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Open Session

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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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SUBCOMMITTEE ON THERMAL HYDRAULICS

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OPEN SESSION

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WEDNESDAY

FEBRUARY 15, 2023

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The Subcommittee met via Teleconference, at 8:30 a.m. EST, Jose March-Leuba, Chair, presiding.

COMMITTEE MEMBERS:

JOSE MARCH-LEUBA, Chair

RONALD G. BALLINGER, Member

VICKI M. BIER, Member

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JOY L. REMPE, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANT:

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

C-O-N-T-E-N-T-S

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

8:30 a.m.

CHAIR MARCH-LEUBA: Good morning, this meeting will now come to order. This is a meeting of the Accident Analysis Thermal Hydraulics Subcommittee. I am Jose March-Leuba, the SC chairman. In addition to in person attendance at NRC headquarters, the meeting is broadcast via MS Teams. Members in attendance are Ron Ballinger, Vicki Bier, Vesna Dimitrijevic, Greg Halnon, Walter Kirchner, David Petti, Joy Rempe, and Matthew Sunseri. Our consultant Steve Schultz is also present.

Today we are reviewing topical report ANP-10353P Revision 0 by Framatome entitled increased enrichment for PWRs. Portions of our meeting will be closed to the public to protect Framatome proprietary information. We have not received requests to provide comments, but we have an opportunity for public comments before the beginning of the closed section of the meeting.

The ACRS was established by a statute, and is covered by the Federal Advisory Committee Act, FACA. As such, the committee only speaks to its published letter reports. The rules for participation in all ACRS meetings were announced in the federal

register on June 13th, 2019. The ACRS section of the U.S. NRC public website provides our charter, bylaws, agendas, letter reports, and full transcripts for the open portions of all full, and subcommittee meetings, including the slides presented there.

The designated federal official today is Christopher Brown. A transcript of the meeting is being kept, therefore speak into the microphones clearly, and state your name for the benefit of the court reporter. If you're in the conference room with multiple people on the line, please remember to identify yourself regularly for the accuracy of the transcript.

Please keep all your electronics, and the microphone on mute when not in use. Let me remind the members that for this particular topical report, the actual enrichment value being requested by Framatome is proprietary, so please refer to it in your questions as greater than five percent, or better yet, as X percent in the open portion of the meeting.

At this point I would like to ask Joe Donoghue from NRC staff if he is present, to present his opening remarks. He is.

MR. DONOGHUE: Yes, I am, good morning Chairman. Thanks for giving me the opportunity to say

a few words. I'm Joe Donoghue, I'm the director of the division of safety systems in NRR, and I wanted to just highlight the topical report that you're going to hear about today is the first of a kind for us, because as you said, it's addressing increased enrichment above 5 percent U-235.

It's applicable only to current burn up limits that the staff has approved in other topical reports, and we expect that there's going to be future reviews, future submittals to address higher burn up in the future, that then could make this useful for those kinds of fuel designs. Framatome, in our view, did a really good job. A high quality topical report was submitted.

They responded to RAIs in a timely manner, and this supported us completing our safety evaluation in two years, pretty much as planned. You're going to hear the other approved topicals that this touches upon when our staff presents to you, and the safety evaluation includes a limited condition that has been agreed upon, and is in the safety evaluation agreed upon with the applicant.

So, with that, thank you for your attention today. I know my staff is prepared to give you a great presentation, and answer your questions,

thank you.

CHAIR MARCH-LEUBA: Thanks Joe. And I concur with you, the evaluation of this is a very important topical report, and we look forward to looking at all the information you have presented. At this point I will ask Gayle Elliot from Framatome to make some introductory remarks, and introduce her team. Gayle? I know you're there, because I saw you before.

MS. ELLIOTT: Yes. Good morning everyone, I'd like to welcome everyone, first of all, to our discussion on Framatome's health report for increased enrichment for PWRs. Thank you for meeting with us today. I'd like to specifically thank the NRC reviewers of this topical report for reviewing the topical report in a timely, and efficient manner while also being transparent to the public.

Mr. Wise, and his colleagues reviewed this topical report, and right around a year time frame, and for a first of a kind topical report, to be able to do that, we greatly appreciate it. Framatome is trying to bring innovation to the industry, and when topical reports get held up in a review, certainly that does not help us to do that.

So, thank you Mr. Wise, and your

colleagues for performing this review in a timely, and efficient manner. So, thank you, for my opening remarks that's it.

CHAIR MARCH-LEUBA: Thanks a lot. I want to present for the record, our Member Brown has joined us, so we have a full house, all members are present. So, let's go ahead, and start with the Framatome open presentation we'll just hear in open session. Who is going to put the slides up, Gayle are you?

MS. ELLIOTT: I can do that, yes. Just one moment while we get those up.

CHAIR MARCH-LEUBA: So, Gayle, then you can introduce your team when you finish that.

MS. ELLIOTT: All right.

CHAIR MARCH-LEUBA: You can maximize, go into presentation mode, we can see that.

MS. ELLIOTT: Yes, one moment. My apologies, my computer is just a little slow this morning.

CHAIR MARCH-LEUBA: Yeah, we need to be managing the time, because in the closed session we have a lot of things, it's been very thorough.

MS. ELLIOTT: Understand, understand. Well, it may be better if you guys run the slide show on your computer, because --

CHAIR MARCH-LEUBA: It's okay, we can start, we can see it. We can start with your presentation, and you can continue playing with it. It's a very short presentation.

MS. ELLIOTT: Yes, okay. So, we are going to be talking about ANP-10353P Rev 0 today, this is on increased enrichment for PWRs, and I'd like to thank also Morris Byram for actually managing this topical report through the NRC review. So, our agenda today for the open session, I'll be talking about the key milestones for this topical report from prior to, and after the review -- submittal of this topical report.

I also want to show you a list of the entire code package, and how they work together. So, we will talk a little bit about the advanced codes, and methods topical reports. We'll talk a little bit about the approval request, and the applicable fuel designs that this topical report will be used for. And also we'll just do a quick, brief outline of the topical report.

And my colleague, Michelle Guzzardo is going to be spending more time on that later in the closed session. So, for the key milestones for this, and again, it went very well. The review, the time line of this, it was just a very smooth running

topical report review. So, the key milestones, we did have a pre-submittal meeting in April of 2020, and we submitted the topical report for review in January of 2021.

It was accepted review a couple months later, March of 2021, very quick. We did have an audit for understanding in September of that same year that went very well. RAIs were received in September also, after that audit of understanding. But one of the things we'd like to mention is we definitely appreciate the audits, because we get a feel for what type of RAIs to be expected, and we can actually talk a little bit more about those in the audit as well.

We submitted our responses in January of 2022, and another audit on the rated parameters in August of 2022, and we received our draft SC in December of last year. So, this is the code package overview. And the reason we wanted to show this, is because we wanted to show you, first of all, each one of these topical reports, and these are only the major methodologies, but these are talked about in the topical report that we just received the draft SC on.

And I want to show you a little bit of how those work together. So, if you take a look at the slides, you'll see those topical reports that are in

green are our new topical reports, they're our newer ones. The blue are some of the older topical reports we have. So, as you can see, we have addressed LOCAs, and neutronics, and non-LOCA fuel performance in this topical report.

You'll see here, you see where the arrows are going, you'll see how one methodology feeds into the other methodologies, and so that'll help you to understand everything that we're doing here. You'll see under LOCA, GALILEO in LOCA is in green, that is actually one of our topical reports that were used in unison with their older realistic logic speculative small break LOCA topical reports.

So, if you see the arrows, ARCADIA feeds into the LOCA, and the non-LOCA methodologies, as well as the fuel performance methodology. Likewise, the fuel performance for topical reports also feed back into ARCADIA, so you can see that basically by the arrows, and where they're going there. As you can see, all of these are approved, except for ARITA, that's why that one is in yellow.

And so, hopefully we'll get that one soon, but very important that that is a part of this topical report as well, and Row Bow does feed into that, the one LOCA methodology. Framatome is requesting

approval for enrichment above five weight percent U-235. The fuel designs that this topical report will support are the GAIA 17 by 17, and the HTP fuel design for 14 by 14, 15 by 15, and 16 by 16 bundles.

The topical report outline that you'll hear more about today from my colleague is basically we talk about neutronics, and the ARCADIA methodology, specifically the critical experiment comparisons. Chromia doped, chromia coating cladding uncertainty analysis, and we'll talk about thermal hydraulics, the CHF correlation, COBRA-FLX, and fuel rod bow.

The topical report outline will also talk about mechanical aspects. Materials, fuel rods, thermal, mechanical, fuel design, external loads, statistical hold down, cladding collapse, and fuel rod bow. We'll also talk about non-LOCA, specifically ARITA, and AREA, and also talk about LOCAs, small break, realistic large break, and the LOCA criteria. And then we'll also be spending some time talking about decay heat.

Okay, thank you, that ends my general session for this topic.

CHAIR MARCH-LEUBA: Let me ask you on the open session, one generic question about ARITA. Typically we always used approved versions of

methodology, and I think the staff is going to talk about that. From your point of view, why are we using a non-approved methodology, ARITA, for this particular case?

MS. ELLIOTT: Well, it was our expectation that ARITA would have been approved by now, so --

CHAIR MARCH-LEUBA: So, you basically handle the limitation condition that ARITA must be approved?

MS. ELLIOTT: It's my opinion that ARITA will not actually have to be published, as long as we have a draft safety evaluation for that, we should be able to reference that as well.

CHAIR MARCH-LEUBA: Well, it would be -- once you have a draft to see, it will be issued. If you have a draft SC that has not been issued, it would be very questionable to use it, because there was a problem with it.

MS. ELLIOTT: Well, the NRC's own internal processes basically state that draft SCs can be referenced in licensing applications. Certainly it's not the most -- it's not what we would like to do. But again, we were expecting to have ARITA approved by now. We should have a draft SC, Joe, you can correct me if I'm wrong, by the end of March. And so we would

certainly --

CHAIR MARCH-LEUBA: Okay, you see this is a problem of timing, instead of substance?

MS. ELLIOTT: Absolutely, absolutely.

CHAIR MARCH-LEUBA: Okay, thank you. I will drill the staff on that too, they're ready for it. So, staff, if you can stop sharing your screen, the staff can share theirs.

MEMBER BIER: One follow-up question Jose. This is Vicki Bier, are there other approved codes that could have been used that you think would have supported the same results, or are there unique features in ARITA that are really necessary for your analysis?

MS. ELLIOTT: Well, I'll speak to that, and ask my colleagues to jump in as well, but again, a number of years ago we committed to the NRC, that we were going to come to the NRC with updated codes, because as you know, some of our codes are on the older version, and we had committed to come to the NRC with newer codes, and more innovative codes. And so, that's what ARITA was doing.

And we want to use that route, instead of some of our older codes. So, again, this is a timing issue, and that preference certainly is to use the

ARITA, rather than relying on some of our older version codes.

MEMBER BIER: Thank you.

DR. SCHULTZ: Gayle, this is Steve Schultz. It seems as if the limitations, and conditions is associated with ARITA, and that also seemed to be a timing issue. That is to say, I would expect that Framatome would have liked that -- the issues of uncertainty associated with ARITA would have been addressed as part of this approval. Is that correct? I want to understand from Framatome's point of view, where that limitations, and conditions stands.

MS. ELLIOTT: Are you talking about all limitation conditions, or specific to ARITA? I can tell you this, again, ARITA has been under review for over four and a half years. So, as you can imagine, this is one that we were expecting to have already been reviewed, and approved by the NRC, and so this wouldn't have been an issue. Again, it's a timing issue. I'm not sure I answered your question though.

DR. SCHULTZ: Well, you're expecting though, that the SER is going to be issued with limitations, and conditions one, that you'll address the uncertainty issues later with the staff, is that

correct?

MS. ELLIOTT: I would imagine that was a correct statement, yes.

DR. SCHULTZ: Okay, thank you.

CHAIR MARCH-LEUBA: While we have Framatome on the line, it's not a problem in my mind, because we're not expecting to put a reload of greater than five percent next month, this is all in the future. By the time this topical report is implemented, we will have plenty of time to have our eye on the books. So, I don't see a problem, as I said, it's timing, not substance.

Anymore questions members? So, then let's move to the staff. And you need to -- good. The microphones are very oriented in the field of -- oh you're going to talk, so we're perfect. Introduce yourself.

MR. WISE: I am Brandon Wise, with the NRC's Nuclear Methods -- is this better? I am Brandon Wise with the NRC's Nuclear Methods and Fuel Analysis Branch, and I'll be presenting the safety evaluation for Framatome topical report ANP-10353P increased enrichment for pressurized water reactors, next slide please.

We'll begin with some background including

the current topical report, the concurrent topical report reviews, and the codes used, and how they relate to this increased enrichment topical report. I'll discuss some applicable regulations, and guidance, and move into the technical topics, which include neutronics, thermal hydraulics, mechanical, non-LOCA, LOCA, and decay heat, and then conclude with limitations, and conditions in the conclusion.

Next slide please. For some background, related increased enrichment industry is pursuing higher burn up, and increased fuel enrichment for cycle optimization, and more economic core designs, and Framatome specifically is seeking to expand the range of applicability of their advanced codes, and methods. This topical report is applicable to current burn up limits. Next slide please.

CHAIR MARCH-LEUBA: Let me ask you there, on that last bullet, it's applicable to current burn up limits because we're in the process of reviewing increased burn up limits. It's not because we have seen any problem.

MR. WISE: Well, Framatome hasn't presented any data that suggests that it would be applicable to higher burn ups, they sort of cut the limit at current limit.

CHAIR MARCH-LEUBA: There's a difference between knowing that it's a problem, and not knowing that it's okay. We're in the not knowing that it's okay.

MR. WISE: Right. There were two concurrent topical report reviews, the first of which being M5, which was related to -- I'll discuss that more in the mechanical section, but it was determined that there's no significant effect of increased enrichment on the review for the M5 topical report. The specific conclusions related to that will be discussed later.

As for the ARITA topical report, we did identify some issues with the uncertainty treatment of various parameters that could be affected by increased enrichment, and that was resolved using a limitation, and condition. Next slide please. There were several codes referenced in the increased enrichment topical report. There was ARCADIA for neutronics, which includes APOLLO2-A, ARTEMIS, and COBRA-FLX.

COBRA-FLX is for thermal hydraulics, there's the GALILEO code, ARITA, which is still under review, which includes ARTEMIS, GALILEO, and ESPIRIT-5. There's the SCALE code, which is used for decay heat analysis, which includes the TRITON and ORIGEN

modules. There's AREA for rod ejection accidents, and ORFEO-GAIA, and ORFEO-NMGRID for critical heat flux calculations.

Next slide please. Can you go back one slide? I want to mention that this topical report serves as a supplement -- as a sort of supplement to these, the Framatome approved codes, and methods, and doesn't fundamentally change the functionality of these codes greater than five percent, or less than five percent. So, for current applications of these codes, there is no change expected.

Next slide please. Some applicable regulations, and guidance, the two most significant regulations are 10 CFR 50.486 for ECCS acceptance criteria, and 10 CFR 50.68, which contains a limit on the maximum fuel enrichment. Also GDC10. As far as guidance, in the SRP there's fuel system design, nuclear design, thermal hydraulic design, review of transient, and accident analysis methods.

These SRP sections contain additional guidance, and regulations related to the increased enrichment topical report. I haven't listed them here. Additionally, this last bullet point is neither regulation, nor guidance, but is an Oak Ridge report related to the trends seen in increased burn up -- or

some enrichment, and higher burn up for PWR fuel.

The staff used this to better understand what to expect out of increased enrichment fuel, and I'll get into more detail about how the staff used that in the closed session. Starting with the first technical topic, neutronics, Framatome provided multi assembly problems which were referred to as color sets of cathected powers for multi assembly problems with varied enrichments, gadolinia loadings, and burn ups.

What is seen is that there's no significant change in uncertainty at increased fuel enrichments. This demonstrates that Framatome maintains acceptable predictive capability at enrichments greater than five percent. The staff reviewed the color set data, and found the increased enrichment color set results to be basically indistinguishable from those in previous submittals, which contain the more enriched color set results.

CHAIR MARCH-LEUBA: In this area I don't see the word criticality in this slide, do you want to address it?

MR. WISE: I omitted that for the open session, there's more detail in the closed session. But we see very similar results here, that there's similar predictive capability.

CHAIR MARCH-LEUBA: The prediction of K effective, which is criticality, is not affected significantly?

MR. WISE: Correct.

CHAIR MARCH-LEUBA: Thank you.

MR. WISE: Next slide please. For thermal hydraulics Framatome uses COBRA-FLX, which predicts departure from nuclear boiling using pressure flow quality, and heat flux, all of which are independent of uranium enrichment. The NRC determined that CHF Correlations, which are independent of enrichment may be applicable at increased enrichments.

Therefore, NRC staff determined that COBRA-FLX maintains acceptable predictive capability at increased fuel enrichments. Next slide please. In the mechanical section, component material performance is mostly independent of enrichment, and tends to be affected more by spools of burn up. Framatome methods that are independent of enrichment provide data demonstrating acceptability in the range of extended enrichment.

Or they're limited by fast fluence, and what the staff has determined that the end of life fast fluence for fuel of higher enrichments is lower than the end of life fast fluence with lower

enrichments, and I'll get into more detail as to the exact physics of why that is later. Therefore, the staff determined that methodologies related to component material performance maintain acceptable predictive capability at increased fuel enrichments.

Next slide please. For the non-LOCA evaluation, Framatome determined that ARITA, and AREA have been demonstrated to have acceptable predictive capability at increased fuel enrichments. However, the NRC staff determined that the uncertainty treatment of various parameters in the ARITA methodology were not adequately discussed in this increased enrichment topical report.

And we wanted to see additional justification as to the applicability of those uncertainty treatments, especially as ARITA is a yet unapproved topical report.

CHAIR MARCH-LEUBA: And here -- no, go ahead.

DR. SCHULTZ: Brandon, was there an RAI issued to Framatome related to this, or was it just determined that we'll handle it later?

MR. WISE: There was not an RAI, we had an audit in August of 2022 to discuss this matter, and it was determined that a limitation, and condition was

the approach that Framatome wanted to take.

DR. SCHULTZ: Okay, so that came from Framatome, and would be addressed later?

MR. WISE: Yes.

DR. SCHULTZ: Thank you.

CHAIR MARCH-LEUBA: And procedurally, you expect this to be addressed only once for the first application, not for every single application, even though the limitation, and condition would apply to every application?

MR. WISE: It's sort of up to Framatome, these are generic parameters. So, it could be addressed in a plant specific application, a supplement is really open ended as to how Framatome wants to address this.

CHAIR MARCH-LEUBA: Up to them, okay, thank you.

MR. WISE: I'll stress that these, the uncertainty treatment of these parameters are all generic in nature. There's already a limitation, and condition in -- there will be plant specific, and parameters will be addressed on a plant specific basis.

CHAIR MARCH-LEUBA: Yeah, I presume the lawyers would prefer that you make one specific

limitation, and condition, then later you release, instead of saying we approve this SER, but it's incomplete.

MR. WISE: Yeah.

MEMBER REMPE: Jose, could Brandon restate what his last -- the end of his sentence cut off remotely, and I couldn't quite hear what he said.

CHAIR MARCH-LEUBA: Can you repeat what you said?

MR. WISE: Yes, so the limitation, and condition one addresses generic parameters only. Plant specific parameters would be addressed on a plant specific basis, and that's consistent with the ARITA topical report.

MEMBER REMPE: Okay, thank you.

MR. WISE: Next slide please. As for the LOCA evaluation, Framatome identified no new phenomena associated with increased enrichment, and the codes, and inputs used in the LOCA analysis have been demonstrated to be acceptable at increased enrichments. The NRC determined that the 10 CFR 50.46 ECCS acceptance criteria, and the codes used in LOCA analysis maintain -- let me restate that.

The 50.46 ECCS acceptance criteria remain applicable at higher enrichments, and the codes, and

methods that Framatome uses in their LOCA analysis maintain acceptable predictive capability at increased fuel enrichments. Therefore, the NRC staff determined that Framatome's LOCA methodologies are acceptable at increased fuel enrichments.

Next slide please. For decay heat, current decay heat models, and standards remain acceptable for Framatome methods, and increased enrichments, that was Framatome's evaluation. The NRC looked at the specific phenomena associated with increased enrichment on decay heat, and found that Framatome's methodologies accurately modeled those phenomena.

Specifically that the decay heat at initial shut down times is slightly higher, and levels off after some period of time, and then for much later periods of time it is a bit lower. Therefore, those Framatome methodologies accurately predict the phenomena, and decay heat, they maintain acceptable predictive capability at increased fuel enrichments.

DR. SCHULTZ: And Brandon, maybe you'll catch it in the next slide, but all of this is presuming that we're staying within the current burn up limitations associated with the fuel?

MR. WISE: That's correct, yes.

DR. SCHULTZ: Thank you.

MR. WISE: There are much different decay heat trends associated with increased burn up.

CHAIR MARCH-LEUBA: Yeah, that's a good question, because you're in the process of reviewing increased burn up for some vendors, and definitely we'll do it for Framatome. So, remember to consider decay heat during that review.

MR. WISE: Yes, it is expected that -- I mean I've been combining increased enrichment, and increased burn up, that the combined effect is what we considered.

CHAIR MARCH-LEUBA: It's easily overlooked when you're doing increased burn up, you're thinking about mechanical, and fuel fragmentation, you don't think about decay heat.

MR. WISE: Yes, there is a graph that will show the decay heat trends at increased burn up in the closed session. For the limitation, and condition I'll read it off. The uncertainty treatment burn up parameters that may be affected by increased enrichment in ANP-10339P, that is ARITA, have not been approved for use at fuel enrichments greater than five weight percent uranium-235.

If you implement ARITA with increased fuel

enrichment, the parameters listed below must have the applicability of their uncertainty treatment further justified for use at fuel enrichments greater than five weight percent U-235. I did not include that list of parameters in this open session, because it is proprietary, so we'll discuss that in the closed session.

But this is the justification for proving this topical report, and moving forward with this topical report without first having approved ARITA. Next slide please. The second limitation, and condition, ANP-10353P is applicable only to the following PWR fuel assembly designs, GAIA 17 by 17, HTP 15 by 15 designs for Westinghouse plants, and HTP 14 by 14, and HTP 16 by 16 for Combustion Engineering plants.

ANP-10353P may be used with other fuel assembly designs with sufficient technical justification, and the applicability of ANP-10353P to the assembly design. These are the same assembly designs that Framatome requested in their topical report, so it was no more restricted than their topical report was submitted. Next slide please.

CHAIR MARCH-LEUBA: It's actually, the last sentence is good, it provides a path to license

the 18 by 18 if necessary.

MR. WISE: In conclusion, the NRC staff determined that Framatome codes, and methods are acceptable for evaluating fuel with increased enrichment, because they maintain acceptable predictive capability in the range of increased enrichment, with the exception of course, for the limitation, and condition associated with ARITA. That will conclude my presentation.

CHAIR MARCH-LEUBA: Any questions from members on the MS Teams line? I see no questions from the room. And I don't remember if I put it on the record that Member Brown joined us, he did. At this point I'm going to open the line for any members of the public that want to make a comment. Remember, it's just comments to place on the record. So, if so, unmute yourself, and place the comment.

We hear no comments, this will conclude the open session of the meeting, and we are going to transfer to the closed one. So, the transcript is off, we are in recess.

(Whereupon, the above-entitled matter went off the record at 9:01 a.m.)

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ANP-10353P, Revision 0
Increased Enrichment for PWRs

Morris Byram

ACRS Subcommittee

February 15, 2023

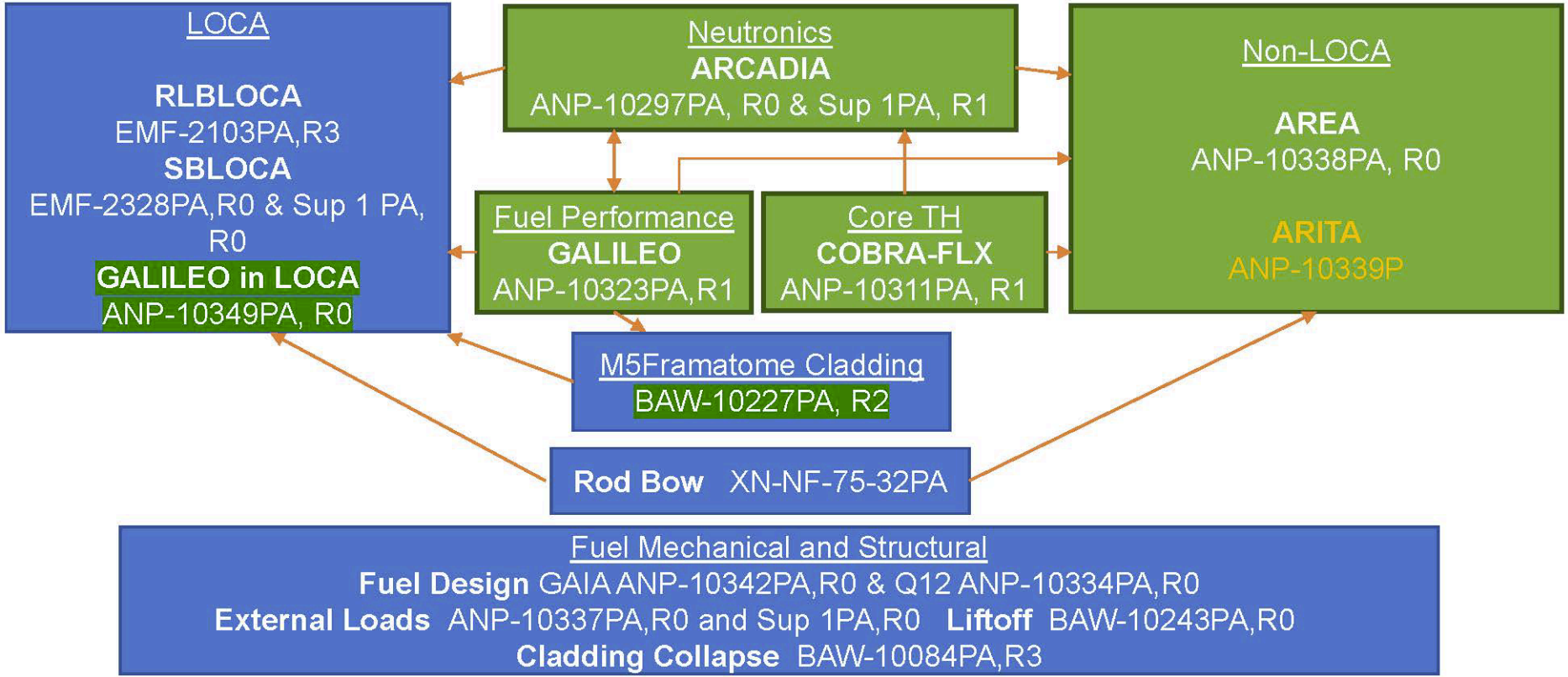
Agenda

- Key Milestones
- Advanced Codes and Methods Topical Reports
- Approval Request and Applicable Fuel Designs
- Topical Report Outline

Key Milestones

- Pre-submittal meeting: April 2020
- Submitted ANP-10353 for review: January 2021
- Accepted for review: March 2021
- Audit for Understanding: September 2021
- RAIs received: September 2021
- Submitted RAI Responses: January 2022
- Audit, ARITA Parameters: August 2022
- Draft SE: December 2022

Framatome PWR Codes and Methods Overview



Only major methodology connections shown

Approval Request

Increased enrichment above 5 wt% U-235

Supported Fuel Designs

- GAIA 17x17
- HTP 15x15
- HTP 14x14
- HTP 16x16

Topical Report Outline

- Neutronics (ARCADIA)
  - Critical Experiment Comparisons
  - Chromia Doped / Chromium-Coated Cladding
  - Uncertainty Analysis

- Thermal Hydraulics
  - CHF Correlation
  - COBRA-FLX
  - Fuel Rod Bow

Topical Report Outline

- Mechanical
  - Materials
  - Fuel Rod Thermal-Mechanical
  - Fuel Design
  - External Loads
  - Statistical Hold Down
  - Cladding Collapse
  - Fuel Rod Bow

Topical Report Outline

- Non-LOCA
  - ARITA
  - AREA
- LOCA
  - SBLOCA
  - RLBLOCA
  - LOCA Criteria
- Decay Heat

Acronyms

AREA – ARCADIA Rod Ejection Accident

ARITA – ARTEMIS/RELAP Integrated Transient Analysis

CE – Combustion Engineering

CHF – Critical Heat Flux

CROV – Framatome's Creep Ovalization Analysis Code

EM – Evaluation Model

FPC – Fuel Performance Code

LBLOCA – Large Break Loss of Coolant Accident

LB - Large Break

LOCA – Loss of Coolant Accident

NRC – U.S. Nuclear Regulatory Commission

PWR – Pressurized Water Reactor

RLBLOCA – Realistic Large Break Loss of Coolant Accident

SB – Small Break

SBLOCA – Small Break Loss of Coolant Accident

W - Westinghouse

DOE Acknowledgment and Disclaimer

Acknowledgment: “This material is based upon work supported by the Department of Energy under Award Number DE-NE0008818.”

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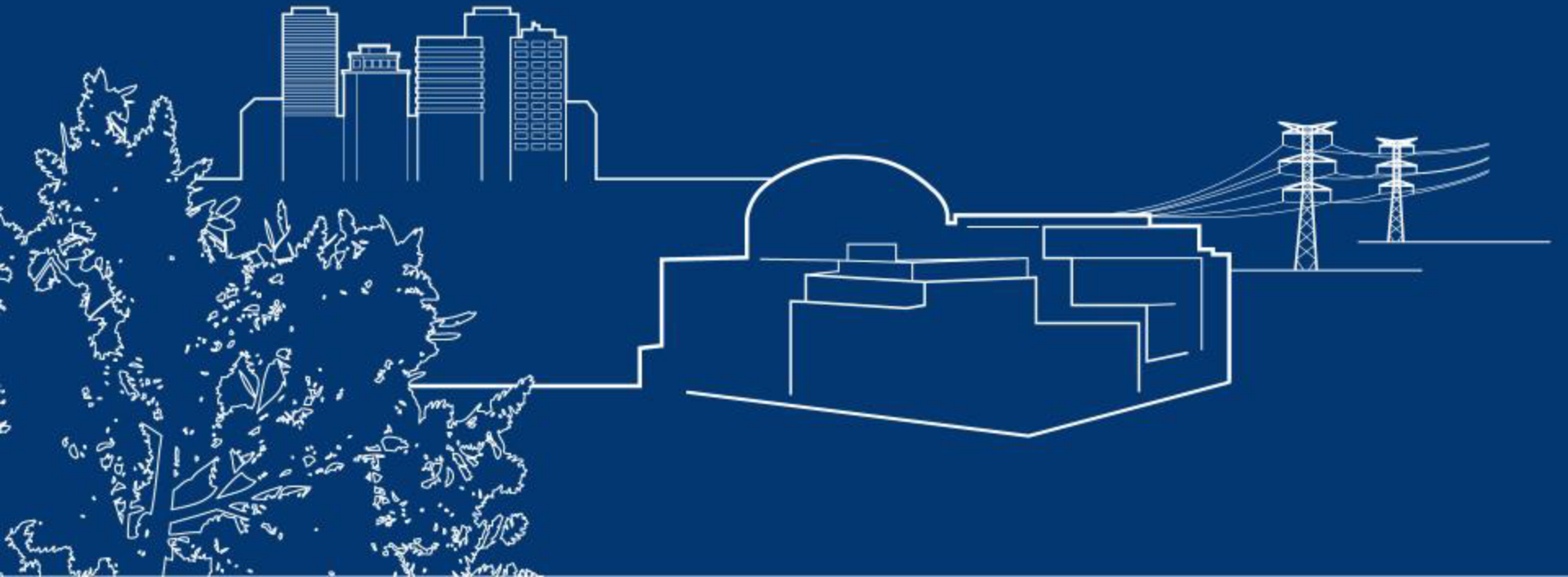

NRC Safety Evaluation of Topical Report ANP-10353 Increased Enrichment for PWRs

Open Session

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Background

- Industry pursuing higher burnup and fuel with increased enrichment for cycle optimization.
- Framatome seeks to expand the range of applicability of enrichment for their codes and methods.
- This TR is applicable for current burnup limits.

Concurrent TR Reviews

- BAW-10227P, Revision 2, “Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel,” December 2019.

- ANP-10339P, Revision 0, “ARITA – ARTEMIS/RELAP Integrated Transient Analysis Methodology,” August 2018.

Codes Used

- ARCADIA (APOLLO2-A, ARTEMIS, COBRA-FLX)
  - Approved 2013, Supplement Approved 2018
- GALILEO
  - Approved 2020
- ARITA (ARTEMIS, GALILEO, S-RELAP5)
  - Under Review, See L&C 2
- SCALE 6.2.3 (TRITON, ORIGEN)

- AREA
  - Approved 2017
- ORFEO-GAIA / ORFEO-NMGRID
  - Approved 2018

Applicable Regulations and Guidance

- 10 CFR 50.46, “Acceptance Criteria for Emergency Core Cooling Systems (ECCS) for Light-Water Nuclear Power Reactors”
- 10 CFR 50.68, “Criticality Accident Requirements”
- 10 CFR Part 50 Appendix A, “General Design Criteria for Nuclear Power Plants, “ General Design Criterion (GDC) 10, “Reactor Design”
- Chapter 4.2, “Fuel System Design,” of the Standard Review Plan (SRP)
- Chapter 4.3, “Nuclear Design,” of the SRP
- Chapter 4.4, “Thermal and Hydraulic Design,” of the SRP
- Chapter 15.0.2, “Review of Transient and Accident Analysis Methods,” of the SRP
- ORNL/TM-2020/1833, “Isotopic and Fuel Lattice Parameter Trends in Extended Enrichment and Higher Burnup LWR Fuel, Vol I: PWR Fuel”

Neutronics

- Framatome Evaluation
  - Provided colorsets of calculated pin powers for multi-assembly problems with varied enrichments, gadolinia loading, and burnups.
  - No significant change in uncertainty at increased fuel enrichments
- NRC Evaluation
  - Reviewed the provided colorset data and found the increased enrichment colorset results to be basically indistinguishable from lower enriched colorset results.
- Conclusion
  - The NRC staff determined that ARCADIA maintains acceptable predictive capability at increased fuel enrichments.

Thermal Hydraulics

- Framatome Evaluation
  - COBRA-FLX predicts DNB using pressure, flow, quality, and heat flux. All of which are independent of U-235 enrichment.
- NRC Evaluation
  - CHF correlations that are independent of enrichment are acceptable for use at increased enrichments.
- Conclusion
  - The NRC staff determined that COBRA-FLX maintains acceptable predictive capability at increased fuel enrichments.

Mechanical

- Framatome Evaluation
  - Component and material performance is mostly independent of enrichment and tends to be affected more by fluence and burnup.
- NRC Evaluation
  - Framatome methods that are independent of enrichment, provide data demonstrating acceptability in the range of extended enrichment, or are limited by fast fluence remain applicable at increased enrichments.
- Conclusion
  - The NRC staff determined that methodologies related to component and material performance maintain acceptable predictive capability at increased fuel enrichments.

Non-LOCA

- Framatome Evaluation
  - The codes and inputs to ARITA and AREA have been demonstrated to be acceptable at increased enrichments and their use in the ARITA and AREA methodologies are unchanged.
- NRC Evaluation
  - The uncertainty treatment of some parameters that may be affected by increased enrichment were not adequately addressed in the ARITA methodology.
- Conclusion
  - L&C 1 requires Framatome to provide additional justification to apply increased enrichment to ANP-10339P. The NRC staff determined that AREA maintains acceptable predictive capability at increased fuel enrichments.

LOCA

- Framatome Evaluation
  - No new phenomena associated with increased enrichment were identified. The codes and inputs used in LOCA analyses have been demonstrated to be acceptable at increased enrichments.
- NRC Evaluation
  - An increase enrichment doesn't challenge the 10 CFR 50.46 ECCS acceptance criteria and the codes used in LOCA analyses maintain acceptable predictive capability at increased fuel enrichments.
- Conclusion
  - The NRC staff determined that Framatome's LOCA methodologies are acceptable for use at increased enrichments.

Decay Heat

- Framatome Evaluation
  - Current decay heat models and standards remain applicable for Framatome methods at increased enrichments.
- NRC Evaluation
  - Studies show that decay heat at increased enrichments tends to be very similar or slightly lower than decay heat at lower enrichments except for the initial decay heat.
- Conclusion
  - Current decay heat models, as used by Framatome methods, maintain acceptable predictive capability at increased fuel enrichments.

Limitation and Condition 1

The uncertainty treatment of parameters that may be affected by increased enrichment in ANP-10339P have not been approved for use at fuel enrichments greater than 5 wt% U-235. To implement ANP-10339P with increased enrichment, the parameters listed below must have the applicability of their uncertainty treatment further justified for use at fuel enrichments greater than 5 wt% U-235.

Limitation and Condition 2

ANP-10353P is applicable only to the following PWR fuel assembly designs: GAIA 17x17 and HTP 15x15 designs for Westinghouse plants, and HTP 14x14 and HTP 16x16 designs for Combustion Engineering plants. ANP-10353P may be used with other fuel assembly designs with sufficient technical justification for the applicability of ANP-10353P to the assembly design.

Conclusion

The NRC staff determined that Framatome codes and methods are acceptable for evaluating fuel with increased enrichment because they maintain acceptable predictive capability in the range of increased enrichment.

Acronyms

AOO – Anticipated Operational Occurrence

AREA – ARCADIA Rod Ejection Accident

ARITA – ARTEMIS/RELAP Integrated Transient Analysis

CFR – Code of Federal Regulations

CHF – Critical Heat Flux

C-M – Calculated - Measured

DNB – Departure from Nucleate Boiling

ECCS – Emergency Core Cooling System

EM – Evaluation Model

FFRD – Fuel Fragmentation Relocation and Dispersal

GDC – General Design Criterion

HTP – High Thermal Performance

LOCA – Loss of Coolant Accident

LWR – Light Water Reactor

MSLB – Main Steam Line Break

ORNL – Oak Ridge National Lab

PWR – Pressurized Water Reactor

RLBLOCA – Realistic Large Break Loss of Coolant Accident

SBLOCA – Small Break Loss of Coolant Accident

SRP – Standard Review Plan

T-H – Thermal-Hydraulics

TR – Topical Report