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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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679TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THURSDAY

OCTOBER 8, 2020

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The Advisory Committee met via Video Teleconference, at 9:30 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

CHARLES H. BROWN., JR., Member

VESNA B. DIMITRIJEVIC, Member

JOSE MARCH-LEUBA, Member

DAVID A. PETTI, Member

PETER RICCARDELLA, Member

DESIGNATED FEDERAL OFFICIAL:

ZENA ABDULLAHI

ALSO PRESENT:

CHRIS ALLISON, Framatome

MARTY BRYAN, NuScale

THOMAS DASHIELL, ACRS

JOSEPH DONOGHUE, NRR

MICHAEL DUDEK, NRC EDO

JERALD HOLM, Framatome

MICHAEL MELTON, NuScale

SCOTT MOORE, NRC

SUNWOO PARK, NRR

JOSH PARKER, NuScale

KYRA PERKINS, NuScale

MATHEW PANICKER, NRR

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

(9:30 a.m.)

CHAIRMAN SUNSERI: Good morning. It is 9:30 Eastern Time. The meeting will now come to order.

This is the first day of the 679th meeting of the Advisory Committee on Reactor Safeguards.

I am Matthew Sunseri, Chair of the ACRS. At this time, I will call the roll. Member Ron Ballinger?

MEMBER BALLINGER: Here.

CHAIRMAN SUNSERI: Dennis Bley?

MEMBER BLEY: Here.

CHAIRMAN SUNSERI: Charles Brown? Charles has an excuse. He may be in and out this morning, but his absence is excused.

Vesna Dimitrijevic?

MEMBER DIMITRIJEVIC: I am here.

CHAIRMAN SUNSERI: Jose March-Leuba?

MEMBER MARCH-LEUBA: I am here.

CHAIRMAN SUNSERI: Walt Kirchner?

MEMBER KIRCHNER: Here.

CHAIRMAN SUNSERI: Dave Petti?

MEMBER PETTI: Here.

CHAIRMAN SUNSERI: Joy Rempe?

VICE CHAIRMAN REMPE: Here.

CHAIRMAN SUNSERI: Pete Riccardella?

MEMBER RICCARDELLA: I'm here.

CHAIRMAN SUNSERI: And myself. I note we have a quorum. The ACRS --

MEMBER BROWN: Matt?

CHAIRMAN SUNSERI: Yes.

MEMBER BROWN: I am here.

CHAIRMAN SUNSERI: Okay, Charlie.

MEMBER BROWN: Thank you.

CHAIRMAN SUNSERI: We understand you may be in and out, so that's okay.

MEMBER BROWN: I should be fine. I just wasn't quite sure. Thank you.

CHAIRMAN SUNSERI: Okay. The ACRS was established by the Atomic Energy Act and is 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 September 25, 2020, and provides an agenda and instructions for interested parties to provide written documents or requests for opportunities to address the committee.

The Designated Federal Official for this meeting is Ms. Zena Abdullahi.

At today's meeting, the committee will consider the following. We have a Framatome topical report on GALILEO fuel rod thermal mechanical methodology for pressurized water reactors. We have a NuScale topical report on improvements in frequency domain soil-structure-fluid interaction analysis.

I would like to note that the item regarding the Kairos topical report has been taken off the agenda, and as reflected in the online agenda, preparation of reports and letter-writing will take place during this time.

As noted in the agenda, portions of the Framatome and NuScale sessions may be closed in order to discuss and protect information designated as sensitive or proprietary information.

A phone bridge line has been opened to allow members of the public to listen in on the

presentations and committee discussions. We have received no written comments or requests to make oral statements from members of the public regarding today's session.

There will be an opportunity for public comments, and we have set aside time in the agenda for comments from members of the public attending or listening to our meeting. Written comments may be forwarded to Ms. Zena Abdullahi, the Designated Federal Official.

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 may be readily heard.

Additionally, participants should mute themselves when not speaking.

And just as I look ahead a little bit, the priorities for this week will be associated with the presentations that we are hearing. Our letter reports will address -- we'll take them up in this order, but I'm open for discussion from members.

But first we'll take up the Framatome topical report, followed by the NuScale topical report, and then we will use our remaining time this week to address our reconciliation memos.

I don't have any other opening remarks. I will open the floor to members for any comments or questions they have regarding the agenda or anything they want to bring up. Members?

Okay. At this time, then, we will begin with the Framatome topical report, and I will turn to Dr. Jose March-Leuba, the subcommittee chairman, for opening remarks and to facilitate this session. Jose?

MEMBER MARCH-LEUBA: Thank you. So we are going to move to the first topic on the agenda, which is the Framatome GALILEO topical report, which is a topical report to calculate the properties for fuel rods, calculate properties on pressurized water reactors.

So we will have an open session, and then we will move to a closed session to discuss proprietary matters. So we are going to have, first, introductory remarks by the NRC staff. Joe Donoghue, are you ready?

MR. DONOGHUE: Yes. Good morning, Dr. March-Leuba and members. I am Joe Donoghue. I am the Director of the Division of Safety Systems in NRR, and thanks for reviewing the staff's document, SER for this topical report.

As you heard, it's detail of the thermal

and mechanical models for fuel, including fission gas release, creep elastic properties, radiation growth. You're going to hear all of those details, or see all of those details in the SER, covered in the topical report and reviewed in the SER.

The staff concluded that the topical report is acceptable for referencing in the licensing applications for Framatome PWR fuel designs. I just want to add that the interaction with Framatome was very positive. We did a lot of work in audit space, and Framatome was very responsive to staff conducting a thorough review, and I'm looking forward to the rest of the meeting.

Thank you.

MEMBER MARCH-LEUBA: Thanks, Joe.

So now we want to have introductory remarks by Framatome. Jerry Holm?

MR. HOLM: Good morning. My name is Jerry Holm. I'm a licensing engineer with Framatome. I want to express my appreciation for having the full committee meeting so soon after the subcommittee meeting to facilitate the NRC prioritization of the -- report.

This topical report is a building block for future topical reports, and we would like to be

able to reference an improved version -- reports.

MEMBER MARCH-LEUBA: Jerry, are you using a speakerphone? Because you are coming -- you are coming in and out.

MR. HOLM: Sorry about that. Yeah, I am on my computer.

MEMBER MARCH-LEUBA: Oh, okay. You sound better now.

MR. HOLM: Do you want me to repeat that or --

MEMBER MARCH-LEUBA: No, no, no. We could hear it, but it was kind of breaking up. So keep going.

MR. HOLM: Okay. So that's the end of my opening remarks. We can proceed.

MEMBER MARCH-LEUBA: Perfect. So we continue with Framatome with Chris Allison, and he is going to give us an introduction to the topical report.

Everybody remember that this is the open session. So if you want -- some questions that have to be covered in the close session, save them for 10:25.

Chris, your turn.

MR. ALLISON: Good morning, everyone. My

name is Chris Allison. I am in the Fuel Thermal Mechanics Division at Framatome, and I am the engineering project leader for GALILEO licensing in the United States.

If you could go to Slide Number 2, please.

So I'd like to start to give you just a little background on GALILEO. So GALILEO was -- the development was initiated to consolidate Framatome's worldwide expertise and experience into a single fuel performance code. And it builds upon the best practices and techniques that Framatome has in our current generation of fuel performance codes and methodologies, and that includes COPERNIC, which is used in France and in the United States, for pressurized water reactors.

It includes RODEX4, which is used in the United States for boiling water reactors. And it includes CARO-3E, which is from Germany and supports both types of plants.

The original development was to support both PWR and BWR applications and to include UO2, gadolinia, and MOX fuel types. During the course of the NRC review, we submitted a revised topical report, and in that revision we removed the application to BWR and to MOX fuel. And so the current request for NRC

approval is for PWR applications with UO2 and gadolinia fuel types with fuel rods that have either M5 or Zircaloy-4 cladding.

MEMBER MARCH-LEUBA: Chris, let me ask you a clarification. Is there any cladding in the United States that is not -- on PWR that is not M5 or Zr-4? I mean, will you -- can you cover all PWR applications in the U.S.?

MR. ALLISON: Other fuel vendors will have their own proprietary cladding types. We would not have the models necessary to model those proprietary cladding types. So any analysis of -- you know, of a Westinghouse type of fuel rod would have to be done by that vendor.

MEMBER MARCH-LEUBA: That's how you envision -- if you have a transition for Westinghouse to Framatome, you would have to have multiple vendors doing multiple analysis?

MR. ALLISON: Yes, certainly. Each vendor would have to do their own fuel rod analysis specific to their fuel type. That's correct.

MEMBER MARCH-LEUBA: Okay. Thank you.

MR. ALLISON: Okay. Slide 3, please?

So the overview of the topical report, it describes the methodology for the realistic evaluation

of the thermal mechanical performance of fuel rods for PWRs, and the methodology is to demonstrate compliance with many of the fuel rod requirements that come from Section 4.2 of NUREG-0800, standard review plan.

The topical report contains two major components, the first being the GALILEO fuel performance code, and then the second being the statistical evaluation methodology that applies GALILEO.

The topical report describes the requirements and the capabilities both of the code and the statistical method. It describes the calibration, validation, and the range of parameters that were studied for the GALILEO fuel performance code.

It also describes the uncertainty analyses and how the uncertainties were determined, and then how they are applied in the statistical method, and then it provides a series of demonstration analyses to show how the code and the method behave for different plant types and different fuel types.

Slide 4, please?

Now I'd like to give you a little viewpoint of how GALILEO fits. Jerry mentioned that this is an important platform or important building block for us, and it really is one of those

foundational pieces as we look forward to advanced technologies and methodologies. And that includes the PWR rod ejection accident analysis.

This is an NRC-approved methodology that we have. GALILEO will be implemented into that, and that helps us support the new requirements and criteria that are listed within Regulatory Guide 1.236.

GALILEO is also implemented in our advanced non-LOCA transient analysis methodology, which is currently in NRC review. And this would be for analysis of AOO and postulated accident-type events.

In terms of future submittals that you will see, there will be an implementation of GALILEO into our LOCA analysis methods, and then you will also see submittals related to our advanced fuel management program. And this is where we will be looking towards things like increasing the burnup limit and the use of higher enrichment fuel in the core.

And then the last piece would be the enhanced accident tolerant fuel program, where GALILEO will be supporting aspects of that. And as I mentioned, you can expect to see that in future submittals.

And that is the conclusion of my opening presentation. I am happy to answer any questions that anybody has.

MEMBER MARCH-LEUBA: Members, do you have any questions for Chris or Framatome? We have to wait an extra five seconds because people have to find their mouse. But I don't hear any questions.

NRC, can you start getting ready to do the slides? Mathew Panicker and Ken Geelhood? We have to transfer control of the desktop.

Mathew, I see your slides. Oh, not anymore. Now I do.

So, NRC, whenever you want to start the open session, you may. I would recommend you unmute yourselves.

DR. PANICKER: My name is Mathew Panicker. I work as a nuclear engineer at the Nuclear Methods and Fuel Analysis Branch of the Division of Safety Systems in NRR.

Next slide, please.

GALILEO gives a realistic evaluation or best estimate methodology for evaluating the thermal mechanical performance of fuel rods of PWR fuels. This is actually applicable to PWR fuels. The fuel is UO2 with burnable absorbers.

The cladding associated with this topical report is Zircaloy-4 and M5, and the methodology provided for all thermal mechanical analysis.

The GALILEO Code assesses all of the models for various fuel performance parameters, and also addresses the integral core predictions. The methodology involves proposed uncertainties using the statistical methodology, and assessment of fuel damage limits is also covered in the topical report.

Next, please?

A short history of the GALILEO review is in October 2013, Framatome submitted ANP-10323 for GALILEO topical report Revision 0. Acceptance was done in March 2014. Because the work involved was tremendous, that is why we contracted PNNL staff as consultant.

Upon review, the staff submitted over 70 RAIs, including subparts. AREVA decided to revise the topical report, and it suspended BWR and MOX fuels, which was really during the topical report in November 2015.

And, in June 2018, Framatome submitted Revision 1 for PWR fuels of UO2 and gadolinia. After that, Framatome submitted RAIs and five RAI responses in final -- ranging from December ’18 through July

2020. And the staff used NRC's FRAPCON -- or now it is called FAST fuel performance code -- for confirmatory calculations to review the results and for comparison to the results from GALILEO.

Next, please?

This is a list of models available in GALILEO, and GALILEO is built on the two codes -- NRC-approved COPERNIC and the German regulator-approved CARO-3. It addressed thermal models, fission gas models, and the rod internal pressure; cladding, corrosion, and hydriding model; cladding, hydride pickup; specification and swelling model; mechanical modeling and properties; fuel mechanical properties; rod void volume; model and resulting growth assessment; licensing applications.

It is work that improves statistical approach, and 99.9 percent probability, 95 percent confidence level, better for uncertainty calculations. And the code is applied -- the applicability of the code is in many applications of the operating reactors with Framatome fuel.

Next, please?

These are the bases of our review based on the regulatory evaluation, GDC 10. These are the -- with the SAFDL, specified fuel design limits for

operation.

The two other ones, GDC 35 and 50.46, generally are applicable to fuel performance codes, but in this case Framatome decided to submit another version of GALILEO or ECCS performance analysis. And then the SRP report will deal with fuel performance -- fuel performance and design. It has to protect the fuel during normal operation and AOOs.

The damage of the fuel should not be able to prevent severe -- to prevent rod insertion, and the number of fuel rods failures should be eliminated or under -- should not be underestimated for postulated accidents. Core coolability should be maintained.

Another complaint is the SRP 15.02. That is the guidance for how a topical report should be submitted to the NRC with documentation, code verification, validation, evaluation model, uncertainty analysis, in order.

Framatome has submitted all of the supporting documents including theory, V&V, and other supporting documents to facilitate the review of this code.

Next, please?

The staff finds the GALILEO code and methodology as described in the Revision 1 of the

GALILEO methodology, as modified as in the RAIs, and we found that it is acceptable. And there are some situations which will be -- which we will be talking about it in the closed session.

I think that is the last slide.

MEMBER MARCH-LEUBA: Members, any questions for the staff in the open session? We are going to have a closed session in a few minutes. I assume most questions will come there, but let's wait five seconds.

CHAIRMAN SUNSERI: This is Matt. I just have maybe one question. And it's probably really obvious, but I just want to confirm it.

So some of the fuel types have been excluded, the BWR and the MOX. I presume that if any work comes along in that area, the previous versions of the topical report would still remain valid and it could be done under those previous revisions. Is that a correct assessment?

DR. PANICKER: Yes. For BWR fuels, we use the RODEX4 from Framatome. And MOX, we don't have any because we found that -- at that time, we found that the data was insufficient.

CHAIRMAN SUNSERI: Yeah, yeah. No, I get it. All right. Great. Thank you. Appreciate it.

MEMBER MARCH-LEUBA: Yeah. But, Mathew, isn't it correct that Revision 0 of ANP-10323P is not approved. I mean, it was -- it was withdrawn.

DR. PANICKER: Revision 0? Yeah. Yes.

MEMBER MARCH-LEUBA: Yeah. The original submittal was 2013, was essentially withdrawn.

DR. PANICKER: Excuse me?

MEMBER MARCH-LEUBA: The Revision 0 was the original submittal, was in 2013 or '14.

DR. PANICKER: Yeah. Okay.

MEMBER MARCH-LEUBA: That has not been approved because it was withdrawn by Framatome because they plan to use their previous methodology, which is a different report number, RODEX4.

DR. PANICKER: Yeah, RODEX4.

MEMBER MARCH-LEUBA: Yeah. Okay.

DR. PANICKER: Yes, in RODEX4.

MEMBER MARCH-LEUBA: And MOX fuel, they don't really have a methodology for MOX.

DR. PANICKER: No. We are looking at it, and it's thought that that was insufficient. So Framatome realized that, and they dropped the -- both the BWR fuel and MOX fuel in 2016.

MEMBER MARCH-LEUBA: Okay. Thank you, Matt.

CHAIRMAN SUNSERI: Yeah, yeah. That addresses my question. I appreciate the clarifications. Thank you.

MEMBER MARCH-LEUBA: If any members have another question, please do so, because I am going to ask for public comments. Can we open the phone line, Thomas?

MR. DASHIELL: Affirmative, Jose. The public line is open for comment.

MEMBER MARCH-LEUBA: If anybody on the public line or any member of the public that is joining on the line wants to make a comment, please do -- state your name and do so now. Again, I want to wait five seconds because since -- I don't hear any comments from the public line. Thomas, can you close it again?

At this moment, we are scheduled to move to the closed session. We are a little bit ahead of schedule, but I propose that we move ahead because we can always use the time for letter-writing or other topics.

So, and it's not worth, after 25 minutes, to have a break, so let's have a 10-minute break just to change sessions. And let me tell you what the procedure is going to be. If you have an nrc.gov

account, if you have signed in on your NRC credentials, you will be admitted to the closed session automatically.

If you are like me, have come in as a guest using your personal computer, you will be put in the lobby and somebody will confirm that you belong in the closed session.

So let's re-establish in the closed session link at let's say 10:10, to give people time to get there.

Matt, are you still here? Are you, Matt? Yeah, I see Matt.

CHAIRMAN SUNSERI: Which Matt? Yeah, yeah.

MEMBER MARCH-LEUBA: The Chairman, Matt Sunseri.

CHAIRMAN SUNSERI: Yeah, yeah.

MEMBER MARCH-LEUBA: Yes. Seeing that we are going fast, we might have time to read the letter in open session when we finish the closed session. Do you want to come back to this open session number, or do you want to wait until this afternoon to read the letter?

CHAIRMAN SUNSERI: No. I mean, it depends on how long the closed session lasts, but we'll have

until 11:30 before we start the NuScale presentation. So if you feel like there is going to be sufficient time to read in the letter and have, you know, a break, then we can --

MEMBER MARCH-LEUBA: Sure.

CHAIRMAN SUNSERI: -- read it, yeah.

MEMBER MARCH-LEUBA: If we finish with sufficient time before 11:00, we might come back to the open session and read the letter.

So, at this moment, this open session is in recess, and we will move to the closed session. And let's reconvene at 10:10.

CHAIRMAN SUNSERI: Yeah. Let me just add a little bit to your point there. So I will ask the staff to monitor the progress of the closed session and provide updates on this public line here to the public, so that they know when we would expect to return to open session, because right now, as it stands, once we go into closed we wouldn't return until 11:30, and we may return earlier than that.

So I just want to give the public a heads-up on that. Okay?

MR. MOORE: This is Scott Moore, the Executive Director. We'll give updates on the public line about every 30 minutes.

Thomas, can you please keep the public line open but not connected to the closed session? And somebody from the staff will go on every 30 minutes and give an update.

CHAIRMAN SUNSERI: Thank you, Scott. Appreciate that.

MR. MOORE: Sure.

MR. DASHIELL: No problem, Scott.

MR. MOORE: Thanks.

MEMBER MARCH-LEUBA: So, again, we're off the record. We are in recess.

CHAIRMAN SUNSERI: Okay.

(Whereupon, the above-entitled matter went off the record at 9:58 a.m. and resumed at 11:30 a.m.)

CHAIRMAN SUNSERI: Okay. It's 11:30. This is Matt Sunseri. We are going to start the NuScale topical report presentation right now.

And, at this point, I will turn to Member Riccardella for leading this topic. Pete, you have the floor.

MEMBER RICCARDELLA: Yes. Good morning. We are going to now cover the NuScale topical report on improvements in frequency domain soil-structure-fluid interaction analysis.

These were addressed at length in a

subcommittee meeting on September 22nd, at which most members were in attendance. Therefore, we will have abbreviated presentations this morning, and I don't believe we need to go into private sessions for the -- for any of this session.

And so, with that, I will ask Michael Dudek of the NRC staff to make a few comments.

MR. DUDEK: Thank you, Chairperson Riccardella. So, and thank you for the rest of the staff, the ACRS full committee staff, for attending and hearing our presentation today.

As Chairman Riccardella stated, we did have a successful briefing of the subcommittee a few weeks ago on this analytical tool and methodology proposed by NuScale.

And, really, at the crux of it is that previously to this methodology being proposed, there was really no analytical tool available to systematically integrate the effects of the soil-structure-fluid interactions in a feasible and logical manner to develop the seismic load for nuclear power plant structures, systems, and components.

However, in this typical report that NuScale is going to present -- and Sunwoo has transformationally reviewed and evaluated and you'll

hear his report out today on -- is that NuScale really proposes, you know, something new and novel that can integrate all of these capabilities of the different programs and handle, really handle this soil-structure-fluid interaction during an earthquake.

You know, NuScale has proposed this novel approach. You know, Sunwoo, as the lead technical reviewer, has really gone above and beyond to -- and in a transformational method to evaluate and bring this all together in a logical format.

So without any further ado, I think I will turn it back over to you, Mr. Chairperson.

CHAIRMAN SUNSERI: Pete, are you still with us?

MEMBER RICCARDELLA: Yes, I am.

CHAIRMAN SUNSERI: Okay.

MEMBER RICCARDELLA: I'm sorry. NuScale, do you want to proceed with your presentation, please?

MR. MELTON: Sure. This is Mike Melton, manager at NuScale licensing. So before I turn it over to Kyra, I just wanted to say welcome, everybody, and we're looking forward to the full committee presentation.

And we are -- as Mike described, we're very excited to get to the disclosure point on our

soil library technical report. Our LTR is definitely a much more efficient process and I believe is backed by sound analysis and technical justification. So I'm looking forward to the team making an effective presentation today and answering any questions.

So, with that, I will pass it off to Kyra Perkins, who is our licensing project manager on this report.

MS. PERKINS: Thank you, Mike. Good morning, everyone. I'm Kyra Perkins, licensing project manager at NuScale. And so let me begin our presentation on the topical report and improvements within the domain of soil-structure-fluid interaction analysis.

Okay. So Josh Parker will be our main presenter today. And Matthew Snyder and myself will be supporting today's discussion.

CHAIRMAN SUNSERI: Hey, Kyra. This is Matt Sunseri. There is a little bit of a background noise, and you sound kind of like you're in a hole. I don't know if that's acoustics on your end or what.

MS. PERKINS: Okay. Let me adjust real quick. Okay. Hopefully, now it's okay?

CHAIRMAN SUNSERI: Oh. Much better. Yes, thank you.

MS. PERKINS: Okay. Great.

Okay. On to the agenda, I will review the purpose and the applications of the topical report, and then Josh will present at a higher level than from the subcommittee meeting on the features of the soil library methodology, a description of the methodology, and an overview of the topical report demonstration problems. We will then summarize the NRC's review of the topical report and conclude with a summary.

Okay. So the frequency domain soil-structure-fluid interaction allows this topical report, as far as a more efficient process for the applicant or licensee to perform seismic analyses of complex interactive structures, soils, fluid systems and major mechanical components.

So today's presentation, as mentioned before, is a higher level summary of the topical report on what was given at the subcommittee on September 22nd. The subcommittee meeting was a more detailed presentation of the methodology and sample problems. NuScale's presentation materials from the subcommittee meeting are available on the NRC's website.

Okay. This topical report is intended to be applicable to multiple licensees, so that includes

future design certification applications, standard design approval applications, and site-specific combined licensing COL analyses. The COL will use a site-specific soil library and will evaluate the adequacy of the NuScale design.

I will also add that NuScale plans to apply this methodology to the standard design approval application.

Before I turn it over to Josh, are there any questions or comments thus far?

CHAIRMAN SUNSERI: No, I don't have any comments. There is still a little bit of a background noise, like a fan or something maybe. Is your microphone close to the computer fan or something?

MS. PERKINS: I don't think so. Hopefully, I can get that figured out. But I'll turn it over to Josh for now. Thank you for the --

CHAIRMAN SUNSERI: It's not terrible.

MR. PARKER: All right. Good afternoon, or late morning. As Kyra said, my name is Josh Parker. I am the supervisor of civil structural engineering at NuScale, and I will be presenting the next few slides.

So, to begin, I like to discuss some of the features that are available with the soil library

methodology that weren't previously available using our previous approach.

The first is that we needed to develop, in the approach taken for the design certification, several models as the analysis and results went between civil structural and subsystem analysis. And this is no longer required, as we can integrate the building and all major subsystems into a single model.

Related to this is that our models can now be much larger. We can incorporate -- as a result, we can incorporate seismic as well as non-seismic loading. Also, even though our models are larger, we have actually seen the run times go down quite significantly.

And given how we have been able to integrate into a single platform, it has allowed us to greatly simplify the process. And all of this has really resulted in more readily allowing for feasibility studies, for example, permutations that come about from having different module configurations, an aspect that is really important for us in SMR design plants particularly.

And, lastly, given our use of ANSYS, we were able to leverage the latest in finite element technologies and developments that are not available

in older codes like SASSI. So several different, pretty exciting features for us given the new approach.

Next slide?

So over the next couple of slides I will describe some of the key aspects of the methodology. So, first, this approach eliminates the need for a two-step analysis process. So whereas before we needed to first create models of our NPM, both very detailed and in simplified models for import into SASSI, and then also a model of our building in multiple programs, we can now develop an integrated model of the backfill soil, the building, the fluid, and the major subsystems like the NPMs.

And having an integrated model in this way really makes for a much more straightforward exchange of data and simplifies all of those interfacing analyses.

Given the use of the ANSYS solver and the not the SASSI solver, we have seen our analysis time shorten significantly as mentioned on the previous slide. And using ANSYS also allows us to overcome the model size constraints that we had previously.

We were running up against maximum numbers of elements or nodes, and that has been overcome given

our use of ANSYS and allowing our models to be much more detailed and eliminating some of those previous constraints.

Next slide?

So, additionally, some aspects of the methodology. First, we still use SASSI. We use it to calculate in an impedance library. That library is then -- or is calculated with the same seismic inputs and soil properties as a traditional approach. But we do use in this -- in our current methodology, we do use the direct method to calculate the impedance library, as opposed to our use of the modified subtraction method previously, which really has to do with not having -- not being limited to model size.

But, as previously described, we no longer have a SASSI building model, but we instead have an integrated model in ANSYS and use the ANSYS solver.

And what we’ve seen -- and we’ll talk about example problems in a later slide -- but what we’ve seen is that the -- and the report shows is that we have a dynamic ANSYS analysis that is functionally equivalent as it would be in SASSI when we do it in ANSYS.

Next slide?

So the last few aspects of the

methodology. One important piece to note is that we -- that the analysis is performed in the frequency domain. So when we combine the soil impedance from SASSI with ANSYS, we still use the ANSYS solver that is done in the frequency domain.

In developing the approach, we employed the same linear elastic or equivalent linear elastic analysis that is used in typical SASSI applications, and this is the case for the soil properties, the structural properties, the constraints and boundary conditions. So that's all -- that all remains the same.

And as we develop the approach -- the methodology, we validate it through a variety of example problems that we'll touch on in the next slide. And those were used to show the equivalency in the results between a traditional SASSI analysis and this -- and our new analysis.

And all of this results in a one-step analysis as opposed to the two-step analysis that we talked about in my opening slide. So the structure-soil-fluid interaction of the buildings, NPM, and cool water. And this allows for a more efficient and elegant approach.

I would also I guess, lastly, point out

that seismic analysis methods of the secondary SSCs and the fuel, those all remain the same, so we're not changing any aspects there. Those are all -- those will all be done the same.

Next slide?

So as part of validating the methodology, we assessed four different example problems. Those consisted of, first, a surface-mounted PWR in a halfspace, and that's a problem that has been used to validate SASSI for quite a while.

Our next problem was an embedded building without fluid, and then we looked at, for our third problem, that same building but with fluid added. And then our -- lastly, our fourth problem was in SMR reactor building with soil-structure-fluid interaction.

And in the problems we looked at a variety of results. For example, transfer function, time histories, and responses. Member design forces where applicable fluid pressure, time histories, and offset, really, a number of other aspects.

And, really, in all cases we saw excellent comparisons in the results. And so our conclusion and what we showed in the report is that we provided a means to say that ANSYS and the soil library solution

really are functionally equivalent to what we would see in a SASSI solution.

So that really concludes the technical slides that I have to present. I'll pause here and see if there is any questions.

MEMBER RICCARDELLA: Anybody on the -- any members have any questions for NuScale?

MEMBER KIRCHNER: Pete, this is Walt. I'll just raise one.

Let's see. Josh, when do you know for the application to the actual NuScale power plant when you would -- because of the large mass involved, when -- and I guess this would be site-dependent, how do you estimate when you would get to slip and -- of the foundation? And then you wouldn't be in the linear elastic domain at that point.

Is there some rule of thumb? And when you use your new, improved method, do you have to -- for the large size of the reactor building envisioned, do you have to do more of the halfspace modeling? In other words, do you need more, you know, larger nodalization of the site and --

MR. PARKER: Yeah. So that's a good question.

MEMBER KIRCHNER: That was several

questions wrapped in one.

MR. PARKER: Yeah. Two questions. So, one, you asked about slip, which I assume you mean sliding. That has to do with building stability. So we will do those checks, just like we did in the design certification portion. So we'll check sliding over turning.

There are standard review plan criteria for performing those types of analysis, and we'll follow that in the same way using this approach as we would using our previous approach. That actually doesn't change.

And then you asked about nodalization of the halfspace, and that also really doesn't change with this approach. The halfspace isn't nodalized, our interface boundaries between the backfill and the halfspace, and we will create -- there is layers of soil that we model up from the surface down to the bottom of the building elevation and then below. And that approach, it stays the same with this or what it would be with any other approach.

MEMBER KIRCHNER: Yeah. But for your particular application for the NuScale reactor building with the 12 modules filled with water, do you have to use more soil layers because of the size of

the building and the mass compared to, say, a PWR?

MR. PARKER: Well, so there again, there are typical equations and rules of thumb having to do with the shear wave velocity, and the overall depth to come up with the layer thickness that should -- we should have. And so that really doesn't have to do with the size of the excavation. It really has to do more with the soil itself and the layerization of the soil.

MEMBER KIRCHNER: Doesn't the fact that you are dealing with a lot larger structure and mass also -- isn't there some coupling there in terms of how you would nodalize the soil layers? Or you --

MR. PARKER: I mean, we want to have, you know, obviously a reasonable number of layers, given our excavation. But the number of layers has to do, like I said, with shear wave velocity and less to do with the total excavation.

MEMBER KIRCHNER: Okay. All right. Thank you.

MEMBER RICCARDELLA: Are there any other comments or questions?

Okay. So, with that, we will move into the NRC --

MR. PARKER: Actually, we've got a couple

more slides.

MEMBER RICCARDELLA: Okay.

MR. PARKER: I'll turn it back to Kyra.

MEMBER RICCARDELLA: Okay. I'm sorry. Go ahead, Kyra.

MS. PERKINS: Yes. Can you hear me okay?

MEMBER RICCARDELLA: Yes.

MS. PERKINS: I switched to my phone.

MEMBER RICCARDELLA: Yes. We hear you fine.

MS. PERKINS: Okay. Great. Okay. So during the topical report review, the NRC requested, through RAI 9676, NuScale to include additional demonstration problems, which would be representative of more complex SMR structures.

So, as Josh discussed, the fourth example was added to the report to include a representative reactor building with soil-structure-fluid interaction.

There is also a subsequent audit where the NRC requested supplemental discussion of the software verification and validation process. Revision 2 of the report was submitted in September, to include an augmented discussion of the V&V.

MEMBER KIRCHNER: Pete, if I may, one

further questions.

MEMBER RICCARDELLA: Go ahead.

MEMBER KIRCHNER: Yeah. Either Kyra or Josh, could you just describe, since we're in open session, how you treat sloshing in the pool and what that effect might be in your sample problem?

MR. PARKER: Sure. I can take that, Kyra, if you want. So we didn't look at sloshing in the example problem. There would be -- the fluid elements were acoustic fluid elements, so they were looking at pressures.

But we would look at sloshing in a similar way as we did previously. You know, that would be a different analysis, and we could calculate a total wave height.

In our previous analysis, we saw pretty reasonable wave heights given our -- the arrangement of our building and the overall water depth. And I would expect those to be pretty similar for this approach also.

MEMBER RICCARDELLA: So you're saying that's --

MEMBER KIRCHNER: So for the public, you have enough -- I'm going to use a nautical term -- enough freeboard in your pool, so that the wave height

from sloshing is well below the top of the pool.

MR. PARKER: That's right. Yep. That's exactly right.

MEMBER KIRCHNER: I didn't say that right, but the lip of the reactor pool.

MR. PARKER: That's exactly right. Yep.

MEMBER RICCARDELLA: And I think what you're saying, Josh, is that that evaluation is independent of whether you use the original multi-step process versus this new, improved process, correct?

MR. PARKER: Exactly right.

MEMBER RICCARDELLA: Okay. So, Kyra, did you have another slide?

MS. PERKINS: Yes. One more slide, summary slide, then we're done.

So the presentation summarized the current methodologies and that it provides an accurate and conservative evaluation of the seismic loads and demand, and a proposed methodology that utilizes a one-step analysis that is functionally equivalent and computationally more efficient.

And the NRC has reviewed the topical report, and approval is documented by the safety evaluation.

So that concludes the presentation. Thank

you.

MEMBER RICCARDELLA: Okay. Thank you.

Are there any further comments or questions for NuScale?

Okay. Well, with that, then we will next proceed to the staff presentation, which I believe is Dr. Sunwoo Park.

DR. PARK: Yes. I put up my slide. I believe, first, our project manager will give a preface. Bill?

MEMBER RICCARDELLA: Okay.

MR. WARD: Yes. I just want to thank the full committee for hearing the slides. I know we presented this a week or so ago. It's a scaled-down version, and nothing new in here, so thank you again.

DR. PARK: Okay.

MEMBER RICCARDELLA: Looks good, Sunwoo.

DR. PARK: All right. Okay. With that, I am Sunwoo Park, a member of the staff with the Office of Nuclear Reactor Regulation. And I am glad and it is my privilege to be able to support the committee today.

First, I would like to give you a brief introduction. Excuse me. I'm sorry, I guess I hit the wrong button. Let me see. I guess I have to

start over.

Can you see my slide?

MEMBER RICCARDELLA: Yes, we see it fine.

DR. PARK: All right. Thank you.

Yeah. A brief introduction to what the applicant proposed in the technical report -- topical report and what the staff found.

Okay. First of all, the earthquake-induced seismic loads are a major contributor to the design loads for nuclear power plant structures, systems, and components, and the effects of soil-structure-fluid interaction, should they be considered in establishing the seismic loads.

This topical report describes an improved methodology for frequency domain analysis of nuclear power plant SSCs, where the structures -- soil-structure-fluid interactive behaviors during an earthquake. Here I would like to emphasize that these interactive behaviors occur due to the dynamic interaction between these different -- the entities during the earthquake.

And the methodology provides a tool for a nuclear power plant licensee or applicant to calculate the load demands for seismic design and the qualification of SSCs.

I am going to pause a couple of seconds between slides for any questions and also give the system time to transmit slides.

NRC regulations require that structures, systems, and components important to safety must be designed to withstand the effects of natural phenomena, and we are going to focus on, again, earthquakes effect here.

So Appendix S to Part 50 requires that safety functions of SSCs are subjected to earthquake ground motion, must be assured during and -- actually, during and after the earthquake through design, testing, and qualification methods.

And also, it specifically requires that evaluation must take into account soil-structure interaction effects. And, of course, we are focusing here on the soil-structure-fluid interaction, and the staff views that soil-structure-fluid interaction is an extension of a soil-structure interaction.

So, therefore, soil-structure-fluid interaction effects should be considered in compliance with the regulation.

As the guidance, NUREG-0800, SRP Section 3.7.2 provides the guidance and acceptance criteria for the types of analysis covered by this topical

report.

Proposed methodologies -- methodology in the technical report -- topical report consists of three substructures. Okay. The elements of applicant's proposed methodology consists of the soil structures representing interacting entities involved in the analysis, which are soil substructure, building substructure, and fluid substructure.

And these substructures collectively represent a couple soil-structure-fluid interactive system, analyzed for a prescribed earthquake random motion.

And the different substructures representing different site soil, as well as seismic conditions, can be created and stored in the soil library, which is a new, novel concept that the applicant came up with and they utilized in developing this topical report.

And then that integrated analysis can be performed for each different soil substructure without impacting the other substructures, which included building substructure and fluid substructure, and also it may include other documented substructures if they are present in the model.

We are on Slide 6.

Staff reviewed different components of the methodology, and I would like to share staff findings for them.

The first is staff reviewed the information concerning applicant's solution workflow for frequency domain, soil-structure-fluid interaction analysis, and we find them acceptable because, one, the soil-structure interaction parameters, which are contained in the soil library, are basically derived within the framework of the established and accepted SASSI methodology.

So they just utilized the available analytical models and also the theoretical -- the bases that are established as part of the assessment methodology. So the concept of a soil library is acceptable based on that.

And the building and the fluid substructures and the fluid-structure interaction parameters are analytically modeled using the ANSYS structure and acoustic elements, which have been scrutinized and used by the engineering community for decades. And the staff believes that they can be accepted without any further validation.

And the modeling and analytical procedures used in the proposed workflow conform to the

guidelines of SRP Section 3.7.2, which I believe provides the most relevant basis for staff's findings.

And, finally, the adequacy of the solution workflow is further supported by the example problems presented in the topical report.

Staff reviewed the information concerning enhanced solution features, which are developed by the applicant and applied to their proposed methodology, and the staff finds them acceptable because all of the mathematical operations involved in developing those enhanced features conform to the established and accepted mathematical principles.

And also, equations and the parameters used in the enhanced features, they are all consistent with the established principles of dynamics of structures, and the dynamics of fluids, and they are interactive behaviors as well.

And, further, the validity of the enhanced features is demonstrated through example problems provided in the topical report.

Staff reviewed example problems and their results and found the following. Results from example problems support the adequacy of the proposed soil library approach described in the soil-structure-fluid interaction problem.

The staff identified and verified good agreement between results from ANSYS and SASSI, which demonstrate that -- which support the validity of the proposed workflow and the enhanced solution features.

Specifically, staff focused on the comparison of results from the traditional SASSI analysis, which is -- which has been the baseline analysis methodology used in the nuclear industry for many decades, and the results from this proposed methodology by NuScale.

And staff confirmed that there is good agreement between those two approaches, you know, which again they support the validity of the soil library concept and approach.

So staff concludes that the example problems in the topical report provides evidence that the proposed frequency domain, soil-structure-fluid interaction analysis methodology, is adequate.

Staff identified the need for limitations and the conditions that need to be placed in the staff's safety evaluation. I believe I -- there was detailed discussion during the subcommittee meeting concerning this matter, and I think it's appropriate for the staff to remind the committee of this -- of these limitations on the conditions.

The NRC staff's approval of this topical report is limited to the proposed analysis methodology applied to problems that satisfy the assumptions set forth by the applicant in Section 3 of this topical report. Specifically, that, one, all material properties are inelastic during the analysis; two, the behavior of boundary conditions and the constraints is linear; and, three, the seismic load is represented by vertically propagating shear and compressible waves.

So a licensee or applicant who intends to apply the analysis methodology approved in the safety evaluation to a site-specific problem must consider the applicability of these limitations to their specific conditions. And then NRC staff will verify that each of these conditions has been satisfied in its review of site-specific application, probably in the context of combined license application that represents NuScale design certification.

So, in conclusion, based on its review of the topical report, the NRC staff concludes that, subject to the limitations and the conditions addressed in the previous slide, as specified, or as also specified in the Section 6.0 of the safety evaluation, the frequency domain analysis methodology described in this topical report is acceptable to

perform seismic soil-structure-fluid interaction analysis to establish seismic demands for the seismic qualification of structures, systems, and components, in accordance with the guidance and SRP 3.7.2, so, therefore, in compliance with the applicable regulatory requirements as delineated in Section 2.0 of the safety evaluation.

I guess that is all I have today.

MEMBER RICCARDELLA: So do any members have any further questions or comments for the staff?

MEMBER KIRCHNER: Pete, this is Walt. Yes, just one observation, maybe it's a question.

Sunwoo, the limitations and conditions on this new methodology, those also apply to previous methodologies; isn't that correct? In other words, the more laborious coupling by hand, SASSI and ANSYS?

DR. PARK: Yeah, that's correct. Those limitations and assumptions that the applicant included in the topical report are not new in the seismic soil-structure interaction analysis of a nuclear power plant.

MEMBER KIRCHNER: That's my point. Those are pretty generic limitations and conditions on almost any seismic structure, soils-structure interaction calculations.

DR. PARK: Yes. But --

MEMBER KIRCHNER: A linear --

DR. PARK: -- you have -- yes. Sorry. Yeah. If I may add a comment on that. We all know that the SASSI, I believe most of the cognizant staff or engineers in this area recognize the limitations of established SASSI methodology, which is applicable to frequency domain linear analysis.

Now, the applicant expanded -- in a sense expanded that to ANSYS platform, and we all -- engineers know that ANSYS is much more versatile and capable software, which can handle not only elastic but also inelastic and non-linear, all different kinds of linear, the situations ANSYS can handle.

Now, I believe it was prudent that staff place those limitations and conditions in staff's safety evaluation to provide awareness to potential users of this methodology that this methodology is working for linear problem only, because, again, ANSYS can handle linear problems, but this particular one is based upon the linear -- within the linear, you know, scope.

The reason, if I can, you know, share with you a little bit more about the technical background of such limitation, is that this methodology depends

on SASSI in developing soil library parameters, which include soil impedance matrices and seismic load vectors. They are developed within SASSI, which is, again, you know, confined to linear elastic analysis.

And then those SASSI soil library parameters are transported or exported to ANSYS, and then use the ANSYS features and, you know, but still you need to stay within the linear limitation because of that.

And also, the frequency domain analysis is for the -- assess the limitation for linear elastic analysis because of frequency analysis implicitly has shown that it is based upon the concept of superposition, which works only for linear problems.

So, for those reasons, staff believes that it was prudent to place those limitations and conditions.

Now, on a practical level, staff does not expect that there will be actual impediments for the applicant or licensee to use this method because they can follow the guidance in SRP 3.7.2, and then they can come up with equivalent linear elastic properties. In other words, they linearize -- appropriately linearize the inelastic or non-linear conditions.

I hope that helps.

MEMBER RICCARDELLA: Thank you. Are there any other comments or questions?

Okay. So, with that, we should open the bridge line to see if there are any comments from the public. Could we do that, please?

(Pause.)

MEMBER RICCARDELLA: Will somebody from staff confirm that the bridge line is open?

MR. MOORE: Thomas, this is Scott. Can you confirm that the bridge line is open, please?

MR. DASHIELL: Affirmative, Scott. The bridge line is open.

MEMBER RICCARDELLA: So I am asking, is there anybody from the public on the bridge line that would like to make a comment on this topical report methodology?

MR. DASHIELL: The public line is open for comment.

MEMBER RICCARDELLA: I don't hear any comments. And so, with that, I believe we can close the bridge line and proceed with our deliberations.

Matt, how do we want to proceed from here?

CHAIRMAN SUNSERI: So we have quite a bit of time. I think, if Sandra is ready, we can pull up the letter report. I know it has been screened for

proprietary information already, and it can be placed in the public. And then we can start with a read-through of that.

MEMBER RICCARDELLA: Okay.

CHAIRMAN SUNSERI: If everyone is agreeable.

MEMBER RICCARDELLA: Works for me.

CHAIRMAN SUNSERI: So we can do that, and just for -- to close out this part of the session, then, this -- the NuScale topical report presentations are complete at this point in time. And we will secure the transcript at this point in time, and we'll transition into letter-writing as soon as Sandra can get the draft report up.

And we'll resume -- the transcript will resume tomorrow, so we will be done today with that.

(Whereupon, the above-entitled matter went off the record at 12:18 p.m.)

October 5, 2020 Docket No. 99902078

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Submittal of Presentation Materials Entitled "ACRS Full Committee Presentation: NuScale Topical Report - Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis," PM-0920-71956, 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 October 8, 2020. The materials support NuScale's presentation of the improvements in frequency domain soil-structure-fluid interaction analysis.

The enclosure to this letter is the nonproprietary presentation entitled "ACRS Full Committee Presentation: NuScale Topical Report - Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis," PM-0920-71956, Revision 0.

This letter makes no regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions, please contact Kyra Perkins at 704-713-5220 or at kperkins@nuscalepower.com.

Sincerely,

Zackary W. Rad
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Enclosure: "ACRS Full Committee Presentation: NuScale Topical Report - Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis," PM-0920-71956, Revision 0

Enclosure:

"ACRS Full Committee Presentation: NuScale Topical Report - Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis," PM-0920-71956, Revision 0

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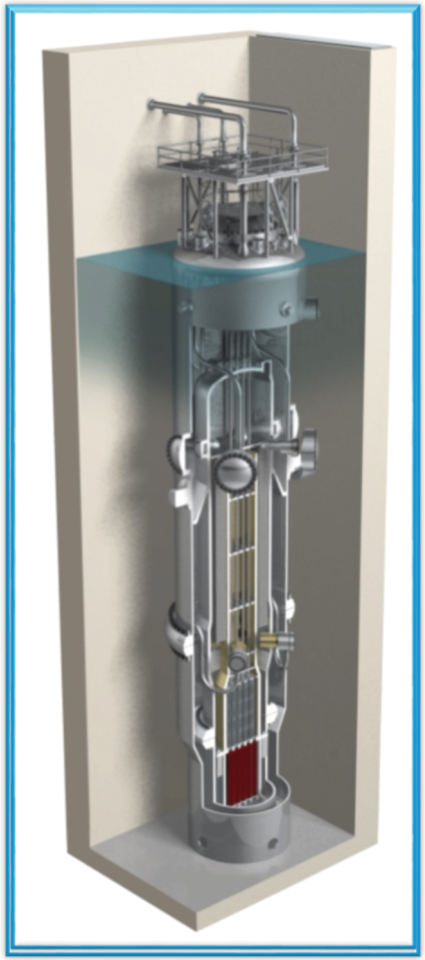
ACRS Full Committee Presentation



NuScale Topical Report

Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis

October 8, 2020

PM-0920-71956
Revision: 0

Template #: 0000-21727-F01 R6

Presenters

Josh Parker
Supervisor, Civil/Structural

Kyra Perkins
Licensing Project Manager

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Agenda

- Purpose
- Applications
- Features of Methodology
- Soil Library Methodology
- Topical Report Demonstration Problems
- Topical Report Review
- Summary

Purpose

- The Frequency Domain Soil-Structure-Fluid Interaction Analysis topical report (Soil Library TR) describes a more efficient process, for use by an applicant or licensee, to perform seismic analyses of complex, interacting structures, soils, fluid systems, and major mechanical components.
- Today's presentation is a higher-level summary of the NuScale topical report. A detailed presentation of this TR was provided in the ACRS Subcommittee meeting of September 22, 2020.
  - NuScale presentation materials for the Subcommittee meeting are available by ML-20262H288

Applications

- Analysis of future Design Certification Applications and Standard Design Approval Applications
- Site Specific Combined License (COL) Analyses
  - Site specific soil library generation for Combined Licenses
  - Evaluation of adequacy of NuScale design as specified in existing COL Items using proposed methodology

Features of the Soil Library Methodology

- Eliminates assumptions at the interfaces between the civil structural and substructure analyses (single model vs. seven different models)
- Single larger model can be used for seismic and nonseismic loading
- Major improvement in runtimes to generate analysis results
- Simpler method
- Facilitates parametric studies for alternate module configurations (any number of module in any location)
- Uses latest finite element technologies and improvements
- Provides additional element formulations that are not in older codes such as SASSI

Soil Library Methodology

- Eliminates two-step analysis process
  - Analysis using single structural model of building, backfill, pool water, and individual power modules
  - Simplifies data exchange and interfacing analyses
- Analysis time shorter by order of magnitude
- Takes full advantage of structural analysis capabilities of ANSYS
  - Overcomes limitations of SASSI structural model size and mesh refinement

Soil Library Methodology

- Proposed methodology in Topical Report
  - Use of a SASSI calculated impedance library
  - No change to seismic inputs and soil properties.
  - Revision to the basic assumptions and methodology for SSI analysis
    - Uses SASSI direct method versus modified subtraction method
  - The replacement of the SASSI building model with an integrated ANSYS model, and using the ANSYS solver
  - Dynamic analysis for SSI is functionally the same as SASSI

Soil Library Methodology

- Dynamic Analysis performed in the frequency domain
  - Soil impedance from SASSI + ANSYS structural model + ANSYS equation solver and post-processing
- Validated using example problems
  - Demonstrates equivalent results from traditional SASSI versus the library method
- Methodology assumes linear elastic or equivalent linear-elastic analysis
  - This applies to both soil and structural properties, constraints, and boundary conditions
- Uses one-step dynamic analysis for SSFI of buildings, NPMs, and pool water
  - Saving of overall analysis calendar time
  - Seismic analysis methods of secondary SSCs and fuel unchanged

Topical Report Demonstration Problems

- Compared ANSYS and SASSI results
  - 1. PWR on surface of halfspace
  - 2. Embedded Building w/o fluid
  - 3. Embedded Building with fluid
  - 4. Representative Reactor Building with Soil-Structure-Fluid Interaction
- Conclusions
  - Excellent results comparisons
    - Transfer functions
    - Acceleration time histories and response spectra
    - Structural member design forces
    - Acoustic (fluid) pressure time histories
  - ANSYS + Soil Library solution is functionally equivalent to a SASSI solution

Topical Report Review

- NRC Request for Additional Information (RAI) 9676 requested the inclusion of additional demonstration problems representative of more complex SMR structures
  - RAI 9676 response provided June 17, 2019
  - Topical Report Revision 1 submitted November 19, 2019 incorporated RAI 9676 responses (ML19168A249)
- Subsequent NRC audit requested supplemental discussion of software Verification and Validation process
  - Topical Report Revision 2 submitted September 2, 2020 augmented the V&V discussion

Summary

- Current methodology provides an accurate and conservative evaluation of seismic loads/demand
- Proposed methodology utilizes a one step analysis that is functionally equivalent and computationally more efficient
- NRC review and approval documented by safety evaluation

Acronyms

ACRS – Advisory Committee on Reactor Safeguards

ANSYS – Analysis Simulation software

COL – Combined License

DCA – Design Certification Application

NPM – NuScale Power Module

PWR – Pressurized Water Reactor

SASSI – Analysis Software for Soil-Structure Interaction finite element analysis

SDA – Standard Design Application

SMR – Small Modular Reactor

SSFI – Soil Structure Fluid Interaction

SSI – Soil Structure Interaction

TR – Topical Report

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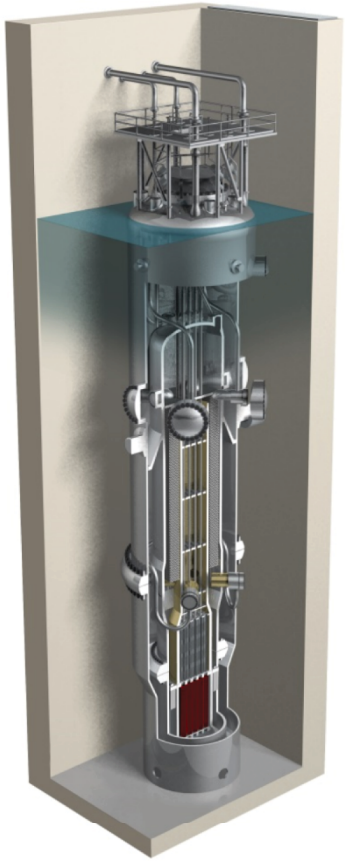

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Staff Presentation to the ACRS Full Committee

NuScale Topical Report, "Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis" (TR-0118-58005)

OCTOBER 8, 2020

Staff

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- William Ward, P.E., Senior Project Manager, Division of New and Renewed Licenses, NRR

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Introduction

- Earthquake-induced seismic loads are a major contributor to the design loads for Nuclear Power Plant (NPP) structures, systems, and components (SSCs) and the effects of soil-structure-fluid interaction should be considered in establishing the seismic loads.
- This Topical Report (TR) describes an improved methodology for frequency-domain analysis of NPP SSCs with coupled soil-structure-fluid interactive behaviors during an earthquake.
- The methodology provides an enhanced tool for an NPP licensee or applicant to calculate the load demands for seismic design and qualification of SSCs.

Regulatory Basis

Regulations

- 10 CFR Part 50, Appendix A, GDC 2: SSCs important to safety must be designed to withstand the effects of natural phenomena such as earthquakes.
- 10 CFR Part 50, Appendix S: Safety functions of SSCs subject to earthquake ground motion must be assured through design, testing, or qualification methods and the evaluation must take into account soil-structure interaction effects.

Guidance

- NUREG-0800, SRP Section 3.7.2, Seismic System Analysis

Proposed Methodology

- The elements of the applicant's proposed methodology consist of substructures representing interacting entities involved in the analysis – the soil substructure, building substructure, and fluid substructure.
- These substructures collectively represent a coupled soil-structure-fluid interactive system analyzed for a prescribed earthquake ground motion.
- Different soil substructures, representing different site soil and seismic conditions, can be created and stored in the Soil Library, and an integrated analysis can be performed for each different soil substructure without impacting the other substructures.

Staff Review: Solution Workflow

NRC staff reviewed the information on the applicant's solution workflow for frequency-domain soil-structure-fluid interaction analysis and finds them acceptable because:

1. The soil-structure interaction parameters contained in the Soil Library are derived within the framework of the established SASSI methodology;
2. The building and fluid substructures and the fluid-structure interaction parameters are analytically modeled using the established ANSYS structural and acoustic elements;
3. Modeling and analytical procedures used in the proposed workflow conform to the guidelines of NUREG-0800, SRP Section 3.7.2; and
4. Adequacy of the solution workflow is supported by the example problems presented in the TR.

Staff Review: Enhanced Solution Features

NRC staff reviewed the information on the applicant's enhanced solution features developed and applied to the proposed methodology and finds them acceptable because:

1. Mathematical operations involved in developing the enhanced features conform to the established mathematical principles;
2. Equations and parameters used in the enhanced features are consistent with the established principles of dynamics of structures and fluids; and
3. The validity of the enhanced features is demonstrated through example problems provided in the TR.

Staff Review: Example Problems

NRC staff reviewed the Example Problems and their results provided in the TR and found the following:

1. Staff observed that results from Example Problems support the adequacy of the proposed Soil Library approach to solving the soil-structure-fluid interaction problem.
2. Staff identified good agreement between results from ANSYS and SASSI, which support the validity of the proposed workflow and enhanced solution features.
3. Staff concludes that the example problems in the TR provide an evidence that the proposed frequency-domain soil-structure-fluid interaction analysis methodology is adequate.

Limitations and Conditions

NRC staff's approval of this TR is limited to the proposed analysis methodology applied to problems that satisfy the assumptions set forth by the applicant in Section 3 of this TR, specifically, that: (1) all material properties are linear-elastic during the analysis, (2) the behavior of boundary conditions and constraints is linear, and (3) the seismic load is represented by vertically propagating shear and compression waves. A licensee or applicant who applies the analysis methodology approved in the NRC staff's Safety Evaluation (SE) to a site-specific problem must consider the applicability of these limitations to the site-specific conditions, and the NRC staff will verify that each of these conditions has been satisfied in its review of a site-specific application.

Conclusions

Based on its review of the TR, the NRC staff concludes that, subject to the limitations and conditions as specified in Section 6.0 of staff's SE, the frequency-domain analysis methodology described in this TR is acceptable to perform seismic soil-structure-fluid interaction analysis to establish seismic demands for the seismic qualification of structures, systems, and components, in accordance with the guidance in NUREG-0800, SRP Section 3.7.2, and thus in compliance with the applicable regulatory requirements delineated in Section 2.0 of staff's SE.

Abbreviations

ANSYS	An Analysis Software
ASCE	American Society of Civil Engineers
FSI	Fluid-Structure Interaction
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
RAI	Request for Additional Information
SASSI	A System for Analysis of Soil-Structure Interaction
SDE	Structural Dynamics Engineering
SE	Safety Evaluation
SMR	Small Modular Reactor
SRP	Standard Review Plan
SSC	Structure, System, and Component
SSI	Soil-Structure Interaction
SSFI	Soil-Structure-Fluid Interaction
TR	Topical Report

Questions?

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Protecting People and the Environment

NRC EVALUATION OF GALILEO CODE AND METHODOLOGY TOPICAL REPORT ANP-10323 REVISION 1

OPEN SESSION

Mathew Panicker Ph.D., P.E.
Nuclear Methods and Fuel Analysis Branch
NRR/DSS/SFNB
ACRS Full Committee Meeting
October 8, 2020

Review of GALILEO Fuel Rod Thermal-Mechanical Code and Methods

- Realistic evaluation of the thermal-mechanical performance of fuel rods for Pressurized Water Reactors (PWRs).
  - Applicable to PWR Fuels
  - UO_2, burnable absorbers
  - Zircaloy-4, M5
  - Methodology provided for all thermal-mechanical analyses

- Review focus
  - GALILEO Code
    - Assessment of individual models
    - Assessment of integral code predictions
  - GALILEO Methodology
    - Assessment of proposed uncertainties
    - Assessment of statistical methodology
    - Assessment of fuel damage limits

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Overview and History

- Revision 0 of ANP-10323 (GALILEO) submitted in October 2013
- Acceptance review was performed by NRC staff, March 2014
- PNNL staff supported the technical review under contract NRC-HQ-20-14-T-0009 under technical supervision of NRC staff
- Upon review, over 70 RAIs (including sub-parts) were issued
- AREVA revised the scope of TR, suspended BWR and MOX fuels, November 2015
- Framatome submitted ANP-10323 Revision 1 for PWR fuels June 2018 (Applicable to PWR fuel, UO_2 and UO_2-Gd_2O_3
- Framatome responded to RAIs in five installments; 12/18, 1/19, 6/19, 9/19,, 5/20, and 7/20
- Confirmatory calculations were performed using the NRC's FRAPCON fuel performance code for comparison to GALILEO

Areas Covered in GALILEO

- GALILEO is Built upon NRC-approved COPERNIC and German TUV approved CARO-3
  - Thermal model and assessment
  - Fission gas release (FGR) model and its impact on internal pressure (RIP) model
  - Cladding corrosion and hydriding model
  - Cladding hydrogen pickup
  - Fuel densification and swelling model
  - Mechanical modeling and properties; Fuel Mechanical properties
  - Rod void volume model and growth assessment
  - Licensing applications
  - Improved statistical approach
  - 99.9%/95% or better approach for uncertainty calculations
  - Code applicability

Regulatory Evaluation

- GDC 10: SAFDLs not exceeded during NO and AOOs
- GDC 35: Provide emergency core cooling following LOCA
- 10 CFR 50.46 Acceptance criteria for ECCS
- 10 CFR 50.34 Analysis and evaluation of design and performance of structures, systems, and components
- SRP 4.2: No damage to fuel during NO and AOOs
  - Fuel damage not severe to prevent control rod insertion
  - Number of fuel rod failures not underestimated for PAs
  - Core coolability is maintained
- Compliance with SRP 15.02; documentation, code verification and validation, evaluation model, uncertainty analysis included

Conclusions in SE

- NRC finds GALILEO code and methodology as described in ANP-10323P Revision 1 and modified as discussed in RAI responses to be acceptable
- Several limitations and conditions were stated regarding applicability range, methodologies that are not approved, and documentation

Acronyms

AOO - Anticipated Operational Occurrences

BWR - Boiling Water Reactor

ECCS - Emergency Core Cooling Systems

LOCA – Loss of Coolant Accident

MOX - Mixed Oxide

NO – Normal Operations

PNNL – Pacific Northwest National Laboratory

RAI – Request for Additional Information

SAFDLs - Specified Acceptable Fuel Design Limits

SRP – Standard Review Plan

UO_2 - Uranium Dioxide

UO_2-Gd_2O_3 - Urania-Gadolinia

ACRS Full Committee Meeting
Topical Report ANP-10323P GALILEO

Chris Allison

October 8, 2020

Background

- Development of GALILEO initiated to consolidate Framatome's worldwide expertise and experience into a single fuel performance code
- Builds upon the best practices and techniques from Framatome's current generation of fuel performance codes and methods, including:
  - COPERNIC (France and US)
  - RODEX4 (US)
  - CARO-3E (Germany)
- Originally developed to support PWR and BWR applications for UO_2, gadolinia, and MOX fuels
- Revised Topical Report requested NRC approval for
  - PWR applications
  - UO_2 and gadolinia fuel types
  - M5 and Zr-4 cladding

Overview of Topical Report

- Describes a methodology for the realistic evaluation of the thermal-mechanical performance of fuel rods for PWR applications
- The methodology is for demonstrating compliance with many of the fuel rod requirements of Section 4.2 of NUREG-0800
- Two major components:
  - GALILEO fuel performance code
  - Statistical evaluation methodology
- Topical report describes the following aspects
  - Requirements and capabilities
  - GALILEO calibration, validation, and range of parameters
  - Uncertainty analyses
  - Demonstration analyses

Advanced Methods Platform

- GALILEO is a foundational piece in Framatome's platform of advanced technologies and methods, including
  - PWR Rod Ejection Accident (REA) analysis – NRC approved methodology
    - Supports RG 1.236
  - Non-LOCA transient analysis – in NRC review
  - LOCA analysis methods – future submittal
  - Advanced Fuel Management (AFM) – future submittal(s)
    - Increased burnup
    - Higher enrichment
  - Enhanced Accident Tolerant Fuel (EATF) – future submittal(s)

Acronyms

ACRS – Advisory Committee on Reactor Safeguards

AFM – Advanced Fuel Management

BWR – Boiling Water Reactor

EATF – Enhanced Accident Tolerant Fuel

LOCA – Loss of Coolant Accident

MOX – Mixed Oxide

NRC – Nuclear Regulatory Commission

PWR – Pressurized Water Reactor

REA – Rod Ejection Accident

RG – Regulatory Guide

Trademarks

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Thank you