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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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NUSCALE SUBCOMMITTEE

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OPEN SESSION

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FRIDAY

AUGUST 24, 2018

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ROCKVILLE, MARYLAND

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

COMMITTEE MEMBERS:

WALTER L. KIRCHNER, Chairman

RONALD G. BALLINGER, Member

DENNIS C. BLEY, Member

CHARLES H. BROWN, JR. Member

MICHAEL L. CORRADINI, Member

JOSE MARCH-LEUBA, Member

JOY L. REMPE, Member

GORDON R. SKILLMAN, Member

MATTHEW SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

MICHAEL SNODDERLY

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

P R O C E E D I N G S

8:33 a.m.

CHAIRMAN KIRCHNER: The meeting will come to order. This is a meeting of the Advisory Committee on Reactors Safeguards, NuScale Subcommittee. I am Walt Kirchner, Chairman for today's Subcommittee meeting.

Members in attendance today are Ron Ballinger, Dennis, Bley, Gordon Skillman, Matt Sunseri, Mike Corradini, Joy Rempe, Jose March-Leuba, Charlie Brown. And Mike Snodderly is the Designated Federal Official for this meeting. Thank you, Mike.

The Subcommittee will review the staff's evaluation of Revision 1 to NuScale's topical report, TR-0915-17564P, subchannel analysis methodology. Today we have members of the NRC staff and NuScale to brief the Subcommittee.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, FACA. That means that the Committee can only speak through its published letter reports. We hold meetings to gather information to support our deliberations. Interested parties who wish to provide comments can contact our office requesting time after the meeting announcement is published in the Federal Register.

That said, we've set aside ten minutes for comments from members of the public attending or listening to our meetings. Written comments are also welcome.

The ACRS section of the US NRC public website provides our charter, bylaws, letter reports, and full transcripts of all full and subcommittee meetings, including slides presented there. The rules for participation in today's meeting were announced in the Federal Register on August 13, 2018.

The meeting was announced as an open/closed meeting. We plan to close the meeting after the open portion to discuss proprietary material, and presenters can defer questions that should not be answered in the public session to that time. No written statement or request for making an oral statement to the Subcommittee has been received from the public concerning this meeting.

A transcript of the meeting is being kept and will be made available, as stated in the Federal Register notice. Therefore, we request that the participants in this meeting use the microphones located throughout the meeting room when addressing the Subcommittee. Participants should first identify themselves and speak with sufficient clarity and

volume so that they can be readily heard.

We have a bridge line established for the public to listen in to the meeting. To minimize disturbance, the public line will be kept in a listen-in only mode. To avoid disturbance, I further request that attendees put their electronic devices like cellphones in the off or noise-free mode.

We'll now proceed with the meeting. And shall I turn to NuScale first or the staff?

MEMBER SUNSERI: To Paul.

CHAIRMAN KIRCHNER: Okay, Paul, would you please begin. Paul Infanger from NuScale.

MR. INFANGER: I'm Paul Infanger, I'm Licensing Project Manager for Chapters 4 and 15, which includes the Subchannel Topical Report. I've been with NuScale for about three and a half years. Prior to that, I worked on the Barakah Plant with the Koreans.

And then before that, I was with UniStar new plants with Calvert Cliffs COLA. And before that I was licensing manager at a number of operating plants for about 25 years.

My background, I went to Ohio State University. I have degrees in physics and a master's in nuclear engineering. And appreciate the

opportunity today to present technical information in support of the staff. This is the third topical report related to our core methodologies. So we had the nuclear codes and methods and the CHF palpables last month.

And so we'll have some presenters here today. Immediately to my left is our lead presenter, is Ken Rooks.

MR. ROOKS: My name is Ken Rooks, I've been with NuScale for four and a half years in the Core TH Group within the nuclear fuels organization. Prior to NuScale, I was with AREVA, or former AREVA, now Framatome, for four and a half years in their fuels T/H organization. And prior to that I was graduated from NC State in nuclear engineering.

MS. CALLAWAY: My name's Allyson Callaway, I'm the Nuclear Analysis Supervisor. I've been with NuScale doing nuclear analysis for the last eight years.

CHAIRMAN KIRCHNER: Do you have other NuScale people now on the line that you want to introduce, or at least confirm they're on?

MS. CALLAWAY: Sure. Kenny, Anderson, are you on the line?

MR. ANDERSON: Yes.

MS. CALLAWAY: Okay, and Kenny Anderson, who's also in the nuclear analysis field.

CHAIRMAN KIRCHNER: And what is Kenny's role in NuScale's operation?

MS. CALLWAY: Nuclear analysis and core thermohydraulics.

CHAIRMAN KIRCHNER: Thank you.

MR. ROOKS: All right, so Ken I will go ahead and get started with the presentation.

All right, so today we're going to cover in this session an overview of the topical report, an overview of the safety analysis process, and then a brief introduction to the NuScale SMR. Then we'll discuss the VIPRE subchannel T/H code, and then the additional qualification for NuScale conditions and the overall methodology approach.

The purpose of the Subchannel Analysis Topical Report is to obtain NRC approval to evaluate the NuScale core using the VIPRE computer code for steady state and transient analyses. We also illustrate NuScale's use of VIPRE and its compliance with the generic SER conditions. And also approval of the conservative methodology for licensing calculations.

So I understand we're --

MEMBER CORRADINI: If I might, whoever's on the line, you might want to mute it on your end. That may reduce the crackling.

MR. ROOKS: Okay. To understand the objective of subchannel analysis, I've kind of presented a simplified flow chart of the safety analysis process. The four components that generally make up the safety analysis processes are nuclear analysis, fuel performance, system transient analyses, and subchannel analysis.

The safety analysis uses the design for input and it's informed by testing, such as CHF. Today we're going to be mostly focused on subchannel analysis. As you can see, this portion's quite integrated, with a lot of input lines that are feeding into it. Nuclear analysis specifically is the core design, core physics provided inputs, which is a topic report that's nearing acceptance that you guys have seen.

Fuel performance already has an approved topic, which is the fuel thermal-mechanical methods. And system transient analyses are specifically the non-LOCA events for which the subchannel analyses are applicable for that provide thermohydraulic boundary conditions.

MEMBER REMPE: Are you, you mentioned that the neutronics analysis report has been reviewed. What about the system transient analysis? Are you planning to submit a report?

MR. ROOKS: That's a good question. It's in review currently. By the staff.

MEMBER REMPE: Okay.

MR. ROOKS: So as mentioned, we'll focus on the subchannel moving forward. The objective of the subchannel analysis is to evaluate margin to acceptance criteria. The specific criteria are SAFDLs, which are specified acceptable fuel design limits.

The fuel design limits evaluated using the methods in this topical report are critical heat flux and fuel center line melting, which correspond to the overheating of cladding and fuel pellets in the standard review plan of Chapter 4. Ultimately, the results of the subchannel analysis are used as inputs to the NuScale FSAR for Chapters 4 and 15.

So now a quick summary of the pertinent NuScale reactor conditions. As you know, the NuScale reactor is a natural circulation PWR, which implies the system flow changes with thermal power level, flow rates hydraulically driven by the density gradient

between the core and the steam generator.

This illustrates how NuScale is unique by not having pumped driven core flow, but it's also important to note that NuScale's not quite that different from a traditional PWR. Our core is operated to maintain the core average exit as subcooled. These subcooled exit quality conditions occur for normal conditions and all AOOs, for off-normal conditions.

These fluid conditions are very similar to traditional large PWRs. Our hot channel exit slightly saturating with an equilibrium quality greater than zero, but that's due to our conservative methodology that we're implemented.

MEMBER MARCH-LEUBA: Can you repeat that? Go back to the hot channel quality is greater than zero because?

MR. ROOKS: Because of our conservative methodology, the way we modeled --

MEMBER MARCH-LEUBA: So it really is not, you don't expect it to be greater than zero.

MR. ROOKS: That's correct.

MEMBER MARCH-LEUBA: But the calculations, because of your uncertainty, conservative assumptions.

MR. ROOKS: That's correct. So NuScale is

using the VIPRE-01 subchannel analysis tool, which was developed by EPRI. And it's maintained by Zachry. It's a finite volume code capable of determining three dimensional core flow and distribution for single and two-phase conditions.

It uses the three equation homogenous equilibrium model and has empirical models to incorporate it for simple boiling and void quality relationships.

From the picture you can see the flexibility in the discritization (phonetic) the VIPRE can handle, from modeling an entire core, which is 37 assemblies, all the way down to a single volume within the subchannel. VIPER-01 has a strong user and licensing base in the traditional PWR fleet.

MEMBER CORRADINI: Maybe it's a little bit off topic, but are you aware of the number of utilities that are using VIPRE as their subchannel analysis tool?

MR. ROOKS: I'm not sure of the total number, but I do know that Duke and Dominion are two large ones that use it.

MEMBER CORRADINI: I knew about Dominion, I didn't know about Duke. Okay, thank you.

MR. ROOKS: So as I mentioned, NuScale is

using the as-approved version of VIPRE, which is the common base used throughout the industry. We've made no changes to the main program, only incorporating NuScale proprietary CHF correlations through a dynamic link library.

VIPRE-01 is managed internally through NuScale's Appendix B software QA program. VIPRE has a generic SER that contains a list of several conditional criteria which NuScale has demonstrated compliance.

With NuScale using the generically approved version of VIPRE, the robust qualification performed by the original co-developers remains applicable. In addition, NuScale performed additional qualification to justify the applicability to NuScale core conditions.

The additional qualification consisted of code-to-code comparisons to a different NRC-approved code, additional experimental comparisons to experiments not in the original SER test suite, and then as well parametric and generalized sensitivity studies.

These three additional techniques provided a strong holistic basis that VIPRE was applicable for NuScale applications.

MEMBER BROWN: And we're going to see those in the closed session?

MR. ROOKS: That's correct.

MEMBER BROWN: Okay.

MR. ROOKS: The analysis methodology we've implemented is premised on the development of a conservative base model using bounding axial power shapes and general radial power distribution. We set the nodalization to accurately capture the hot channel local conditions for evaluating a conservative MCHFR.

The uncertainties on inputs are applied in a deterministic manner, meaning the biases are applied in a conservative direction. In addition, we have a detailed analyst-completed checklist that's performed on the analysis level that ensures the method was incorporated correctly and the results are acceptable.

So in summary, NuScale had developed a conservative subchannel analysis methodology for evaluating steady state and transient conditions. The topical report provides details about NuScale's use of VIPRE and its compliance with all SER conditions, as well as VIPRE's applicability to the NuScale design and a deterministic methodology for, with supplemented sensitivities.

The results using this NuScale subchannel

analysis methodology are used as inputs to the NuScale final safety analysis report for Chapters 4 and 15.

CHAIRMAN KIRCHNER: Since we're in the open session, can you just qualify what family of transients that you used this for versus what you would do the rest of Chapter 15 with?

MR. ROOKS: This would apply to heat-up events and cool-down events or control rod reactivity events. It's applicable to most NuScale Chapter 15 events, with the exception of LOCA.

CHAIRMAN KIRCHNER: Sure, okay, thank you.

MEMBER BROWN: So, okay, so if I reverse it, except for LOCA, it's not only just AOOs, but a number of the DBAs would be you'd be using VIPRE as part of your analysis?

MR. ROOKS: That's correct.

CHAIRMAN KIRCHNER: Okay, at this point then -- yeah, before we do, are there any questions here in the open session? Or I assume people are going to wait for the closed session.

MEMBER MARCH-LEUBA: You assume correctly.

CHAIRMAN KIRCHNER: Okay, yes, okay, Mike, let's bring up the staff then. Thank you.

Okay, now we'll turn to the staff. Bruce.

PARTICIPANT: I don't think your mic's on.

CHAIRMAN KIRCHNER: Just pull it closer, please.

MR. BAVOL: Good morning, my name is Bruce Bavol, I'm a project manager in the Office of New Reactors. Today's presentation from the NRC is on the subchannel analysis methodology. The NRC technical reviewers that are involved with this morning's presentation, the lead, Syed Haider, who's to my right.

Also, we have Matt Thomas, who's on the bridge line. Matt is currently on rotation as a resident inspector at Watts Bar. He's found some time to call in this morning, because Matt was a support in the review of this presentation, or this topical report.

And then to my left at the side desk, Tim Drzwiecki, also was a support with this review and is currently Acting Branch Chief and representing Reactors Systems Branch this morning.

First, I'd like to point out that your hard copy presentation has the first bullet there, it should be the subchannel analysis Revision 1, not the codes and methods. I changed it on a presentation. February 15, 2017, Revision 1 was submitted for review. In October of 2016, Revision 0 was submitted,

but the change from Rev 0 to Rev 1 was a proprietary update of information in the topical report. And so staff is working with Revision 1.

The request for additional information, there the following RAIs are listed there. They're mentioned within the safety evaluation, and the responses from NuScale are also, the ML numbers are also listed.

There is, I believe, one confirmatory item that we'll be looking for an update in Revision 2 of the document when we complete this process of going through ACRS.

We plan to go to full committee on September 6. And staff plans a final safety evaluation late October. And then the dash A we're scheduled for early 2019.

MEMBER MARCH-LEUBA: How is that going to work? Are we going to write a letter on a draft SER?

MEMBER CORRADINI: The intention is that we're, they're asking for a letter from us based on the documentation we have now.

MR. BAVOL: That's correct. So the updates to that, for confirmatory reasons, will be annotated in the safety evaluation as such. It'll just be --

MEMBER MARCH-LEUBA: As long as everybody's happy, I'm happy.

MEMBER CORRADINI: No, I think so far we've had topical reports that have all the open items closed. There have been confirmatory items.

MR. BAVOL: Right.

MEMBER CORRADINI: So we're in the same situation here.

MR. BAVOL: That's correct. Okay, I'd like to now turn it over to Syed to start the presentation. And just let me know when you want to shift your slides.

MR. HAIDER: Thank you, Bruce. Good morning, my name is Syed Haider. I'm the lead technical reviewer at NRO for the NuScale subchannel analysis methodology topical report, Revision 1, that was submitted in February 2017.

I would like to acknowledge the contributions made to the review by Matt Thomas, my colleague, who is also on the line, from the Reactor Systems Branch. And Joe Kelly from the Office of Research.

While Matt and I performed the topical reviews and wrote the respective SER sections, Joe performed all necessary VIPRE confirmatory analyses

that were needed to support the review. Last but not least, thanks to Bruce for handling all of our coordination with NuScale.

The staff conducted the review of the NuScale subchannel analysis methodology topical report per General Design Criterion 10 on reactor design from 10 CFR Part 50, Appendix A. The related regulatory guidance is stipulated in NuScale design specific standards, Sections 4.4 on thermal and hydraulic design and 10 CFR 53.4.

The NuScale subchannel analysis methodology uses the NRC approved VIPRE-01, dash the 01, subchannel thermal-hydraulic computer code, Version MOD-02, to conduct the NuScale fuel design subchannel safety analysis. The earlier VIPRE version MOD-01 was approved by the NRC is 1986, which the version MOD-02 that is used in the NuScale methodology was approved in 1993.

The NRC approvals of VIPRE-01 MOD-01 and MOD-02 code versions that were developed by EPRI are documented through their respective NRC generic safety evaluation reports. Note through the rest of the open and closed sessions I will be referring to the NuScale subchannel analysis methodology as an acronym, N-S-A-M, or NSAM.

This slide also lists the four elements of approval for the NuScale subchannel analysis methodology, or NSAM, that NuScale applied for in the topical report.

These four elements required the staff to focus on that VIPRE-01 code's applicability to the NuScale steady state and transient subchannel analyses; how the methodology fulfills the NRC's requirements, as specified in the generic SERs for VIPRE-01 MOD-01 and MOD-02 versions; whether the methodology is independent of any specific CHF correlations; and whether the methodology for treatment of uncertainties in the subchannel's methodology is also appropriate.

So the two generic SERs that document the NRC approval of VIPRE-01 versions MOD-01 and MOD-02 identify a total of nine conditions that an application of VIPRE code has to meet. These nine conditions that mainly deal with VIPRE modeling assumptions and qualifications provided the technical basis for the staff review of the NSAM topical report.

Out of the nine conditions, the first five conditions belong to the 1986 MOD-01 SER. And the later four conditions belong to the MOD-02 SER that got approved in 1993. The review required the staff

to focus on several respects of the methodology application and the treatment of uncertainties.

Even though generic VIPRE-01 qualifications for subchannel analyses had been reviewed as a part of the original MOD-01 and MOD-02 approvals, the staff closely looked into certain areas to ensure the VIPRE-01 licensing applicability to the NuScale design.

These respects include questions about the NSAM applicability range and any VIPRE-01 code limitation applicable to the NuScale fuel design, NuScale operating conditions, ensuring that the current number criterion is met and numerical solution is stable, inlet boundary condition consistency between the system level and RELAP-5 and VIPRE-01 codes, verifying that the VIPRE predictions are not made close to two-phase fluent stability, and qualification of the VIPRE model and assumption, especially the two-phase flow models used in NSAM.

In our review, the information the analysis staff considered in addition to NSAM topical report included the responses to RAIs 9080, 9086, 9099, and 9129, as well as the documents NuScale provided for the auditor.

Now I'll summarize the applicability of

the nine MOD-01, MOD-02 SER conditions to the NSAM and the how applicant met them.

Condition 1 requires that the application of VIPRE-01 should be limited to PWR licensing calculations that cover the heat transfer regimes up to the critical heal flux. Any use of VIPRE-01 in boiling water reactor calculations or post-CHF calculations will require a separate analysis.

The applicant did not seek the VIPRE approval for both CHF calculations, and rather limited the NuScale VIPRE-01 application up to the point of CHF.

MEMBER MARCH-LEUBA: Syed, has VIPRE been approved for BWR after this SER was issued?

MR. HAIDER: Yes. I forgot to mention that.

MEMBER MARCH-LEUBA: Okay.

MR. HAIDER: It's also worth mentioning that Condition 1 is rooted in VIPRE version MOD-01. That was not approved for BWR, while NuScale has rather used the most recent version, MOD-02. That was approved for PWR and BWR. However, the staff closely reviewed the two-phase response of the NuScale boiling transients.

In the closed session, I will present

additional information on the NuScale two-phase operation conditions to show that Condition 1 is met, and there are no staff concerns regarding the NuScale's PWR, like two-phase flow attributes or VIPRE codes limitation to handle the two-phase regimes encountered.

MEMBER MARCH-LEUBA: Maybe I'll wait for the closed session, but I don't 100% agree with what you said about NuScale being a pressurized water reactor all of the time. There is --

MR. HAIDER: I think let's wait until closed session.

MEMBER MARCH-LEUBA: Maybe we should discuss this in the closed session.

MR. HAIDER: Sure. Condition 2 mandated the submittal of a separate topical report for the staff review and approval for an unapproved CHF correlation to be used in the VIPRE application. The staff had to ensure that the methodology is applied within the range of applicability of the CHF correlation, including fuel assembly during design pressure coolant mass velocity and quality.

NuScale submitted a separate topical report for approval of the use of NuScale specific NSP CHF correlation applicable to its new fuel STP 2 fuel

that is referenced in the NSAM topic report.

The applicant used VIPRE-01 to reduce the experimental CHF data to calculate the local fluid parameters to develop the CHF correlation and the MCHFR for the NuScale fuel. The NSP 2 correlation has been approved by the NRC.

The NSAM topical report also provides assurance that only approved CHF correlations will be used with VIPRE-01 MOD-02 for the NPM safety analyses when the NSAM PR is referenced in the NuScale DCA.

In this regard, the staff has developed a condition as a part of the present SER that requires that an applicant referencing the NSAM topical report in the safety analysis must also reference an approved CHF correlation. So now it's a condition of the current SER.

Based on the submittal of a separate TR for the NuScale CHF correlation, and pursuant to the SER condition use, NRC staff finds that the applicant satisfied the generic VIPRE SER Condition 2. And this discussion of the range of applicability of NSAM vis-a-vis the NSP 2 CHF correlation will be covered in the closed session. That is also tied to the question that you had raised.

Condition 3 asked for the specifications

for using specific modeling assumptions, choice of two-phase flow models, heat transfer correlation, input values of plant-specific data such as turbulent mixing coefficient, two-phase slipper issue and loss coefficient.

The applicant met Condition 3 by providing sufficient information in the NSAM topical report, RAI responses, and the audit documents about the factors that are summarized in the present, on the present and the next slides.

These factors typically belong to various thermal-hydraulic input parameters, sensitivities, uncertainties, penalties, heat transfer coefficients, VIPRE model geometry and nodalization, and boundary conditions. Some of them are described in detail by the applicant in their presentation.

So the staff has presented some confirmatory analyses that the staff performed about the key sensitivities in the closed session to demonstrate that the applicant has provided sufficient information to justify the specific VIPRE models and assumptions so that a Condition 2 is met by NuScale. Next slide please.

Condition 4 requires that if a profile fit a subcooled boiling model, which was developed based

on steady state data is used in boiling transient, care should be taken in the time step sizing used for transient analysis to avoid a Courant number less than one. A defect is that NSAM indeed uses the existing VIPRE-01 steady state support boiling correlations, so this condition does apply to NSAM.

So a Courant number greater than one is required for the convergence of the numerical solution of the mass momentum and energy equations in a VIPRE simulation of boiling transients while using subcooled void correlation that is based on steady state data.

MEMBER MARCH-LEUBA: I guess this can be discussed in the open session. That's a very surprising condition, because most of us are used to a Courant number less than one as the stability condition. So you use Courant number greater than one with an implicit method to offer them the solution and converts to the steady state faster and more reliably. And that I can understand.

Now, when you want to apply this methodology to transients, where this overdamping is giving you the wrong transient solution, and I realize you didn't review VIPRE, that that was an old SER that this came from. But this looks a little, something is not kosher here.

But using a highly damp implicit method, you are not reducing the transient. So when you are ejecting a control rod, you're not getting the proper profile or whatever you're tracking in the subchannel. Have you considered that maybe that condition of Courant less than one was before a steady state, not for transients?

MR. HAIDER: Okay, the staff kind of expected this question. And I think they have a detailed slide in the closed section. I'm sorry, the staff expected this question, and there is material in the closed session where we will be discussing this particular issue.

CHAIRMAN KIRCHNER: Okay, but I think this is a good point that Jose brought. Because I have to admit, the first few times reading through the material, I went like this -- for the record, I scratched my head. And saying wait a minute, this is, you're forcing a solution.

MEMBER MARCH-LEUBA: I thought it was a typo.

CHAIRMAN KIRCHNER: I thought it was a typo, and I kept revisiting this each time I tripped over it. So we will look forward to your analysis of this condition in the closed section.

MR. HAIDER: Okay, the staff will offer their thoughts.

CHAIRMAN KIRCHNER: Okay, thank you. Again, for the record, this is counterintuitive.

MR. HAIDER: I think here I would just like to say that the VIPRE uses an implicit scheme. It is inherently--

CHAIRMAN KIRCHNER: You're drifting away again.

MR. HAIDER: Sorry, the VIPRE uses an implicit numerical scheme, which is inherently instable. So this Courant number criterion emerged out of the special uses of subcooled void correlation under boiling transients. So it should not be looked in the same light that is available in the open literature about Courant number being less than one being a condition for numerical stability.

MEMBER MARCH-LEUBA: I propose that we wait.

CHAIRMAN KIRCHNER: We can wait, but no, that's a good enough answer now for the record that, why this is being done. And then we can revisit it in the closed session. Okay, thank you.

MR. HAIDER: So VIPRE-01 MOD-01 SER describes the quality control requirements. The

objective of these requirements, this requirement is to ensure consistency in the development and application of the VIPRE-01 code for safety analysis.

This essentially means that only an as-approved version of VIPRE-01 can be used in an application, and any modification to VIPRE-01 is implemented under Quality Control.

The applicant used the as-approved VIPRE-01 code, Version MOD-02, and no code modification was made for NSAM applications. Besides, no QA issues or additional Quality Control requirements were reported in the VIPRE-01 MOD-02 SER, beyond what had already been documented in the VIPRE-01 MOD-01 SER, the earlier one.

So there were only enhancement made to VIPRE-01 MOD-02 for NSAM application. That was the implementation of the NuScale CHF correlation into VIPRE-01 MOD-02 suite. This was done through a dynamic link library, or the LL file, that allowed using the user program CHF correlation without any modification for the VIPRE-01 source code.

The staff has no QA concern about VIPRE-01 MOD-02 version use with the NSAM. Therefore, Condition 5 has been met.

MEMBER MARCH-LEUBA: And did I understand

you correctly that the MOD-02 SER issued in 1993 approved it for BWR conditions?

MR. HAIDER: That's right.

MEMBER MARCH-LEUBA: So the Condition 1 was kind of moot after that point, the one that said only applies for pressurized water reactors? Couple of the slides before.

MR. HAIDER: That is the staff's understanding, but we still studied, closely studied the two-phase attributes and performed confirmatory analysis.

MEMBER MARCH-LEUBA: So MOD-02 is acceptable for both generally subcooled operation and also for relatively high quality conditions?

MR. HAIDER: Not the Courant number condition, but the Condition 1. The Courant number condition is Condition 4.

MEMBER MARCH-LEUBA: Not Courant, I'm talking now a steady state void quality. If you go back to slide number --

MEMBER CORRADINI: I think, if I read the submittal by NuScale, although they're aware that their MOD-02 of VIPRE can do it, they are not asking for approval beyond CHF.

MR. HAIDER: That's true, that's true.

That part of Condition 1 is met.

MEMBER MARCH-LEUBA: Yeah, but they're asking for approval with 50% voids. Whereas, if you go back to slide 6 please. It says, Condition for more one -- now I can read more one, is that you have to be on PWR conditions. But then you see MOD-02, which is approved for boiling water reactor conditions?

MR. HAIDER: Yeah, MOD-02 is also applicable --

MEMBER MARCH-LEUBA: So this condition really is not applicable to NuScale, because they used MOD-02. It's not just that it's met, it's not applicable.

MEMBER CORRADINI: I think it's, I guess I'm reading it differently. They're basically, and NuScale can correct me if I'm misunderstanding their submittal, but as long they're below CHF, they're going to use VIPRE. Once they get past CHF, they're not relying upon VIPRE for their calculation.

I could have a void fraction much higher than 50% and not be past CHF.

MEMBER MARCH-LEUBA: That's correct.

MEMBER CORRADINI: They're not linked.

MR. HAIDER: That's right, yeah, yeah.

MEMBER CORRADINI: It's based on CHF transition that they're not going to use VIPRE beyond.

MR. HAIDER: That's true.

MEMBER MARCH-LEUBA: Okay.

MR. HAIDER: That is true.

MEMBER REMPE: So again, stop me if I'm getting into proprietary information, but several times you as well as NuScale have said, We haven't done anything to change VIPRE except for the CHF correlation and how it's implemented.

If I read the technical report, it's actually on page 65 of the PDF, but page 54, it talks about that, how they do some comparisons with another code related to thermal conductivity, and they may calibrate VIPRE, if needed. Is that a change to the code, or is that an input?

MR. HAIDER: See, the only --

MEMBER MARCH-LEUBA: That would be input parameters.

MEMBER REMPE: It's an input parameter. That's what I wanted to know, because I --

MEMBER MARCH-LEUBA: Well, you need to ask them, but.

MEMBER REMPE: It is through input parameters is how you calibrate the code. Because

that sure sounds like you're --

MEMBER CORRADINI: If you're going to answer, go to a mic.

MR. GALIMOV: Azat Galimov, NuScale. If, in case of the calibration, we actually tuned the based model, and it's input parameter.

MEMBER REMPE: It is an input parameter, thank you.

MR. HAIDER: Okay, and so we are done with Condition 5. So with Condition 5, this concludes all five conditions that were a part of 1986 SER for VIPRE-01 MOD-01. Now I will present the four additional conditions that were identified in the 1993 VIPRE-01 MOD-02 SER.

Condition 6 requires that the licensing models used in VIPRE-01 MOD-02 should be qualified. Besides, as is stipulated by some other conditions in the two generic SERs for VIPRE MOD-01 and MOD-2, NuScale needed to justify its two-phase modeling and assumptions for using VIPRE over the range of expected two-phase flow conditions expected in the design application.

So there is also some overlap in the conditions when it comes to qualifying various modeling assumptions. It's like you would hear two-

phase in Condition 1, you'll also hear about two-phase modeling assumptions in Number 6. So there is some overlap, that should be recognized.

NSAM does not use the VIPRE user option to specify a slip ratio as an input to the model. Rather, VIPRE formulation is based on a three equation compressible homogenous equilibrium model that solves 3D core flow and distributions through raw temperatures and minimum critical heat flux ratio or MCHFR.

NSAM uses non-mechanistic empirical two-phase correlations to reflect subcooled boiling non-equilibrium and concurrent vapor liquid phase slip in two-phase flow.

So this continues to the next page. The homogenous equilibrium formulation may not be sufficient to apply for cases with a large relative phase velocities typical of transient boiling. Which may raise convergence problems in transient boiling calculations when using the subcooled boiling models and bulk void correlations to account for the phase slip.

The applicant also performed a sensitivity study that is presented in the topical report, using the drift flux model. The drift flux model calculates

the void fraction by using the physically more realistic conservation of vapor mass generated by wall superheat instead of defining the void simply as a function of flow and quality with an empirical slip formulation.

So drift flux model is physically more realistic. The staff audited the applicant's drift flux model sensitivity cases applicable to NuScale conditions and confirmed that the use of drift flux model had a negligible impact on void fractions and CHFRs at any point along the hot channel.

MEMBER CORRADINI: Remind me, what did the staff do to audit it? They used trace?

MR. HAIDER: The staff reviewed the documents.

MEMBER CORRADINI: They didn't do a calculation.

MR. HAIDER: They didn't do the calculations.

MEMBER CORRADINI: Did they ask, I guess, well, I'll ask this one. Did you ask NuScale to do some sensitivities for them to look at the effect? In other words, you can put in a phase, you can put in a slip velocity to verify that it has a small effect. Was the audit based on NuScale calculations that staff

asked to have additional calculations done?

MR. HAIDER: The staff did not ask for additional calculations.

MEMBER CORRADINI: Just looking at what was given.

MR. HAIDER: Looking at what was given, but for a range of transients, so.

The applicant's use the drift flux model to justify its VIPRE-01 two-phase modeling assumptions is appropriate. The staff believes that the Condition 6 has been met, but will provide further supporting information in the closed session about the staff's sensitivities studies of the VIPRE two-phase modeling.

So Condition 7 from the generic VIPRE-01 MOD-02 SER requires the applicant to declare any possible use of the GEXL Correlation with the proposed subchannel analysis methodology. The GEXL Correlation in the only correlation having the NRC approval for using critical power ration CPR calculations for a core containment fuel. This is just one of the conditions.

NSAM TR, topical report, states the NuScale does not perform CPR calculations for BWR fuel with VIPRE-01. That essentially means that NuScale will not use the GEXL Correlation with the NSAM VIPRE-

01 application. In addition, the present SER condition bounds NSAM to use only the CHF correlations that are approved by the NuScale, for NuScale application, and GEXL is not one of them. So clearly Condition 7 is met.

VIPRE-01 manual identified limitations for VIPRE code Condition 8 requires that users submit information certifying that the code is not being used in violation of these limitations. The VIPRE conservation equations are based on homogenous equilibrium formulation, which is not sufficient to apply to cases with large relative phase velocities. Their countercurrent flows are conditions under which the flow regimes may change radically.

VIPRE should not be applied to situations that in damp conditions such as low flow boil-off and overflow phase separation involving a sharp liquid vapor interface for a countercurrent flow.

The applicant has provided sufficient information in the topical report, as well as the audit documents, and has appropriately addressed the staff's concerns expressed in RAI 9080 and its supplement about VIPRE-01 code limitations for a NuScale application.

RAI 9080 details, and its resolution will

also be discussed in the closed session, will demonstrate that an NSAM VIPRE application is not susceptible to code limitations, and Condition 8 has been met.

The generic NRC acceptance of VIPRE-01 MOD-01 did not endorse procedures and users of the VIPRE-01 code described in the code manual. So the users are advised that the suggested imports and procedures are only for best estimate.

So the user is expected to justify the import selection for licensing applications. Condition 9 about import selections, uncertainties, and sensitivity analyses is fairly generic and overlaps with several other conditions. However, I would like to report two confirmatory analyses the staff performed to look into the import selection and sensitivity studies about the VIPRE code.

One such aspect was inlet flow boundary condition consistency between the system level code and the RELAP 5, and VIPRE-01 application in NSAM. The other was potential two-phase flow instability in VIPRE predictions. The staff checked to a confirmatory analysis that I will be presenting.

So more details will be provided during the closed session to demonstrate consistency between

the VIPRE and RELAP outputs. The staff also performed a sensitivity study to establish that VIPRE did not show any potential for two-phase instability, so Condition 9 has been met with supporting information.

CHAIRMAN KIRCHNER: Doesn't the conclusion on two-phase flow instability require some caveat about a range of transient or operating conditions and pressures?

MR. HAIDER: Yes, it does.

CHAIRMAN KIRCHNER: You just can't say point blank doesn't show any potential for two-phase instability.

MR. HAIDER: We conducted the confirmatory analysis for the limiting case for the rod --

MEMBER MARCH-LEUBA: Can I suggest that we wait for this discussion for today's closed session?

CHAIRMAN KIRCHNER: Speak up so that we heard you last statement. Just finish your, repeat your last statement.

MR. HAIDER: Okay, the staff performed the confirmatory study for the limiting case of misoperation, which was to take the single rod withdrawal.

CHAIRMAN KIRCHNER: Okay, so that was the two-phase flow instability confirmatory calculation

you did.

MR. HAIDER: That's right, that's right.

CHAIRMAN KIRCHNER: My only caveat here is that this reads as a much broader validation of the code for two-phase flow applications than is intended in the actual -- we'll hear what the applicant intends. But as I understand it, there are limits as to drawing that conclusion.

MR. DRZEWIECKI: This is Tim from the staff. I just wanted to clarify. The staff's SER makes no findings about the stability of the design based on those calculations. Both are just there just for, you know, illustration purposes only.

But there was no findings associated with this methodology in terms of stability. That's a separate topical report that's in our review.

CHAIRMAN KIRCHNER: Okay.

MEMBER MARCH-LEUBA: I just want to put on the record that I want to talk about this in the closed session, because I disagree with most of the conclusions and the analysis itself.

CHAIRMAN KIRCHNER: Okay. Please go on.

MR. HAIDER: So as I mentioned early, okay, so as I mentioned early in the backdrop of the CHF discussion, the staff had formulated a position

the part of the present the staff CR that an applicant referencing the NSAM topical report in a safety analysis must also reference an approved CHF correlation.

Again, the objective of this SER condition is to ensure that only NRC-approved correlations are used with NSAM.

MEMBER MARCH-LEUBA: Is your intent that the CHF correlation be developed with VIPRE? I mean, you collect experimental data. You should analyze it with VIPRE to be able to use it on VIPRE, or can you analyze it with something else? You know what I mean? You would, depending on -- because VIPRE uses an number of approximations through the condition for the channel on the electrically heated bundle test. You should really -- with tool you're planning to use for the analysis in the real reactor. Is that the intent of the condition?

MR. HAIDER: As a matter of fact, the applicant did ensure that they used consistent model and consistent code origin, both in the CHF development and NSAM.

MEMBER MARCH-LEUBA: Yeah, but was that the likely coincidence? In my opinion, the condition should specify that. Because VIPRE is an

approximation. I mean it's not, it's close to our best estimate call, but it's not our best estimate call. It uses slip voids and it uses a number of conservative assumptions.

The condition should probably be that the CHF correlation you want to use on VIPRE had to be developed using VIPRE on the experimental data.

MR. DRZEWIECKI: This is Tim from the staff, I just want to clarify that. Okay, so as far as the NSP-2 and the NSP-4 CHF correlations, which were developed with VIPRE, staff's SER there does have a condition that those CHF correlations with those limits have to be used using this methodology. Which is, you know, which is VIPRE-01 with certain models frozen and certain parameters frozen. So yes, I agree with you completely.

MEMBER MARCH-LEUBA: Yeah, what I'm saying is the language in this condition should include, I know you put the condition on the NSP-4 TR. It should be on this TR for completeness.

MEMBER REMPE: I second what's he saying, because if someone else could come in, the applicant could come in with a different correlation in the future. And I think he's right.

MR. HAIDER: Yeah, so far the staff has

not reconciled this condition with the condition in the CFHR SER.

MEMBER REMPE: But in the future, NuScale may have a different fuel and come up with a different CHF correlation that was not generated with VIPRE. And so for legal purposes you need to do that, I think. He's right.

MEMBER MARCH-LEUBA: Don't be surprised if our letter says that you should put that in your condition.

MR. DRZEWIECKI: Okay.

MEMBER MARCH-LEUBA: And that's my opinion, not the ACRS opinion.

MR. DRZEWEICKI: Okay, just so that we're clear, you would like staff to make this condition a little tighter to make sure that that says that it has to use the CHF correlation that was developed using this precise methodology.

MEMBER MARCH-LEUBA: If I was writing, I would say, If the CHF correlation was not developed using VIPRE, its applicability has to be reviewed by the staff.

MR. DRZEWIECKI: Okay.

CHAIRMAN KIRCHNER: And a caution here, because these are opinions of individual members, not

the opinion of the Committee writ large.

MEMBER REMPE: Yes.

CHAIRMAN KIRCHNER: So.

MR. HAIDER: The staff would also like to clarify that NSAM TR uses several example values of input parameters and includes the subchannel analysis just to demonstrate the NSAM application to perform subchannel analyses and enhance the understanding of the analytical methods. The staff SER does not approve the use of any specific example where new inputs or reserves presented in the topical report.

The staff would approve the specific input values and ensuing reserves for the reactor core design for this subsequent licensing submittal in DCA, referencing the NSAM topical report. And the staff will review these final design and planned specific input values used in the subchannel analyses as a part of the separate licensing submittals.

I'll elaborate further on the example values during the closed session.

So here are the staff SER conclusions. The NRC staff has reasonable assurance that the use of the VIPRE-01 MOD-02 code with NSAM as described in the topical report is appropriate for the NuScale fuel thermal-hydraulic design and plant safety analyses,

provided that the present SER condition is met.

The staff also found that the sufficient information has been presented for the requested elements of approvals, so the staff concludes that VIPRE-01 applies to the NuScale steady state and transient subchannel analyses. NSAM fulfills the NRC's requirements in the SERs for VIPRE-01 MOD-01 and MOD-02.

NSAM is independent of any specific CHF correlation and is used for NuScale applications with an NRC-approved NuScale specific CHF correlation. NSAM describes a methodology for the treatment of uncertainties in the NuScale subchannel analysis that is appropriate.

So this concludes the open part of my presentation. And now the staff would like to invite any further questions on the staff review of the NuScale subchannel analysis methodology.

MEMBER REMPE: Am I misreading your report? I liked the statements in the prior slide because there are several examples where you say we didn't approve the input value and we didn't approve the methods for calculating the uncertainty associated with it.

This last sub-bullet where you say they

described the methodology for treatment of uncertainties and analysis that's appropriate seems inconsistent with some of the things that I read in your technical or topical report.

And we can into the details later, but I guess I'm just wondering what that last sub-bullet meant, because it seems like there's several cases where you bring up areas where you're saying, hey, it doesn't make sense what you've done here, or we couldn't follow the logic, and so we don't approve it.

MR. HAIDER: There are several parameters that were used in NSAM to produce the results and conduct the sensitivity analysis. But those parameters are fuel-specific, and they even sometimes there are CHF-correlation-specific.

And they may change, and they should ideally be reviewed where they are actually being implemented in the safety analysis, like Chapter 15 review or Chapter 4 review. So their review will be performed in the DCA, but their review--

MR. THOMAS: Syed?

MR. HAIDER: Yes, Matt? You want to?

MR. THOMAS: Let me ask a quick question. This is Matt Thomas, Reactor Systems Branch. You perhaps, I think we could probably discuss this in the

open portion right now.

MR. HAIDER: Okay.

MR. THOMAS: Considering it's coming directly from the topical report. Can you point me to a specific example where you see this inconsistency? And that way we can try to work through it and clear up what this even actually means on the slide.

MEMBER REMPE: Again, I hope I don't get in trouble for things, but there was a concern about the reflector and core barrel and guide tube instrumentation tube IPLAS (phonetic) flow pin at least that were selected. There was concern about the axial power distribution that was selected.

Later in the closed section, you're going to be talking about high impact parameters that had more effect on the methodology. And when I look at what the staff did, some of the concerns were expressed about some of those parameters.

And again, I'll admit, maybe I'm just not used to looking at staff SERs approving the methodology. But it seemed like that this last sub-bullet, it's a bit of an overstatement of what was concluded by the staff, if I look at the details.

MR. THOMAS: Okay, so let me try to explain. So those certainty values that you allude

to, like the penalties bypass flow and things like that, those are specific values that we are not proving that are deemed as example values in the topical report. Not approving.

MEMBER REMPE: Yeah, they clearly aren't, I agree with you. They aren't approving that. Likewise with the --

MR. THOMAS: Uncertainties in that the applicant has used a deterministic method for applying uncertainties.

MR. ROOKS: I think if I could jump in here and help, maybe I can help. This last bullet I think addresses uncertainty methodology in the actual subchannel analysis, the method, not inputs.

So things like reconciling a systems code input to inlet core flow rates or bypass is not an uncertainty treatment within the subchannel methodology. That's when I go to the systems analysis and test the validity of the systems code meshing with the subchannel analysis code that's looking at detailed in-core phenomena.

MEMBER REMPE: Like that's also true with the axial power distribution and how they've done --

MR. ROOKS: And I view axial power as an input parameter.

MEMBER REMPE: Okay. This is all fine then.

MR. ROOKS: The methodology I think is flexible about how it treats axial power. So I don't see any limitation there.

MEMBER REMPE: Okay, that's fine --

MR. THOMAS: I would agree with those statements.

MEMBER REMPE: Okay.

MR. THOMAS: And specifically for this bullet point, it's referring to, that's right, the methodology of the application of uncertainty methodology, i.e., certainties and penalties by biasing the actual parameter in a conservative direction versus --

MEMBER REMPE: Okay, that's fine.

MR. THOMAS: Of applying uncertainties.

MEMBER REMPE: That's fine. I guess I got confused because of all these conditions on using VIPRE and how that there was a lot of concerns raised. So thank you.

MR. THOMAS: Yes, understood, thank you.

MEMBER MARCH-LEUBA: I have a generic comment. I am a little -- I realize that the approval of this topical report is based on two old SERs, on

MOD-01 and MOD-02. And there are a series of limitations and conditions from one and the other. But when you go through that, it confuses a lot to me what are we talking about. Are we talking about MOD-01 or MOD-02?

NuScale is requesting that we approve MOD-02 for their use, and the SER doesn't make that clear, I don't think. I mean, by going through so much back and forth between limitations for 01 and 02, it feels as if you're approving both.

MR. HAIDER: Again, maybe this is a regulatory documentation issue. Nowhere in the MOD-02 generic SER there is a statement that would say that, that will state that the five conditions approved in MOD-02 are superseded.

MEMBER MARCH-LEUBA: I'm just looking for regulatory certainty. The SES you say NuScale should use MOD-02 and forget about MOD-01. With this SER, could they run calculations with MOD-01? Not that they want to, but we are approving VIPRE MOD-02 for use in NuScale.

MR. HAIDER: But to the best of my knowledge, the five conditions from MOD-01 are also applicable.

MEMBER MARCH-LEUBA: And they are

applicable.

MR. HAIDER: To MOD-01.

MEMBER MARCH-LEUBA: Yeah, the limitation conditions are applicable. You can make them applicable and write the new SER. What I'm saying is it's not clear what we are approving.

MR. HAIDER: But the staff agrees that there is a nuance, that since MOD-01 was approved only for BWR, while MOD-02 was approved for both BWR and PWR. So the BWR aspect of Condition 1, how much of that applies.

MEMBER MARCH-LEUBA: Yeah.

MR. HAIDER: So there is uncertainty about that, but the staff tried to look into the two-phase flow conditions that the --

MR. HAIDER: I just put my concern on the record. I would like to see more, a clearer language that NuScale plans to use MOD-02 and that's what we're approving.

MEMBER CORRADINI: Can I ask the applicant, what's the plan of NuScale? I assumed it was to use MOD-02, which was an approved NRC standard tool, with the limitation that you must use that analysis technique to then develop your CHF correlation, which then must be used in concert with

it. What is the applicant's --

MEMBER MARCH-LEUBA: They're not listening. That question is for you.

MEMBER CORRADINI: You guys hear the question? Are you planning to use VIPRE MOD-01 or MOD-02 in your analysis?

MR. GALIMOV: We installed only MOD-02, so we're going to use only that version.

MEMBER CORRADINI: Only MOD-02.

CHAIRMAN KIRCHNER: Would you just identify yourself.

MR. GALIMOV: Azat Galimov, NuScale.

MEMBER CORRADINI: But so your plans are to use MOD-02.

MR. GALIMOV: Yes, and in my understanding, MOD-01 is not used by, probably excluded from use from many vendors anyway.

MEMBER CORRADINI: Okay, thank you.

CHAIRMAN KIRCHNER: Okay, members, any other questions at this point? Then let me turn to the audience and see if there's anyone from the public who wishes to make a statement, please come up and identify yourself and make your comment.

Seeing no one, the bridge line is open.

OPERATOR: It's open.

CHAIRMAN KIRCHNER: If there is anyone from the public who wishes to make a comment, please speak up, identify yourself, then make your comment.

Hearing none, let's then take a short recess is the proper thing.

MR. SNODDERLY: When would you like to come back?

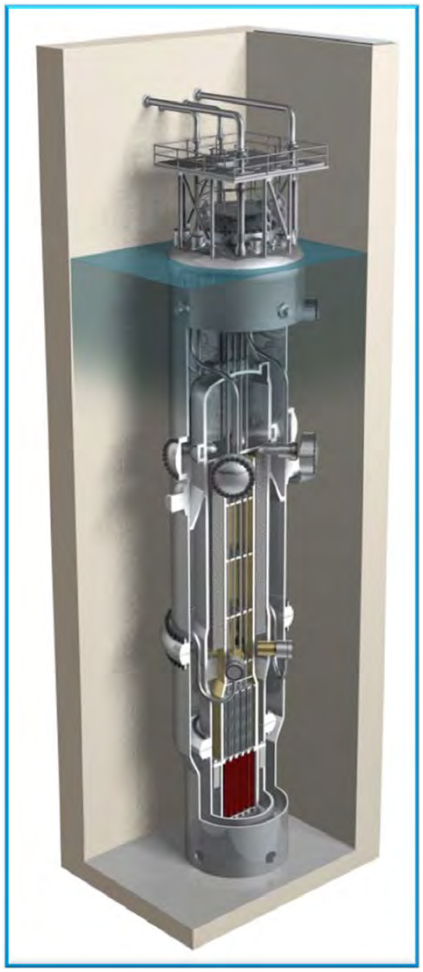
CHAIRMAN KIRCHNER: Let's reconvene at five minutes of ten.

MR. SNODDERLY: Five minutes of ten. Okay, with the closed session.

CHAIRMAN KIRCHNER: With a closed session. So we are recessed.

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

Subchannel Analysis Methodology TR-0915-17564 ACRS Presentation



Kenneth Rooks

ACRS Open Session – August 24, 2018

PM-0818-61290
Revision: 0

Acknowledgement & Disclaimer

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Agenda

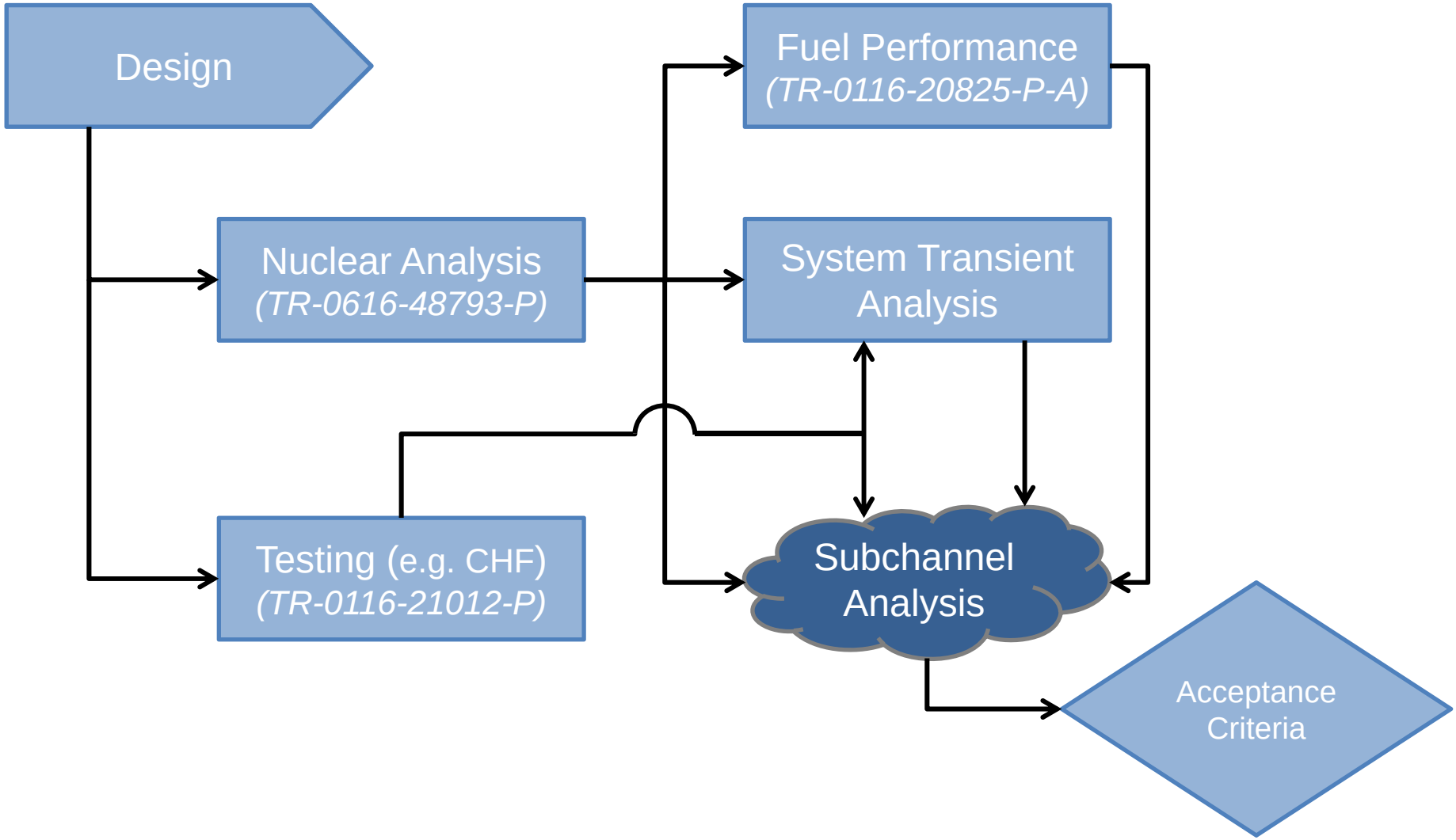
- Overview
- VIPRE-01 Subchannel T/H Code
- Qualification & Methodology Approach

Overview

NuScale seeks approval for:

- VIPRE-01 use for steady-state and transient analysis
- Methodology fulfills requirements of VIPRE-01 generic safety evaluation report (SER) limitations
- Methodology application and treatment of uncertainties

Overview – Safety Analysis



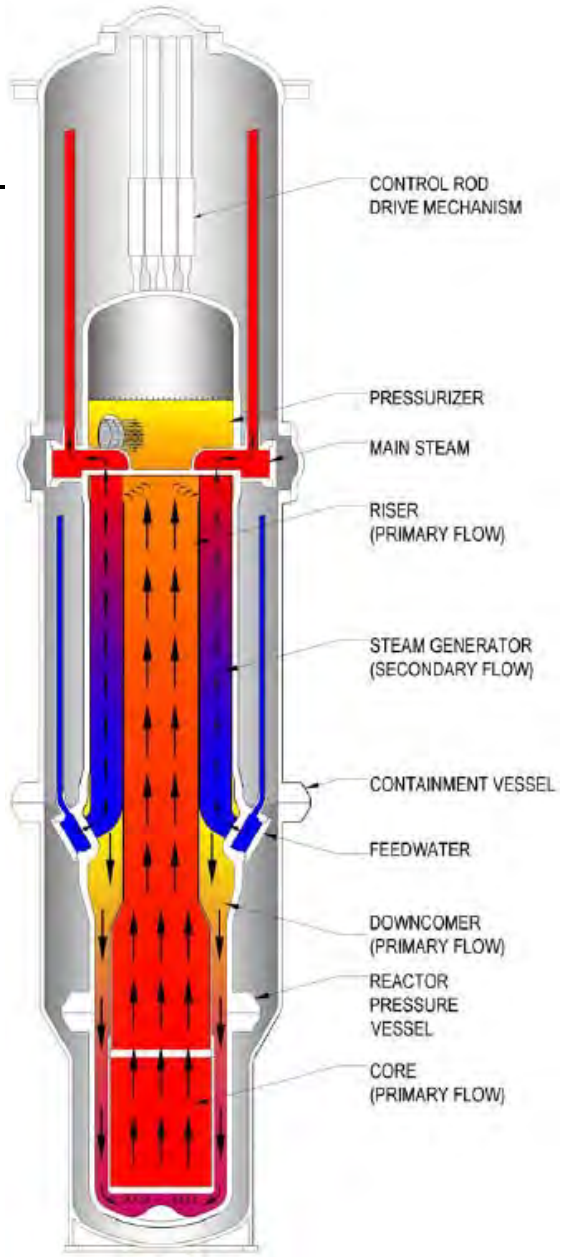
Overview – Subchannel Analysis

- Objective is to determine margin results for:
  - Critical Heat Flux
  - Fuel Centerline Melt
- Regulatory requirements
  - General Design Criterion 10, 10 CFR 50 Appendix A
  - SRP 4.2 – Fuel System Design
  - SRP 4.4 – Thermal & Hydraulic Design

Calculates critical information for FSAR Chapters 4 and 15

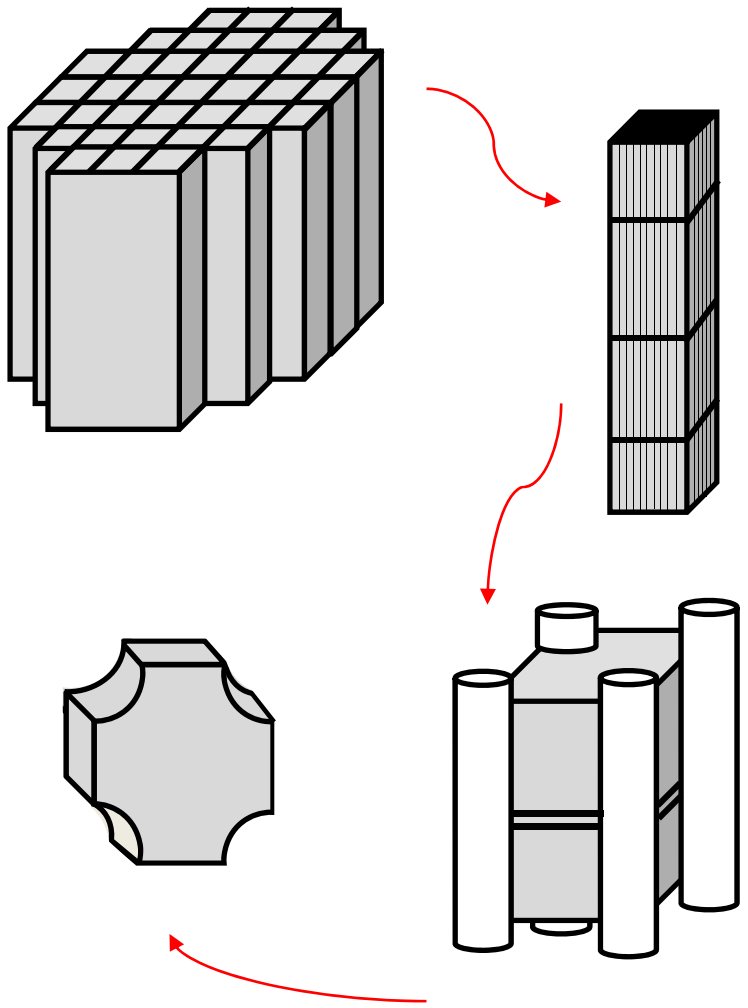
NuScale SMR

- Natural circulation PWR
  - system flow a function of power level
  - flow driven by density gradient between core and steam generator
- Core-average exit fluid conditions remain subcooled
- Hot channel exit quality greater than 0



VIPRE-01 Subchannel T-H Code

- Developed by EPRI and maintained by Zachry
- Finite-volume subchannel analysis code
- Solves 3-D core flow and enthalpy distributions, fuel rod temperatures, and MCHFR
- 3-equation homogeneous equilibrium model (HEM)
- Empirical correlations for two-phase conditions
- Mature PWR licensing history



NuScale Application

- NuScale using the industry-standard, “as-approved” version, no modifications to main program
  - design-specific CHF correlations incorporated through dynamic link library (DLL) *(NSP2 and NSP4 submitted in TR-0116-21012)*
- Managed through NuScale software QA program
- Generic VIPRE-01 SER in EPRI-NP-2511-CCM-A
  - conditional limitations for use
  - NuScale meets SER conditions as demonstrated in topical report

Leverages mature and robust basis for PWR analysis

VIPRE-01 Qualification

- Extensive qualification for PWRs previously performed as part of original approval
- To support SER conditions, NuScale performed additional qualification to ensure VIPRE-01 applicability
  - code-to-code comparison with NRC-approved code
  - additional experimental phenomena comparisons
  - parametric and generalized input sensitivity studies

VIPRE-01 applicable for NuScale conditions

Methodology Approach

- Conservative basemodel development
  - generic cycle-independent radial power distribution
  - bounding axial power shapes
  - detailed radial and axial nodalization evaluations
- Input uncertainties are treated independently; no credit for statistical randomness
- Uncertainties are accounted for as model and acceptance criterion limit biases
- Detailed checklist to ensure compliance with method

Summary

- A conservative subchannel analysis method analyzing steady-state and transient conditions
- Topical report provides details and justification for:
  - how NuScale's use of VIPRE-01 satisfies all SER requirements
  - applicability of VIPRE-01 to the NuScale reactor core
  - deterministic methodology using VIPRE-01
  - appropriate treatment of uncertainties
- Results from NuScale Subchannel Analysis Methodology application provide input to FSAR Chapters 4 and 15

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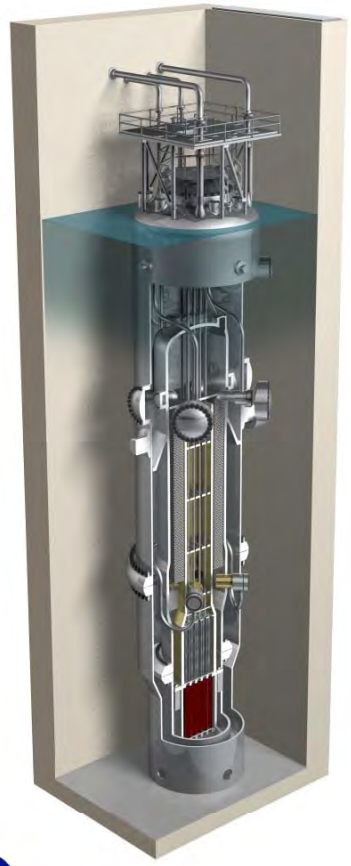

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Presentation to the ACRS Subcommittee

Staff Review of NuScale Topical Report

TR-0915-17564, REVISION 1

"SUBCHANNEL ANALYSIS METHODOLOGY"

Presenters:

Bruce Bavol - Project Manager, Office of New Reactors

Syed Haider, Ph.D.- Reactor Systems Engineer, Office of New Reactors

Matt Thomas - Reactor Systems Engineer, Office of New Reactors

August 24, 2018

(Open Session)

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  Syed Haider (Lead)

- Reactor Systems NRO/DSRA/SRSB:

  Rebecca Karas (BC)

  Jeffrey Schmidt

  Timothy Drzewiecki

  Matt Thomas

Staff Review Timeline

TR-0915-17564, "Subchannel Analysis Methodology"

- NuScale submitted its Topical Report (TR) 0915 17564 P, "Subchannel Analysis Methodology," Revision 1, on February 15, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17046A333).
- Staff issued the following request for additional information / NuScale provided response:
  - RAI 9080 – 09/11/2017 (ML17254A439) / 11/09/2017 (ML17313B205) & S1 (ML18061A109)
  - RAI 9086 – 09/09/2017 (ML17252A688) / 10/30/2017 (ML17299A973)
  - RAI 9099 – 09/02/2017 (ML17251A368) / 09/13/2017 (ML17251A368)
  - RAI 9129 – 11/17/2017 (ML17321A597) / 01/15/2018 (ML18015A012)
- Staff plans to brief advisory committee on reactor safeguards (ACRS) full committee on September 6, 2018
- Staff plans to issue its final SER in late October 2018.
- Staff plans to publish the "-A" (approved) version of the TR in early 2019.

Scope of the Staff Review (1/2)

- Regulatory Basis
  - General Design Criterion (GDC) 10, “Reactor Design,” in 10 CFR Part 50, Appendix A
  - NuScale DSRS , Section 4.4, “Thermal and Hydraulic Design”
  - 10 CFR 50.34, “Contents of Applications; Technical Information”
- NRC approved VIPRE-01 subchannel analysis code, version MOD-02
- Elements of approval for the NuScale Subchannel Analysis Methodology (NSAM)
  - VIPRE-01 applies to the NuScale steady-state and transient subchannel analyses.
  - Methodology fulfills the NRC’s requirements in the SERs for VIPRE-01, MOD-01 and MOD-02.
  - Methodology is independent of any specific CHF correlation and is used for NuScale. applications if the methodology requirements are satisfied and if the NRC approves the CHF correlation.
  - Methodology for treatment of uncertainties in the NuScale subchannel methodology is appropriate.

Scope of the Staff Review (2/2)

- Technical basis for the NRC staff review
  - Nine conditions in the generic SERs for VIPRE-01 MOD-01 and MOD-02
  - VIPRE-01 modelling assumptions and qualifications
- Areas requiring additional review
  - NSAM applicability range and VIPRE-01 code limitations
  - NuScale operating conditions
  - Stability of the numerical scheme
  - Inlet boundary condition consistency
  - Two-phase flow instability verification
  - Qualification of VIPRE-01 MOD-02 models and assumptions
- Information considered by NRC staff
  - NuScale Topical Report, TR-0915-17564, Revision 1, “Subchannel Analysis Methodology”
  - Responses to RAIs 9080, 9086, 9099, 9129
  - Audit documents

1. Post CHF Application Limitation

Summary of the VIPRE-01, MOD-01 SER Condition No. 1

- Application of VIPRE-01 is limited to PWR licensing calculations with heat transfer regimes up to CHF. Any use of VIPRE-01 in boiling-water reactor (BWR) calculations or post-CHF calculations will require prior NRC review and approval.

Applicant's Meeting the Condition in the NSAM

- Limits the VIPRE-01 code to PWRs up to CHF
- VIPRE approval not sought for post-CHF calculations.
- NuScale is a PWR -- the BWR limitation not applicable.
- NSAM meets the post-CHF application/BWR limitation on the use of the VIPRE-01 code for the NuScale design.
- Condition 1 is met.

2. CHF Correlation Requirement

Summary of the VIPRE-01, MOD-01 SER Condition No. 2

- Use of an unapproved CHF correlation will require the submittal of a separate TR for review and approval.
- Application is within the range of applicability of the CHF correlation including fuel assembly geometry, spacer grid design, pressure, coolant mass velocity, quality, etc.,

Applicant's Meeting the Condition in the NSAM

- A separate TR submitted/approved for the NuScale specific NSP2 CHF correlation.
- VIPRE-01 used to reduce the experimental CHF data to calculate the local fluid parameters to develop the NuScale specific CHF correlations/MCHFR.
- NSAM TR provides assurance that only approved CHF correlations will be used with VIPRE-01 for the NuScale safety analyses supporting the NuScale DCA.
- Submittal/approval of a separate TR for the NuScale specific CHF correlation met the present NSAM TR SER Condition 1. So, the generic VIPRE SER Condition 2 has been met.
- Range of applicability of the NSAM is covered in the closed session.

3. VIPRE-01 Models and Assumptions (1/2)

Summary of the VIPRE-01, MOD-01 SER Condition No. 3

Provide justifications for specific modeling assumptions, choice of two-phase flow models, heat transfer/CHF correlations, input values of plant specific data such as turbulent mixing coefficient, slip ratio, and grid loss coefficient, including defaults.

Applicant's Meeting the Condition in the NSAM

The applicant provided sufficient information on:

- Turbulent mixing coefficient
- Grid spacer loss coefficient
- Heat transfer correlations
- Model geometry
- Radial and axial nodalizations
- Bypass flow
- Inlet flow/temperature distributions

3. VIPRE-01 Models and Assumptions (2/2)

Applicant's Meeting the Condition in the NSAM (cont.)

- Radial and axial power distributions
- Rod and assembly bow penalties
- CHF correlation and DNBR limit

Applicant provided sufficient information to justify the specific VIPRE models and assumptions.

Key sensitivities/confirmatory analyses are discussed in the closed session to demonstrate that Condition 3 has been met.

4. Courant Number Criterion

Summary of the VIPRE-01, MOD-01 SER Condition No. 4

If a profile fit subcooled boiling model, which was developed based on steady state data, is used in boiling transients, care should be taken in the time step size used for transient analysis to avoid the Courant number (N_C) less than 1.

Applicant's Meeting the Condition in the NSAM

- A subcooled void correlation based on steady-state data is not suitable for modeling boiling transients in VIPRE with $N_C < 1$. $N_C > 1$ is required for the convergence of the numerical solution of the mass, momentum, and energy equations in VIPRE.
- NSAM uses the VIPRE-01 steady-state subcooled boiling correlations.
- NSAM TR presents results for three design-basis example transients. Transient time step selected on a case-by-case basis for the axial nodalization & coolant velocity, to ensure $N_C > 1$.
- Staff audit showed the condition was met throughout the transients.
- Staff confirmatory calculations showed no numerical stability issues resulting from the transient time step selection for $N_C > 1$.
- Condition No. 4 has been met.

5. Quality Assurance

Summary of the VIPRE-01, MOD-01 SER Condition No. 5

- Quality control requirements, described in Section 2.6 of the VIPRE-01 MOD-01 SER, to ensure consistency in the development and application of the VIPRE-01 code for safety analysis.
- Only an as-approved version of VIPRE-01 is used and any modification to VIPRE-01 is implemented under quality control.

Applicant's Meeting the Condition in the NSAM

- No QA issues or additional quality control requirements reported in the VIPRE-01, MOD-02 SER (1993), beyond the VIPRE-01, MOD-01 SER (1986).
- No modifications were made to VIPRE-01, MOD-02 for NSAM.
- Implementing CHF correlation into VIPRE through a .DLL file allowed using the user-programmed CHF correlation without any VIPRE source code modification.
- No QA concerns about the VIPRE-01, MOD-02 version use with NSAM.
- Condition 5 has been met.

6. Qualification of VIPRE-01 MOD-02 Models (1/2)

Summary of the VIPRE-01, MOD-02 SER Condition No. 1

- The use of VIPRE-01 MOD-02 is contingent upon full qualification of the licensing models.
- Besides, as stipulated by Condition 3 of the SER for VIPRE-01, MOD-01, and Conditions 6 and 8 of the SER for VIPRE-01, MOD-02, to support qualification of the modeling assumptions, NuScale needed to justify its two-phase modeling and the selected parameters for using VIPRE-01 for the design application over the range of expected two-phase flow conditions.

Applicant's Meeting the Condition in the NSAM

- Slip ratio not used as a modeling assumption in NSAM – No slip ratio specified as a VIPRE input.
- VIPRE formulation
  - 3-equation incompressible, homogeneous equilibrium model (HEM)
  - Solves 3-D core flow field and enthalpy distribution, fuel rod temperatures, and MCHFR.
  - Non-mechanistic empirical two-phase correlations used to reflect subcooled boiling non-equilibrium and concurrent vapor/liquid phase slip in two-phase flow

6. Qualification of VIPRE-01 MOD-02 Models (2/2)

Applicant's Meeting the Condition in the NSAM

- The HEM formulation of VIPRE-01 using the subcooled boiling models and bulk void correlations to account for phase slip may not be sufficient for cases with large relative phase velocities.
- Applicant's drift flux model sensitivity study
  - The drift flux model calculates the void fraction by using the physically realistic conservation of vapor mass generated by wall superheat instead of defining the void as a function of flow and quality with an empirical slip correlation.
  - Audited the applicant's drift flux model sensitivity cases applicable to NuScale design conditions. The use of the drift flux model had a negligible impact on void fractions and CHFR at any point along the hot channel.
- The applicant's use of the drift flux model to justify its VIPRE-01 two-phase modeling assumptions is appropriate. Condition 6 has been met.

7. GEXL Correlation

Summary of the VIPRE-01, MOD-02 SER Condition No. 2

The GEXL correlation is the only correlation that currently has NRC approval for use in critical power ratio (CPR) calculations of a core containing GE fuels. However, use of the GEXL correlation for other vendors' fuels or use of any other correlation requires a separate submittal for NRC review and approval.

Applicant's Meeting the Condition in the NSAM

- This VIPRE-01, MOD-02 SER condition requires the applicant to declare any possible use of the GEXL correlation with the proposed subchannel analysis methodology.
- NSAM TR states that "NuScale does not perform CPR calculations for BWR fuel with VIPRE-01."
- Condition 7 has been met as the above cited statement means that NuScale will not use the GEXL correlation with the NSAM VIPRE-01 applications.

8. VIPRE-01 Code Limitations

Summary of the VIPRE-01, MOD-02 SER Condition No. 3

- VIPRE-01 manual identifies VIPRE code limitations. Each user, in its documentation for NRC approval, should certify that the code is not being used in violation of these limitations.
- The VIPRE code should not be used to model cases with large relative phase velocities, countercurrent flow, or conditions under which the flow regime changes radically. VIPRE should not be applied to situations that entail conditions such as low-flow boil off, annular flow, phase separation involving a sharp liquid/vapor interface, or countercurrent flow.

Applicant's Meeting the Condition in the NSAM

- The applicant provided sufficient information in the TR, and appropriately addressed the staff's concerns in RAI 9080 about VIPRE-01 code limitations for NuScale application.
- RAI 9080 details will be discussed in the closed session to show that NSAM VIPRE-01 application is not prone to code limitations and Condition 8 is met.

9. Input Selection, Uncertainties and Sensitivity Analyses

Summary of the VIPRE-01, MOD-02 SER Condition No. 4

NRC acceptance of VIPRE-01 MOD-02 does not endorse procedures and uses of VIPRE described in the code manual. Each user is advised to note that values of input recommended by the code developers are for best-estimate use only and do not necessarily incorporate the conservatism appropriate for licensing type analysis. Therefore, the user is expected to justify or qualify the input selections for licensing applications.

Applicant's Meeting the Condition in the NSAM

The staff performed confirmatory analyses to look into the following two aspects of the NuScale VIPRE model:

- Inlet flow boundary condition consistency
- Two-phase flow instability

More details will be provided in the closed session to demonstrate consistency b/w VIPRE inlet flow BC and the system code output. VIPRE results did not show any potential for two-phase instability. Condition 9 has been met.

NSAM TR Conditions & Limitations

Condition No. 1

An applicant referencing the NSAM topical report in a safety analysis must also reference an approved CHF correlation. The basis for this condition is provided in Section 4.1 of the staff SER of the NSAM topical report.

NSAM TR Example Values

- The NSAM TR uses several example values of input parameters and includes the subchannel analysis results just to demonstrate the NSAM applicability to perform subchannel analyses, and enhance the understanding of the analytical methods. The staff SER does not approve the use of any specific example value inputs or results presented in the TR.

- In various subsections of the SER, the staff has documented the review of various input parameters and the determination of the aspects that are approved.

- The staff would approve specific input values and ensuing results for the reactor core design for the subsequent licensing submittals (e.g., DCAs) referencing the NSAM TR. The staff would review these final design- and plant-specific input values used in the subchannel analyses as a part of these separate licensing submittals.

Staff SER Conclusions

- The NRC staff has reasonable assurance that the use of the VIPRE-01, MOD-02 code with the NSAM described in the TR is appropriate for the NuScale fuel thermal-hydraulic design and plant safety analyses, provided that the SER conditions and limitations are met.

- Elements of Approval
  - VIPRE-01 applies to the NuScale steady-state and transient subchannel analysis using the methodology presented.
  - NSAM fulfills the NRC's requirements in the SERs for VIPRE-01, MOD-01 and MOD-02.
  - NSAM is independent of any specific CHF correlation and is used for NuScale applications if the methodology requirements are satisfied and if the NRC approves the CHF correlation as confirmed by Condition 1 of this SER.
  - NSAM describes a methodology for treatment of uncertainties in the NuScale subchannel analysis that is appropriate.

Questions/comments from members of the public before the closed session starts?