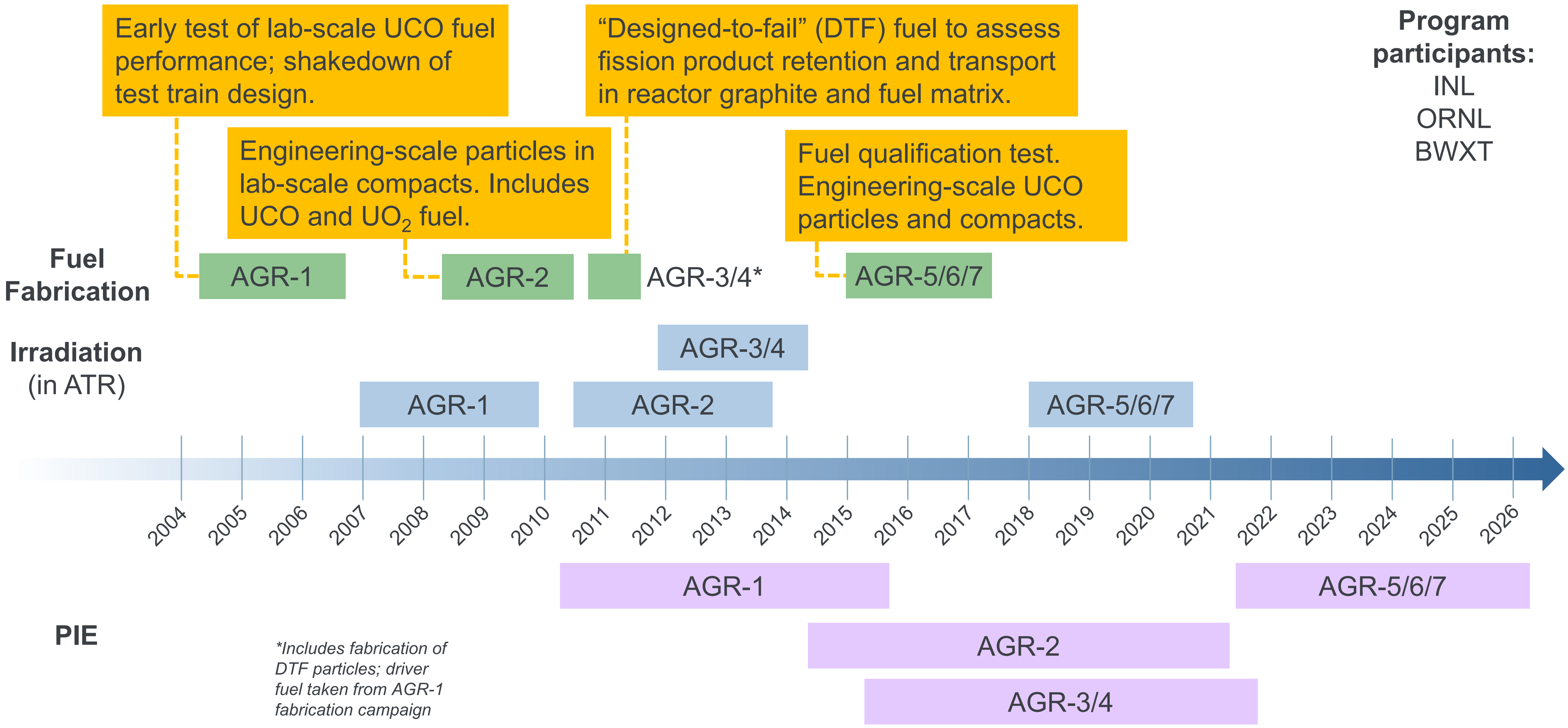
- Provide data for fuel qualification in support of reactor licensing
- Establish a domestic commercial vendor for TRISO fuel

Reduce market entry risk

Approach

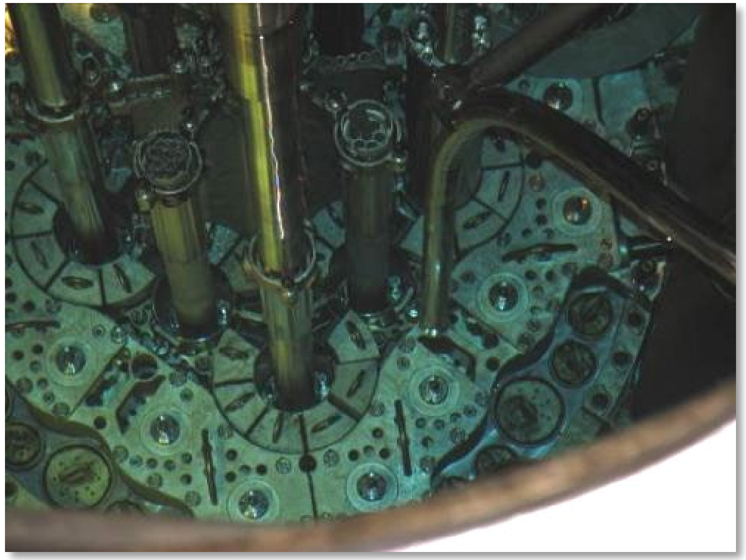
- Focus is on developing and testing **UCO** TRISO fuel
  - **Develop fuel fabrication and quality control measurement methods**, first at lab scale and then at industrial scale
  - **Perform irradiation testing** over a range of conditions (burnup, temperature, fast neutron fluence)
  - **Perform post-irradiation examination and safety testing** to demonstrate and understand performance during irradiation and during accident conditions
  - **Develop fuel performance models** to better predict fuel behavior
  - **Perform fission product transport experiments** to improve understanding and refine models

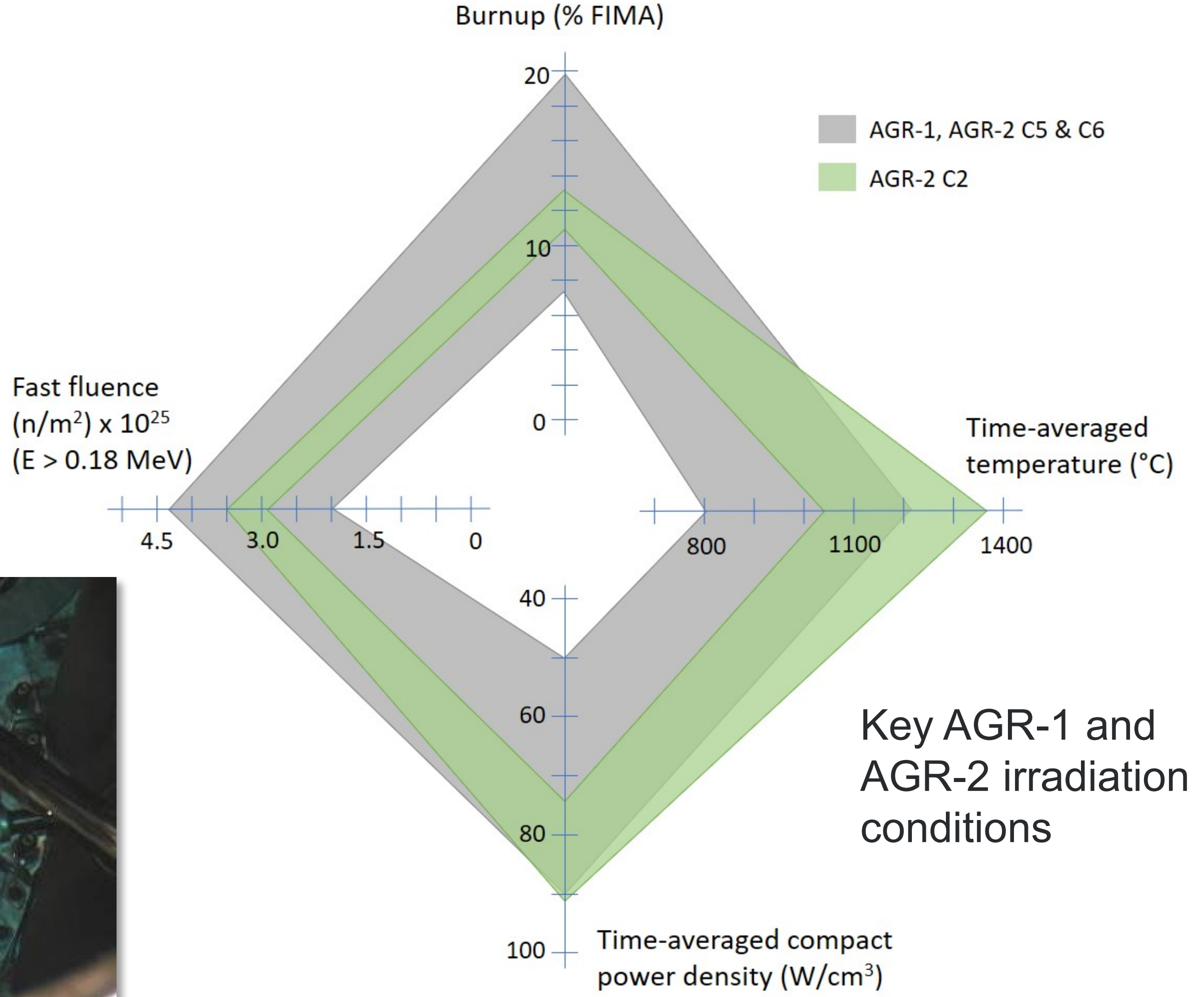
AGR Program Timeline



AGR-1 and AGR-2 Fuel Irradiations

- Advanced Test Reactor – Large B positions
- Six independent capsules; 12 fuel compacts per capsule
  - AGR-1: ~300,000 UCO particles
  - AGR-2: ~114,000 UCO particles
- Approx. 2-year irradiation time to simulate 3-year reactor lifetime
- Temperature controlled with He/Ne gas mixtures
- Fission gas release monitored throughout experiment to assess fuel condition

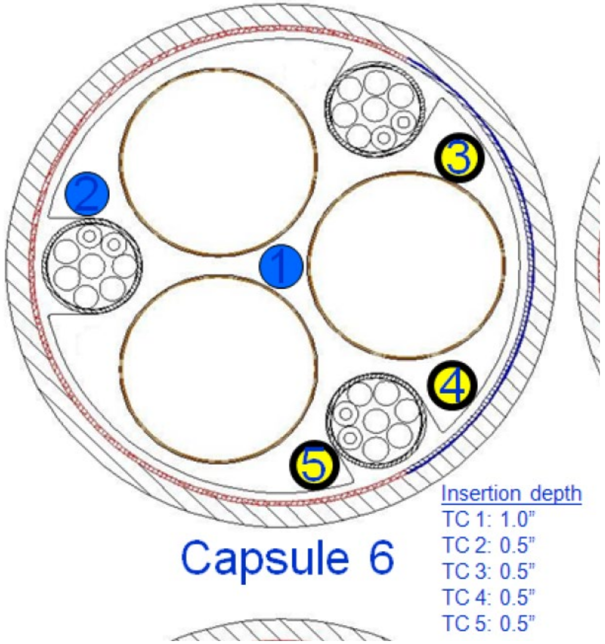




Key AGR-1 and AGR-2 irradiation conditions

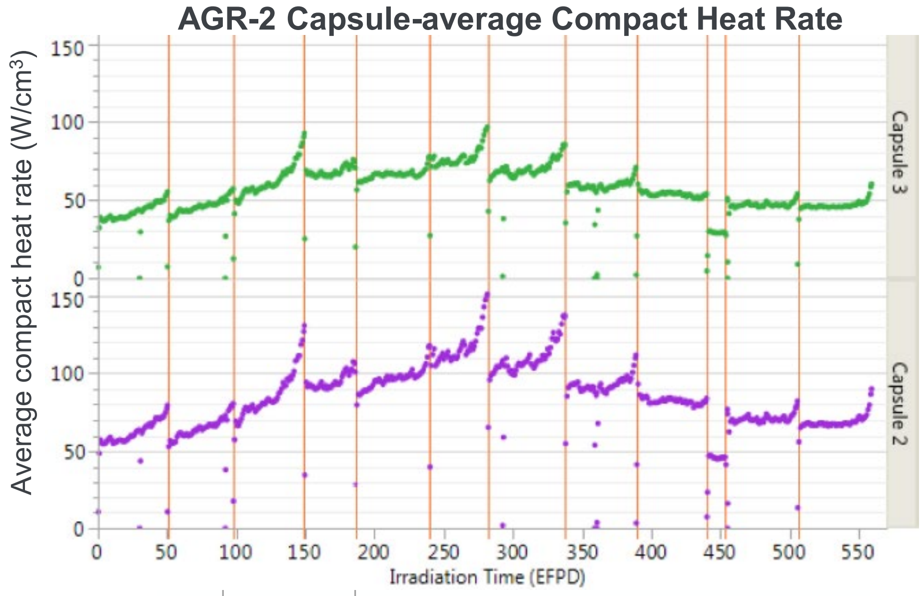
AGR-1 and AGR-2 Temperature Measurement and Control

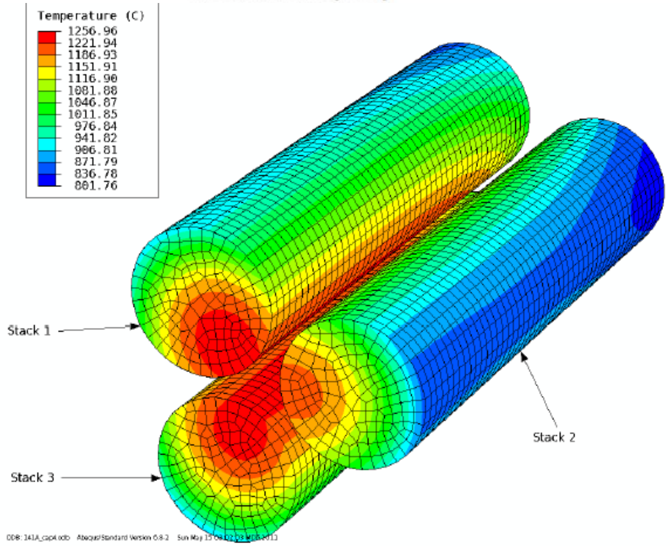
- Thermocouple (TC) types:
  - AGR-1: Type N (9) and Mo/Nb (10)
    - Similar in-pile failure rates
  - AGR-2: Type N (11); larger diameter than AGR-1
    - All failed by end of irradiation, but less drift compared to AGR-1
- Temperature measurement
  - TCs placed in graphite holder surrounding compacts
  - Calculated TC temperatures compared to measurements
    - Early cycles most important, because TCs were still functioning and had experienced no drift
  - **Fuel temperatures calculated using the benchmarked thermal model**
  - Most TCs <1000ºC in both experiments (a few exceptions T<1100ºC)
  - Similar approach for AGR-1 and AGR-2



Physics and Thermal Models

- Physics
  - MCNP-ORIGEN coupled code
  - Included daily depletion of TRISO fuel, ATR driver fuel, and capsule components, and shim cylinder rotation
  - Post-irradiation comparison to (a) actinide isotopics, (b) fuel burnup, (c) flux wire measurements
  - Accounted for relocation of experiment (AGR-2)
- Thermal model
  - 3-D finite element model
    - ~350,000 nodes per capsule
    - Roughly 1 node per particle in the compacts
  - Considered all relevant phenomena:
    - Conduction; radiation; heat rates in fuel, graphite and metallic components; graphite shrinkage and changes in thermal conductivity with fluence; thermal conductivity of compacts

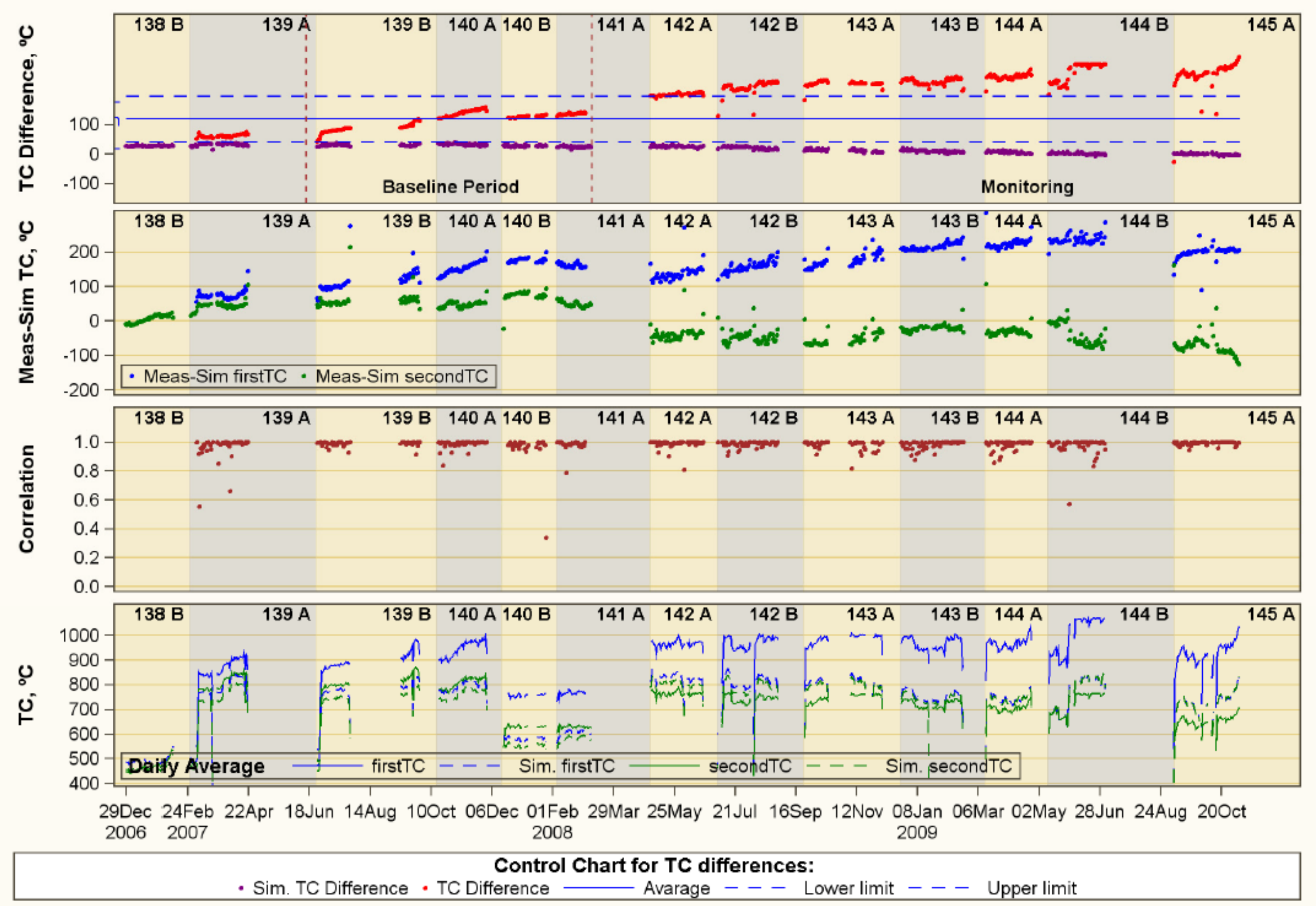




Thermocouple Drift

- Thermocouple drift evaluated continuously throughout irradiation using control charting
  - Compared TC readings to calculated temperatures (captures operating condition changes) and to other TCs in same capsule (indicates differences in TC behavior under similar conditions)
- If control TC was determined to be drifting or failed, control was switched to an alternate TC
- If no functioning TCs remained, control was based on the model predictions

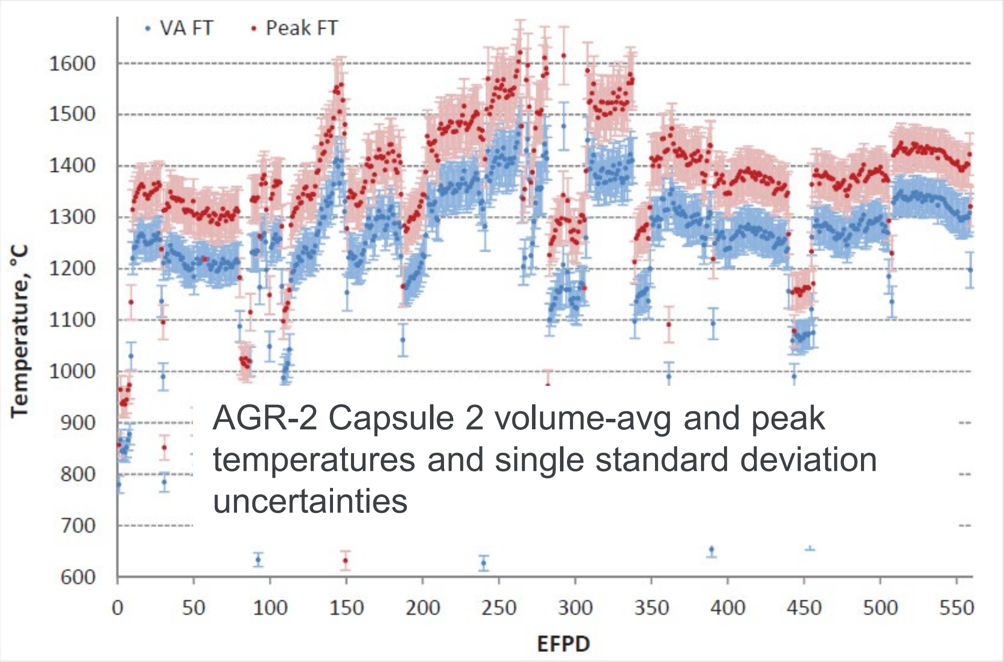
AGR-1 Capsule 5 TC1 and TC3 Drift Monitoring



Source: B.T. Pham and J.J. Einerson, “AGR-1 Thermocouple Data Analysis,” INL/EXT-12-24761 (2012)

Temperature Uncertainty

- Temperature uncertainty analyses were performed for AGR-1 and AGR-2
- Considered contribution from uncertainty in all fuel temperature calculation input parameters:
  - **Fuel heat rate** (from physics simulations)
  - **Thermal conductance gap width** (graphite and fuel compact dimensional change; data from PIE)
  - **Graphite thermal conductivity**
  - **Fuel compact conductivity**
  - **Ne gas fraction**
  - **Capsule shell emissivity**
  - **Graphite emissivity**
  - **Non-fuel component heat rates** (from physics simulations)
- Sensitivity studies performed to determine parameters with highest impact on temperature uncertainties
- Uncertainty in individual parameters estimated and total uncertainty in calculated fuel temperatures determined
- Capsule volume-average, time-average temperature uncertainties (σ_T):
  - AGR-1: 33 – 55ºC
  - AGR-2: 28 – 39ºC
- Uncertainty on instantaneous (daily) temperatures higher than time-averaged values

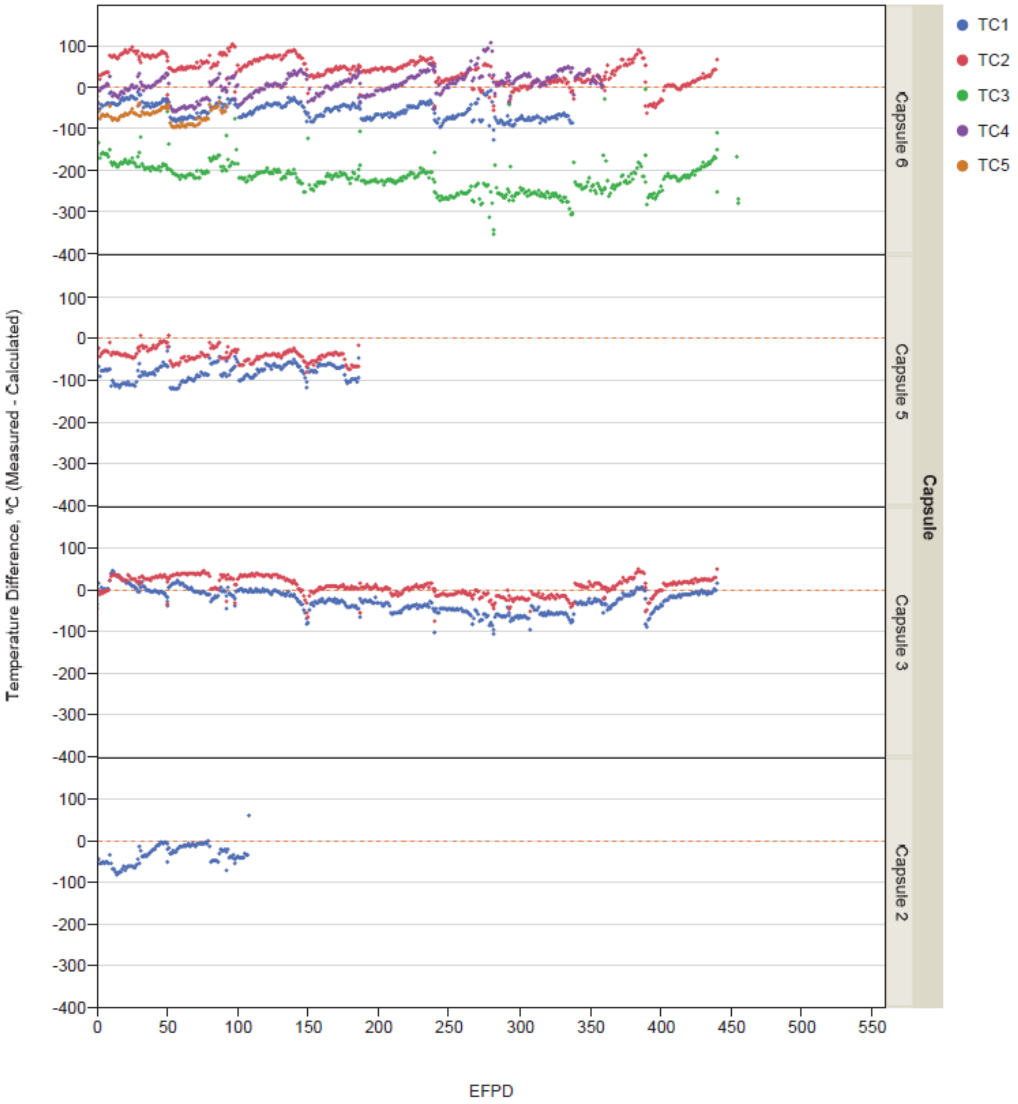


AGR-2 Capsule 2 volume-avg and peak temperatures and single standard deviation uncertainties

AGR-2 Temperature Bias

- Temperature bias between measurements and model was assessed by examining TC residuals ($T_{measured} – T_{calculated}$) during early cycles when TC drift was negligible
- TC 6-3 determined to be drifting and unreliable
- For Capsules 2, 3, and 6 the overall bias was close to zero
- For Capsule 5, the bias was assessed as -60ºC (60ºC overprediction in fuel temperature)
- Higher-temperature capsules (AGR-2 Capsule 2, AGR-7) were included in the program plan to address risk of potential temperature bias

AGR-2 TC residuals

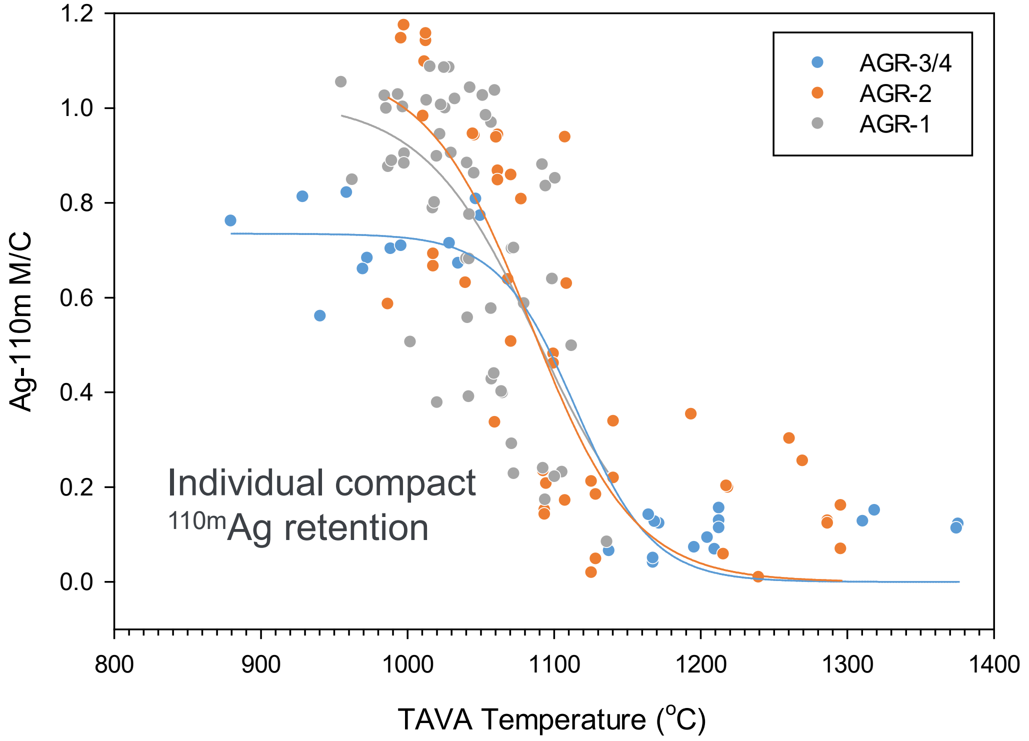


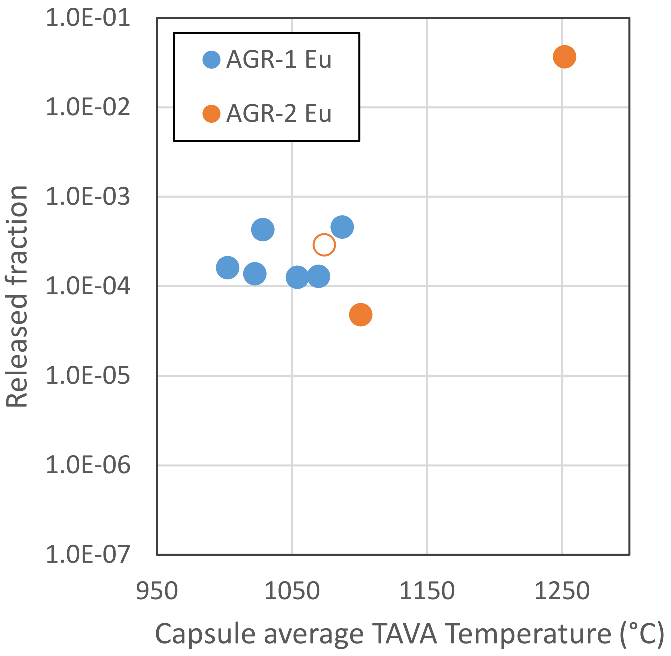
Fission Product Release from Fuel Compacts vs. Temperature

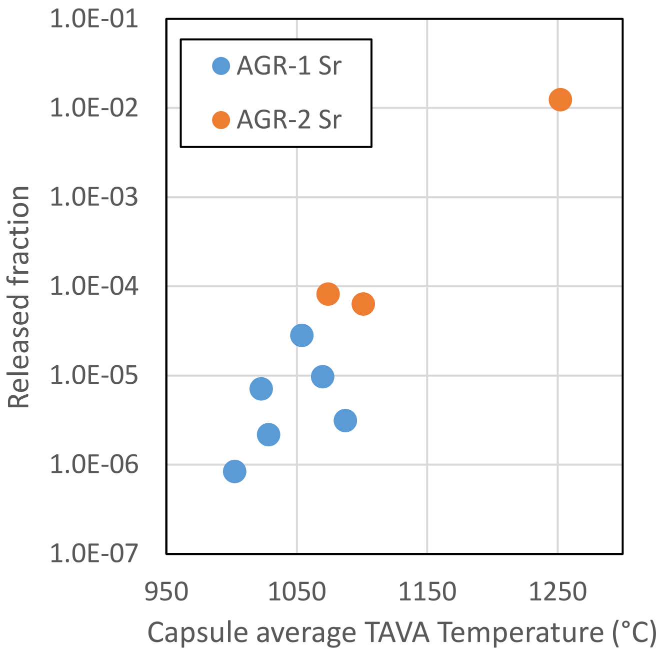
Fission product release data support the temperature uncertainties and biases determined by analyses

- Ag retention in fuel compacts from AGR-1, AGR-2, and AGR-3/4 follow a very similar dependence on temperature
- Inflection points all within ~30ºC

- Sr and Eu retention in AGR-2 Capsules 6 and 5 very similar to AGR-1 at same temperature range. Notably higher release from AGR-2 Capsule 2 (150 to 250ºC higher time-avg vol-avg temperatures).







Eu and Sr release from compacts for each capsule

Publications Relevant to AGR-1 and AGR-2 Temperature Measurement, Calculation, and Uncertainty

- B.T. Pham and J.J. Einerson, “AGR-1 Thermocouple Data Analysis,” INL/EXT-12-24761 (2012)
- B.T. Pham and J.J. Einerson, “AGR-2 Final Data Qualification Report for U.S. Capsules – ATR Cycles 147A through 154B,” INL/EXT-14-32376 (2014)

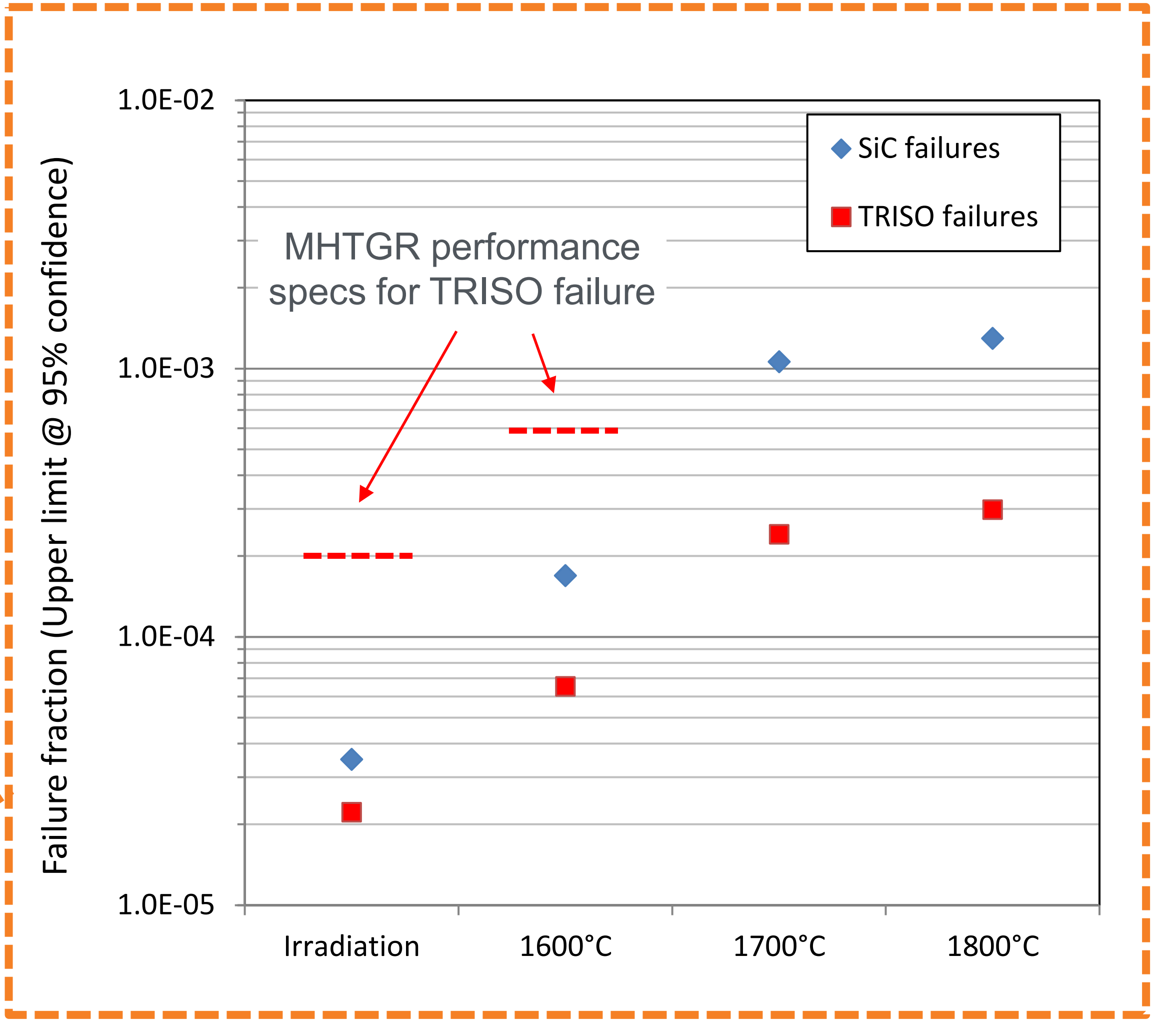
- G.L. Hawkes, “AGR-1 Daily As-Run Thermal Analyses, ECAR-968 Rev. 4 (2014)
- G.L. Hawkes, “AGR-2 Daily As-Run Thermal Analyses, ECAR-2476 Rev. 1 (2014)

- B.T. Pham, J.J. Einerson, and G.L. Hawkes, “Uncertainty Quantification of Calculated Temperatures for the AGR-1 Experiment,” INL/EXT-12-25169, Rev. 1 (2013)
- B.T. Pham, J.J. Einerson, and G.L. Hawkes, “Uncertainty Quantification of Calculated Temperatures for the U.S. Capsules in the AGR-2 Experiment,” INL/EXT-15-34587 (2015)

- Over a dozen peer-reviewed technical journal articles and conference papers

Results Summary

- Fission gas release during experiment indicated zero failures in AGR-1; PIE indicated ≤4 failures in AGR-2
- Kernels and coatings generally held up very well in all irradiation conditions
- PIE has helped to elucidate SiC layer failure mechanisms
- High-temperature performance is exceptional, with low coating failure rates at 1600 – 1800ºC in pure helium
- Fission product release data obtained (e.g., Ag, Cs, Eu, Sr, Kr)
- Significant margin exists between observed coating failure rates and historic design specs for allowable failures

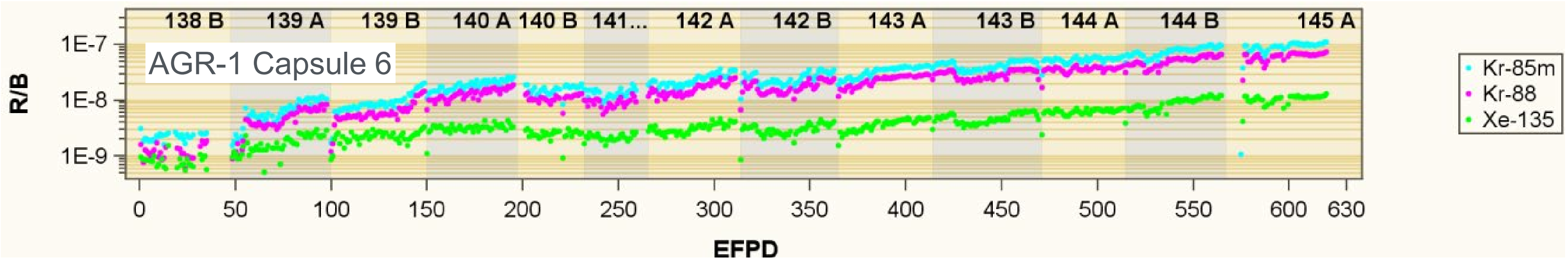


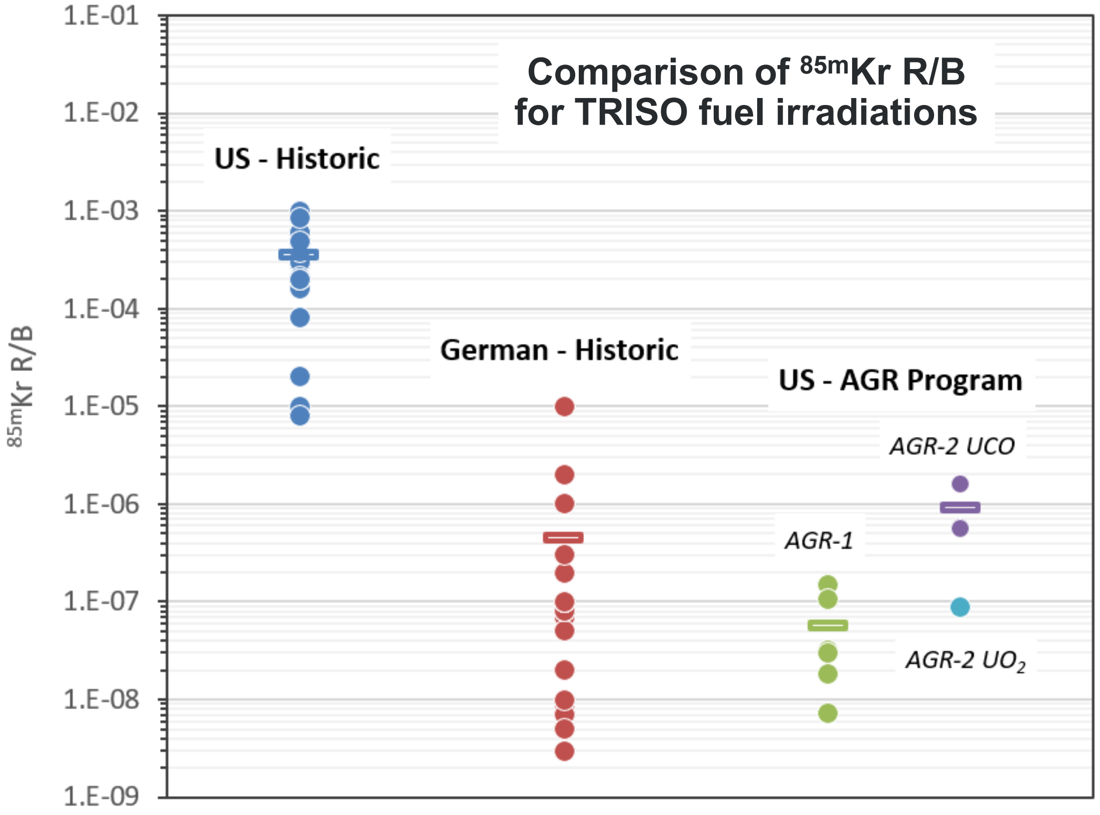
Request for Additional Information (RAI) Response Overview

- NRC submitted four technical RAIs
  - Important operating conditions beyond temperature and burnup
  - Other important fuel properties or coating process parameters
  - Acceptable particle parameter ranges (Table 5-5)
  - Limitations on fission product release data
- RAIs reflected a careful reading of the report and good grasp of key issues impacting the conclusions
- Applicant provided NRC staff with responses to RAIs
  - Additional information and technical discussion
  - Revisions to the topical report

Extra Slides

Fission Gas Release

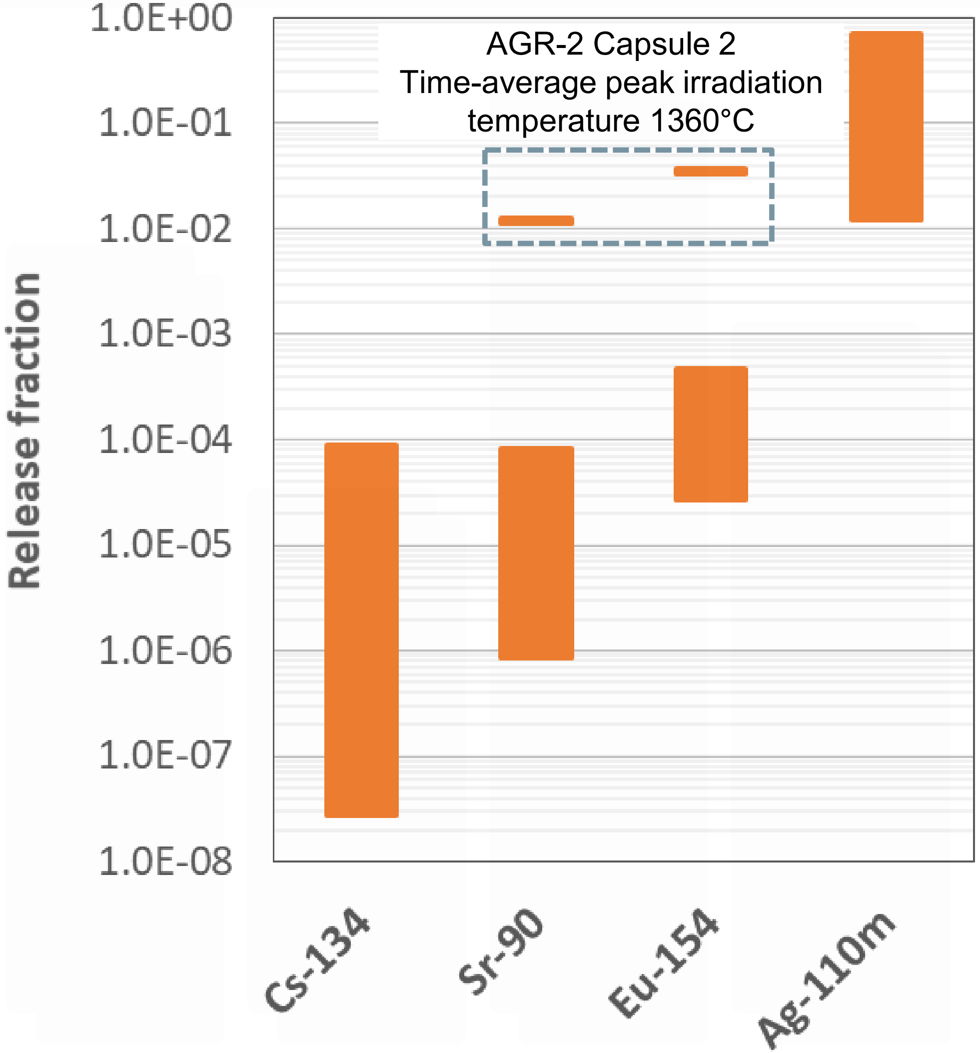




- R/B ratios during AGR-1 remained $<2 \times 10^{-7}$, indicating no failures out of 300,000 particles
- AGR-2 R/B indicated no failures through three cycles; R/B data for remainder of irradiation not qualified because of hardware problems
- Current PIE estimate indicates ≤4 particle failures during AGR-2 irradiation
- R/B data compare favorably to historic German values, but at ~20% FIMA (AGR-1)

Fission Product Release from AGR-1 and AGR-2 Fuel Compacts

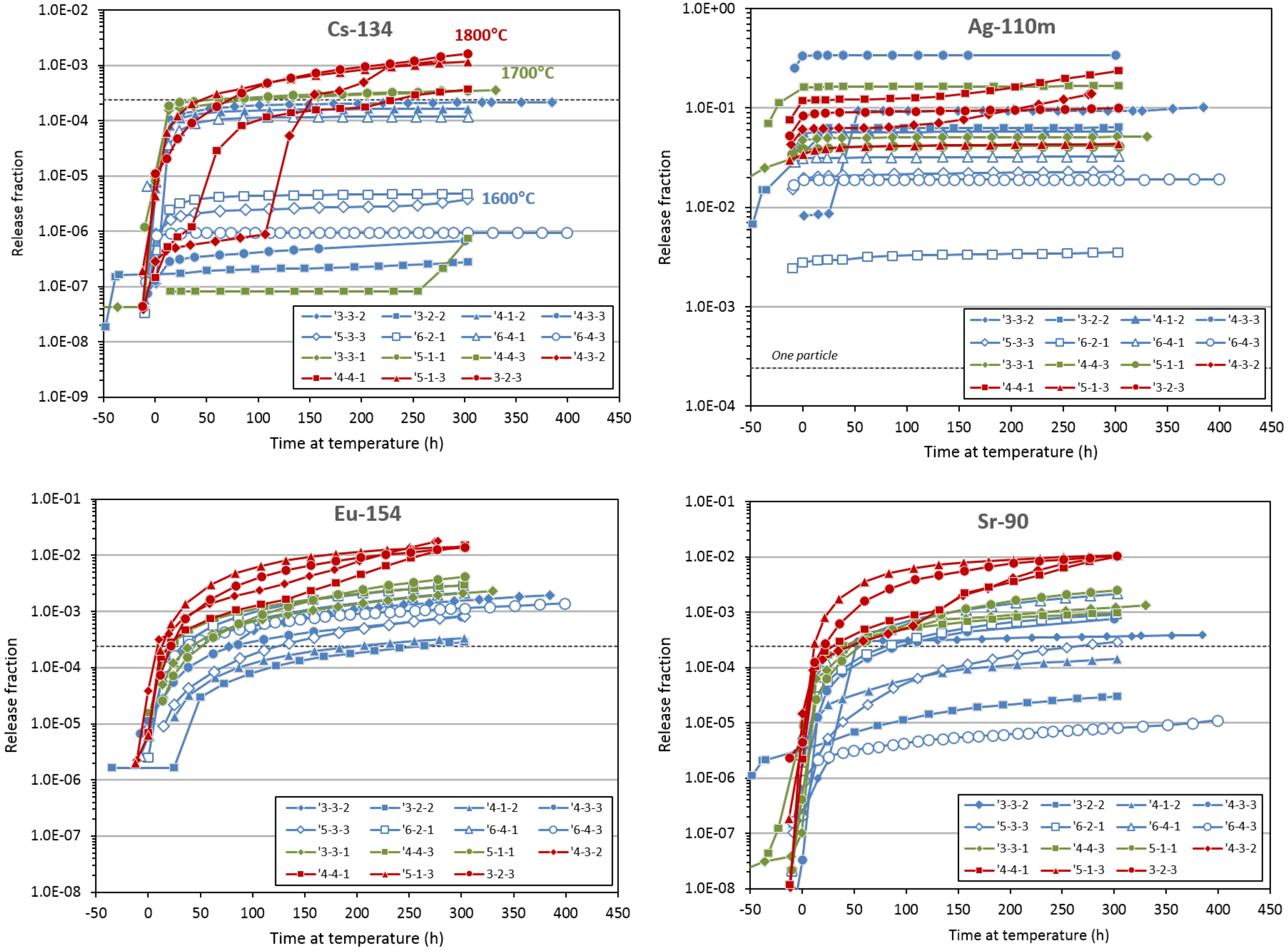
Fission product release from AGR-1 and AGR-2 UCO fuel compacts



- Cs release is very low through intact SiC; higher releases are associated with a limited number of particles with failed SiC
- Sr and Eu can exhibit modest release; release is much higher with high in-pile temperatures (AGR-2 Capsule 2 time-average peak temperatures 1360˚C)
- High Ag release, consistent with historic TRISO fuel observations

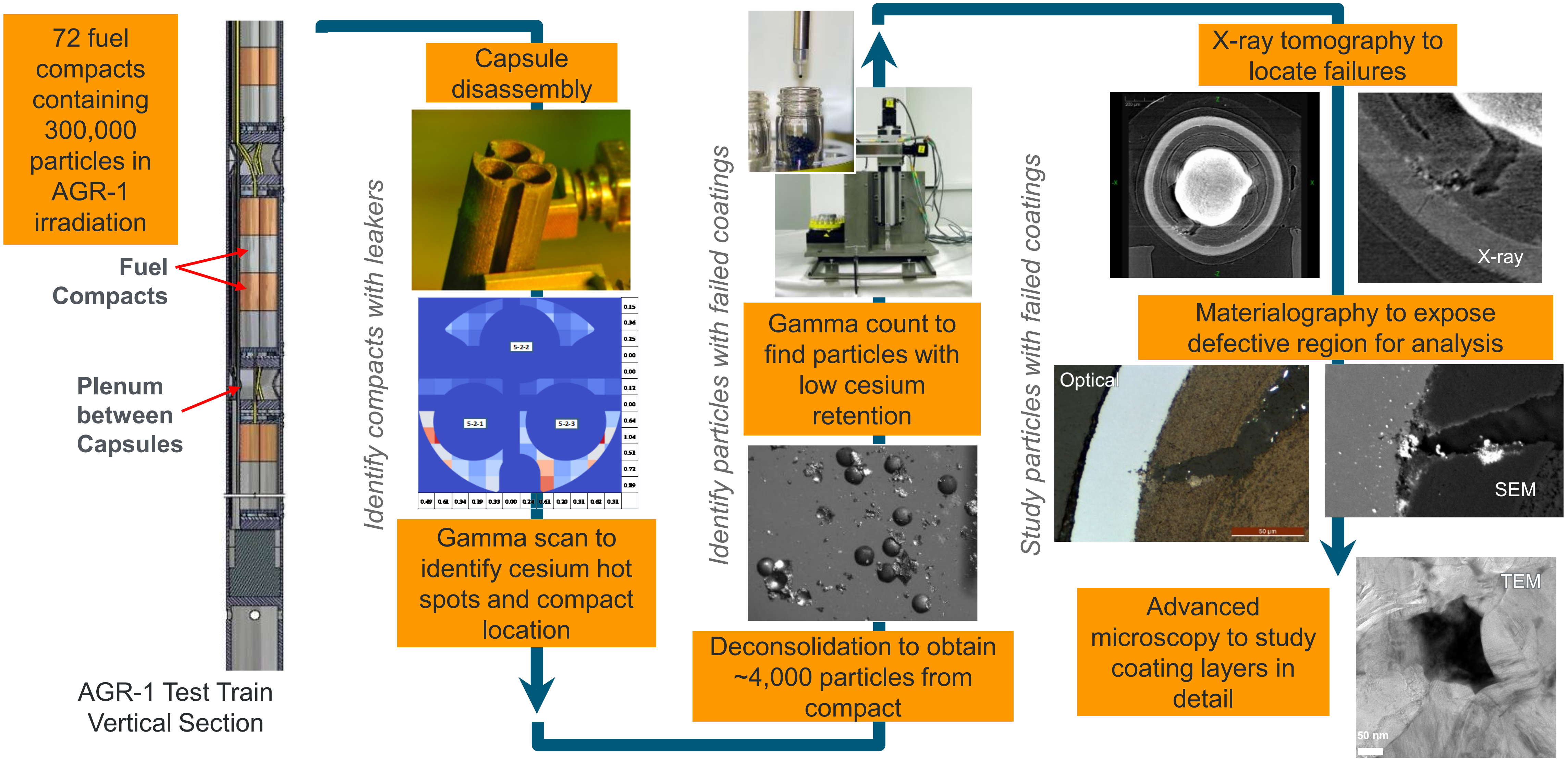
Safety Testing Results

AGR-1 safety test results



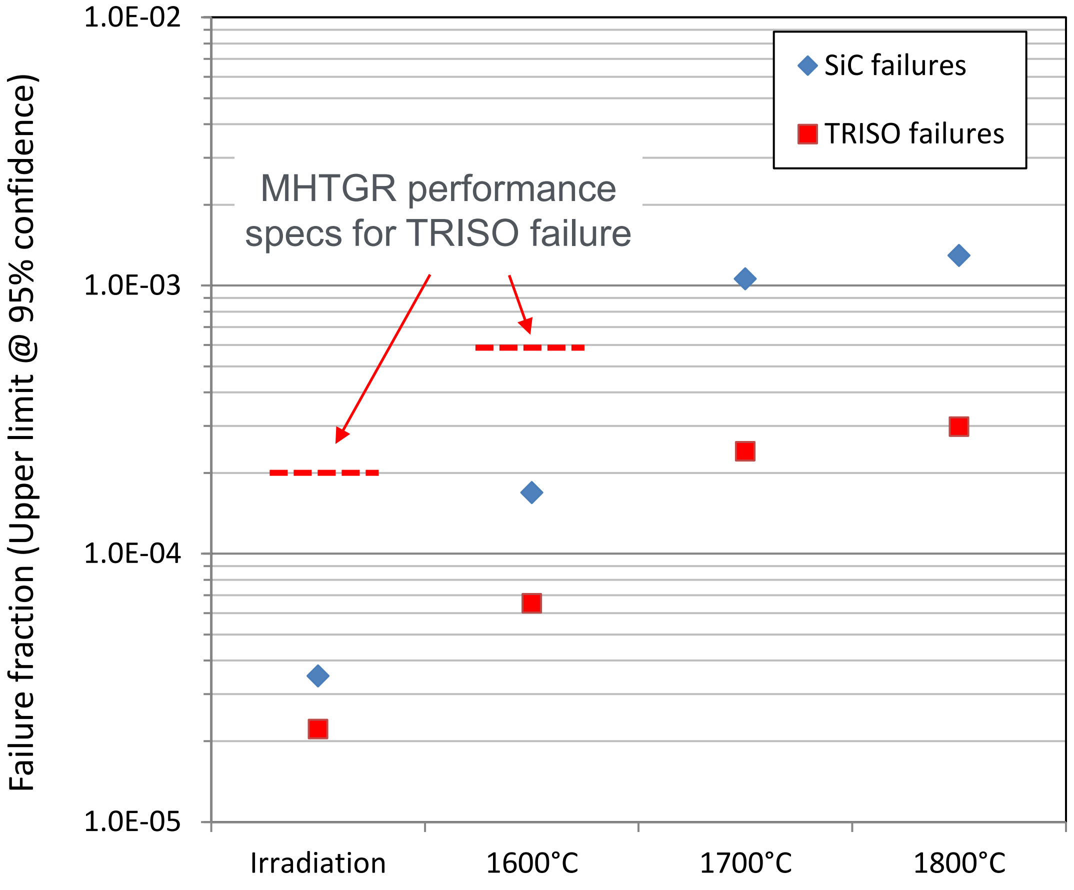
- Cs release fraction very dependent on SiC layer failure; not released through intact SiC
- Frequency of SiC layer failure increases with increasing test temperature but remains relatively low even at 1800˚C for 300 h (~10^{-3})
- Eu and Sr release increases with test temperature; dominated by release from inventory in the matrix at 1600-1700˚C
- Ag release is from inventory stored in the matrix
- Kr release is directly related to TRISO failures (failure only observed in 1800˚C tests)

Studying failed particles greatly improves understanding of fuel performance



Particle Failure Statistics

- Use binomial statistics to determine upper bound on failure fractions at 95% confidence based on (1) observed failures and (2) number of particles in sample
- Historic design specifications and empirical failure fractions only concerned with TRISO failure
- AGR program has been successful at quantifying discrete failure of the SiC layer of UCO fuel as well
- AGR-1 and -2 TRISO failure fractions are ~10x lower than historic MHTGR design specs at 95% confidence



Significant Topical Report Changes Related to RAIs

- Added fast neutron fluence and power density to key irradiation conditions
- Added data on silicon carbide (SiC) stress metric σ (relates to acceptable kernel-to-buffer volume ratio)
- Added standard for silicon carbide microstructure grain size
- Clarified that uninterrupted coating is considered a process requirement when applying the results of this topical report
- Refocused Table 5-5 on as-irradiated property ranges and addressed comparison of a fuel particle population to the AGR-1 and AGR-2 fuel
- Revised text of Conclusion 3 to state that fission product release data "can be used to support licensing of reactors" and clarified that Conclusion 3 only applies to fission products specifically referenced in the report

ScreenShots – Attendees: July 7, 2020; Metallurgy and Reactor Fuels SC Meeting