# Official Transcript of Proceedings

# NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguards

Docket Number: (n/a)

Location: teleconference

Date: Thursday, March 2, 2023

Work Order No.: NRC-2290 Pages 1-43

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**(202) 234-4433**

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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703RD MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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THURSDAY

MARCH 2, 2023

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The Advisory Committee met via video-teleconference at 8:30 a.m., Joy L. Rempe, Chairman, presiding.

COMMITTEE MEMBERS:

JOY L. REMPE, Chairman
WALTER L. KIRCHNER, Vice Chairman
DAVID A. PETTI, Member-at-Large
RONALD G. BALLINGER, Member
VICKI M. BIER, Member
CHARLES H. BROWN, JR., Member
VESNA B. DIMITRIJEVIC, Member
GREGORY H. HALNON, Member

JOSE A. MARCH-LEUBA, Member
MATTHEW W. SUNSERI, Member

ACRS CONSULTANTS:
DENNIS BLEY
STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:
MATTHEW SNODDERLY

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

(8:30 a.m.)

CHAIRMAN REMPE: Good morning. It's 8:30 on the East Coast. I hear an echo that is going to disappear now. This meeting will now come to order.

This is the first day of the 703rd meeting of the Advisory Committee on Reactor Safeguards. I am Joy Rempe, the Chairman of the ACRS. Other members in attendance are Ron Ballinger, Vicki Bier, Vesna Dimitrijevic, Greg Halnon, Walt Kirchner, Jose March-Leuba, Dave Petti, and Matt Sunseri. We expect to be joined by Member Charles Brown soon.

We do have a quorum and today the Committee is meeting in person and virtually. The ACRS was established by the Atomic Energy Act and is governed by the Federal Advisory Committee Act. The ACRS Section of the U.S. NRC public website provides information about the history of this Committee and documents such as our charter, bylaws, Federal Register Notices for meetings, letter reports, and transcripts of all full and subcommittee meetings, including all slides presented at these meetings. The Committee provides its advice on safety matters to the Commission through its publicly available letter reports.

The Federal Notice announcing this meeting was published on February 14, 2023. This announcement provided a meeting agenda as well as instructions for interested parties to submit written comments or request opportunities to address the Committee.

The Designated Federal Officer for today's meeting is Mr. Mike Snodderly. A communications channel has been opened to allow members of the public to monitor the open portions of the meeting.

The ACRS invites members of the public to use the MS Teams link to view slides and other discussion materials during these open sessions. The MS Teams link information was placed in the Federal Register Notice and the agenda on the ACRS public website.

We have received no written comments or requests to make oral statements from members of the public regarding today's session. However, the meeting will be periodically opened to accept comments from participants listening to our meetings. Written comments may also be forwarded to Mr. Mike Snodderly.

During today's meeting the Committee will consider the following topics: Framatome topical report on increased enrichment for pressurized water reactors, and then we'll be following that with our planning and procedures and meetings. Note that portions of the Framatome topical report discussion may be closed, as stated in the agenda.

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

Before we start the first topic today I will ask members if they have any opening remarks.

Hearing none, I then would like to ask Member March-Leuba to lead us in our first topic for today's meeting. Jose.

MEMBER MARCH-LEUBA: Thank you. The topic as you can see on the screen is the increased enrichment for PWRs by Framatome.

This is a very important topic and I think everybody has done a good job in carrying it to fruition. It is going to increase the enrichment from the current approved 5 percent to a higher level.

Without much ado I am going to allow the Staff, MJ Ross-Lee to make introductory remarks. MJ, you can go ahead.

MS. ROSS-LEE: Good morning and thank you.

My name is MJ Ross-Lee. I am the Deputy Division Director for the Division of Safety Systems in NRR. You will hear from my staff today as part of the presentation.

This topical report is a first of the kind for increasing enrichment beyond 5 weight percent U-235 in PWRs. This topical report is applicable only to current burnup limits and does not address any effects of higher burnup.

I would like to commend Framatome for doing their part in submitting a high-quality topical report and responding to RAIs in a timely manner which aids in an efficient and effective review.

The topical report topics span nearly every aspect of fuel performance and design extending the enrichment limit for over 20 topical reports.

With that, I will turn it back over to Staff. Thank you.

MEMBER MARCH-LEUBA: Thank you, MJ. Now I would like to give the floor to Framatome. I believe Gayle Elliott is going to give us some introductory remarks and then introduce the presenters. Gayle.

MS. ELLIOTT: Good morning. I am Gayle Elliott from Framatome. I am the Director of

Licensing & Reg Affairs here.

I would first like to welcome to all who are attending our discussion today on Framatome's topical report on increased enrichment for PWRs, both the ACRS Full Committee, the NRC, and our own folks here at Framatome.

This topical report is the result of the efforts of our field organizations, Michelle Guzzardo, Keith Maupin, Jim Hoerner, and Morris Byram, and our Licensing & Reg Affairs organization.

I would just like to say that their time and efforts resulted in a quality submittal to the NRC in January of 2021 and NRC's review of the report in approximately two years, so thank you all for your efforts in this.

I would also like to recognize the NRC reviewers for their efforts to perform a detailed review of the report and the timely and efficient manner in which they performed their review.

This topical report was successfully reviewed in about two years, which I think is certainly reasonable for the manner in which this topical report (audio interference).

I would just note Framatome's objective is to give innovation and improved performance methods to the industry and with our submittal and the NRC's review is as cohesive and efficient as the review on this topical report then we are able to meet that objective, so thank you NRC reviewers for that.

As we continue to work towards quality reports for all of their submittals I would like to encourage the NRC to continue to develop your reviewers to be able to perform audits for understanding that result in a draft essay during the audit or the short duration afterwards.

I understand that some of our topical reports are more complex than others, but we have found that if there is a large time lapse between audits and discussions with our subject matter experts then context and understanding may not be as distinct.

So for this topical report again thank you all, both Framatome and NRC Staff for the quality report that was submitted and the efficient review that was performed at the NRC. That concludes my remarks.

MEMBER MARCH-LEUBA: Okay. So now we'll have the presentation by Framatome. It's either Michelle or Morris.

MR. BYRAM: Yes.

MEMBER MARCH-LEUBA: We can see your

slides.

MR. BYRAM: Yes. Can everyone hear me?

MEMBER MARCH-LEUBA: Yes, we can.

MR. BYRAM: Great. This is Morris Byram. I have the slides up on the screen for everyone. I apologize, I am on the phone only today. I have technical difficulties, probably not enough bandwidth for what I have going on. Do we have the slides up?

MEMBER MARCH-LEUBA: We have the slides up.

MR. BYRAM: Okay, great. Okay. This is Morris Byram and I am Product Manager for Framatome for this topical report and Michelle Guzzardo is with me today and she is going to be speaking to the slides after I am finished.

Okay, on Slide 2 we are going to talk the agenda, key milestones, advanced codes and methods topical reports review. We are going to talk about the approval requests and applicable fuel designs. Michelle then will start with the major topic evaluations and deliver the summary.

First, Slide 3, the key milestones for this topical report pre-submittal meeting was April 2020. We submitted the ANP-10353 for review in January of 2021. It was accepted for review in March of 2021.

The Audit for Understanding was held in September of 2021. RAIs were received September 2021. We submitted the RAI responses in January of 2022, another audit occurred on the ARITA parameters that might be impacted in August of 2022, and we received the draft SE in December 2022.

Next slide, please. What you see on this slide before you are the Framatome PWR codes and methods that will be used with the increased enrichment topical report for submittals.

Notice, please, that grouped in the boxes here of the different types of analyses, LOCA, non-LOCA, neutronics, fuel performance, core TH, N5 Framatome cladding, the rod bow and the fuel mechanical and structural topical reports.

All of these topical reports are approved except for the ARITA topical report over in the non-LOCA box. That is close to being approved and that is part of the discussion that we had in the last audit that we had for this topical report of how they work together and the inputs that are, the parameter of uncertainties that are possible affected.

The blue in the boxes indicate the older codes. The green background indicates the newer codes. Notice in the LOCA area one of the latest to be approved is GALILEO in LOCA, ANP-10349, PA REV-0.

Also, the N5 Framatome cladding was revised, REV-2. If you will notice the arrows and the orange lines between boxes indicates the flow of information between the approved topical reports.

Note that not all of the connections are noted here, just the major ones. So are there any questions on this slide?

MEMBER MARCH-LEUBA: If you don't hear anything for five seconds keep going.

MR. BYRAM: Okay. The next slide, the approval requests for a list for increased enrichment above 5 percent U-235, there is no change that was requested for the current license burnup limits.

It supports fuel designs of GAIA 17x17, HTP 15x15 for the Westinghouse plants, and HTP 14x14 and 16x16 for the combustion engineering plants.

Now the next slide Michelle is going to start with the evaluations. Michelle.

MS. GUZZARDO: Thank you, Morris. As you can see on the first slide here -- We are on Slide 6, Morris.

MR. BYRAM: Okay.

MS. GUZZARDO: The neutronics discipline

included mostly for the ARCADIA code package, the ARCADIA code package consists of several things but mostly the APOLLO2 code, which is the cross-section generator, and ARTEMIS, which is the nodal simulator.

So to extend the range of the ARCADIA code package additional critical experiments were modeled and comparisons made to the measurement which extended that range of enrichments to greater than 5 weight percent.

We also discussed a bit of the impact on the codes and how the codes can handle the chromium doped and chromium-coated cladding materials within the advanced, the ATF arena.

Colorsets were performed in the original ARCADIA evaluations. These are 4x1/4 assembly comparisons that tested some of the ARTEMIS features and we added some of these colorsets with fuels greater than 5 weight percent and we combined the results with the existing colorset calculations to show that the ARCADIA uncertainty analyses remain applicable.

We also looked at the detector behavior sensitivity and lifetime to show that they remain applicable for greater than 5 weight percent U-235 since detectors are an important part of the measurement system in the cores.

The neutronic summary says that the ARCADIA code system is acceptable for use of fuel enrichments greater than 5 weight percent U-235.

The next discipline we looked at was thermal hydraulics.  This includes the critical heat flux correlations, the COBRA-FLX code, and the fuel rod bow penalties.

We found that the thermal hydraulic components shown above are applicable to fuels with greater than 5 weight percent U-235 since the correlations and the property used within the codes are dependent of enrichment.

The mechanical disciplines contain quite a few different sub-disciplines, if you will, and these include the materials the fuel rod thermal mechanical code, GALILEO, different fuel designs, external loads, statistical hold down, cladding collapse, and fuel rod bow.

Each of these disciplines was looked at thoroughly and evaluated.  As you can see on this slide the materials and methodologies generally depend on the argument for fast fluence.

The fast fluence does decrease as U-235 enrichment increases.  So for the same burnup limit the current end of life fluence and fluxes are bounding with the lower enriched fuel.

Though the remaining parameters and methodologies that are not dependent on fast fluence or flux are independent of U-235 enrichment except for the GALILEO code.

The GALILEO code has several benchmarks, which included fuel center line melt benchmarks, fission gas release benchmarks, internal pressure, rod volume, things like that, and those benchmarks contain data that bound the enrichment that is being requested.

So for the mechanical discipline all methodologies and materials that were evaluated are acceptable for greater than 5 weight percent enrichment.

The next methodology that we -- The next discipline we looked at was the non-LOCA category and this included ARITA and AREA. The ARITA methodology incorporates the ARCADIA code package, decay heat models, the COBRA-FLX code, the ARTEMIS, fuel rod model, and GALILEO, as well as the S-RELAP5 code.

All of these were shown to be applicable to fuel with greater than 5 weight percent enrichment or they are not dependent on enrichment.

We also evaluated neutronics and thermal key parameters and noted that the generation of these parameters were not affected by enrichment. Basically what I mean by that no code changes were required to evaluate these parameters with greater than 5 weight percent fuel.

There was an audit held with the NRC in August of 2022 in which the uncertainties associated with some of these key parameters could be affected by increased enrichment.

That discussion led to Limitation and Condition 1, which you have to look at the parameters that have to be justified before their uncertainty treatment can be used in the ARITA process, and I believe the NRC will talk more about that in their presentation.

The next methodology in the non-LOCA discipline is AREA, it's rod eject methodology. This methodology includes ARCADIA, GALILEO, COBRA-FLX, and the S-RELAP code, I'm sorry, RELAP5 code.

All of these again were shown to be applicable to fuel with greater than 5 weight percent or they are not dependent on enrichment.

Similar to ARITA, the neutronics and thermal key parameters were reviewed and generations of these parameters were not affected by enrichment.

We pointed out that the methodology for AREA was designed to be consistent with the regulatory guidance and is flexible enough to handle any changes that come with that regulatory guidance, regulatory guidance being REG Guide 1.236, and we found that that guidance was applicable for enrichments greater than 5 weight percent.

The next discipline is LOCA and -- small break LOCA and realistic large break LOCA. Both of these methodologies rely on GALILEO and S-RELAP5. Again, both of these codes were shown to be independent of enrichment or already applicable.

For both small break LOCA and realistic large break LOCA the evaluation models were reviewed for important fuel-related phenomena and is shown to remain valid for fuel with greater than 5 weight percent U-235.

It was noted that the small break LOCA evaluation model used a specific enrichment within the GALILEO input and that was updated to be more generic for greater than 5 weight percent U-235 with no impact on results. It was also noted that for LOCA the relevant 10 CFR 50.46 limits remain applicable.

There are several decay heat models used within the methodologies that were discussed. We evaluated these models using TRITON to determine the best estimate effects of decay heat with U-235 enrichment and all current decay heat models used within the methodologies remain valid for use with fuels having enrichments greater than 5 weight percent U-235.

So in summary, all the codes and methods discussed in ANP-10353 are acceptable for use with fuel enrichments greater than 5 weight percent U-235.

MEMBER HALNON: Michelle, this is Greg Halnon. Could you -- back on-- you don't have to go back to any slides, but statistical hold-down, can you give me a brief description of what that is and how the enrichment is affected by it?

MEMBER MARCH-LEUBA: It's Slide 8.

MS. GUZZARDO: Yes.

MEMBER HALNON: I'm not familiar with the term.

MS. GUZZARDO: Jim is on the line and Jim is our mechanical expert. Jim, do you have -- would you like to say some words on this?

MR. HOERNER: Michelle, this is not my discipline, it's pure mechanical. I am thermal mechanical.

MS. GUZZARDO: Okay.

MR. HOERNER: Buck, can you help with this one?

MEMBER MARCH-LEUBA: Maybe, Brandon, do you know what it is? Can the staff help and give us a line?

MEMBER HALNON: I didn't mean to ask a stumping question.

MR. BARNER: I can talk to this one. It's the assembly hold-down analysis. It's just the --

MEMBER HALNON: Who is talking?

MR. BARNER: Oh, sorry. This is Buck Barner.

MEMBER HALNON: Very good. I'm sorry. I interrupted you because I wasn't familiar with your voice. Could you try the definition again?

MR. BARNER: Yes. This is Buck Barner. The statistical hold-down analysis is the assembly hold-down analysis, so it's independent of enrichment. It's a mechanical analysis for --

MEMBER HALNON: Okay. So it's not affected by enrichment?

MR. BARNER: Correct.

MEMBER HALNON: Okay. That will suffice. I will look it up for more detail later. Thanks.

MR. BARNER: Yes.

MS. GUZZARDO: Thank you, Buck.

MEMBER MARCH-LEUBA: Just in principle, the weight of the assembly changes by a little bit, you're replacing 238 by 235 --

(Simultaneous speaking.)

MEMBER HALNON: Well, there is spring tension, I mean compression.

MEMBER MARCH-LEUBA: Yes.

MEMBER HALNON: There is mechanical hold downs, there is, you know, expansion of the whole assembly. I can see where it could be affected, but I just didn't understand how that was factored into this decision.

MEMBER KIRCHNER: It's the rods. The rods are held by the --

(Simultaneous speaking.)

CHAIRMAN REMPE: Folks, use your mics.

MEMBER KIRCHNER: -- and so you wouldn't expect the enrichment to have any impact on that kind of mechanical behavior. As Jose said there is negligible changed in weight and the same flow horses and other structural loads are the same essentially.

MEMBER HALNON: Okay. Thanks, Walt.

MEMBER MARCH-LEUBA: Okay. I believe we

have reached the end of the presentation. Does Framatome want to make additional comments?

Michelle?

MS. GUZZARDO: I'm sorry. What was the question?

MEMBER MARCH-LEUBA: I believe you reached the end of your presentation before we asked you the question, correct?

MS. GUZZARDO: Yes, sir.

MEMBER MARCH-LEUBA: And do you want to make -- anybody at Framatome want to make additional comments?

MS. GUZZARDO: No, I'm good.

MEMBER MARCH-LEUBA: Okay. So with that we will transfer the microphone to the staff on this. Switch slides.

MEMBER KIRCHNER: Jose, may I ask one clarification question of Framatome?

MEMBER MARCH-LEUBA: You certainly may.

MEMBER KIRCHNER: You listed in your slide deck the different field geometries that the methods are applicable for. Is GAIA 17x17 a successor to HTP 17x17? I am not sure I know your nomenclature for your fuel bundles. Is it of generic applicability to 17x17 bundles?

MS. GUZZARDO: Both the GAIA and the HTP designs are currently in use. I don't know if that answers your question or not.

MEMBER KIRCHNER: Well I was curious whether this methodology is also applicable then to an HTP 17x17 fuel configuration.

MS. GUZZARDO: We would have to provide additional justification to go there because we are only including the four designs that were listed.

MEMBER KIRCHNER: Thank you.

MEMBER MARCH-LEUBA: Since I was in the Subcommittee and I know a little more about it, can you explain to us what would be the process that you will use to, for example, license HTP 17x17? The SE allows you to do that, correct?

MS. GUZZARDO: Yes.

MEMBER MARCH-LEUBA: And this process, can you explain to us what process you will follow?

MS. GUZZARDO: All right. So we have a process that is contained within a different topical report that we would follow to extend the range of applicability to do it a different fuel design.

Morris, do you have more to say on that?

MEMBER MARCH-LEUBA: We'll handle it from there during this presentation -- I will leave you.

Anymore questions for Framatome?

MR. BYRAM: Jose, this is Morris Byram. We can get back with you on that question and answer to that.

MEMBER MARCH-LEUBA: No, I think -- I was giving you kind of a leading question that the SE, the Safety Evaluations report, allows you to extend this to other fuels and there is a procedure to do that. The staff will discuss that. You don't need to follow up.

So let's have the staff slides. Brandon, is that you?

MR. WISE: Yes, sir.

MEMBER MARCH-LEUBA: State your name.

MR. WISE: I am Brandon Wise with the NRC's Nuclear Methods and Fuel Analysis Branch. I will be presenting the staff safety evaluation for Topical Report AMP-10353, Increased Enrichment for PWRs.

Next slide, please. I will begin discussing the background of why industry is pursuing increased enrichment as well as some specifics related to Framatome and its topical report.

I will also discuss some concurrent topical report reviews as well as the codes used to justify the increased applicability for enrichment based off of reports.

I will then discuss some applicable regulations and guidance and then move into the technical topics associated with increased enrichment. These include neutronics, thermal hydraulics, mechanical, non-LOCA, LOCA, decay heat, and then I will conclude the presentation with a discussion on limitations and conditions and the staff's final safety conclusion.

Next slide, please. For the background, industry is pursuing higher burnup and increased fuel enrichment for cycle optimization and more economical core designs.

Specifically, Framatome is seeking to expand the range of applicability of enrichment for their codes and methods to a value greater than 5 weight percent and this topical report is applicable only to current burnup limits.

Next slide, please. This increased enrichment topical report was reviewed concurrently with two other topical reports. The first is the Framatome N5 topical report.

The staff determined for the reasons that we'll discuss in the mechanical section that there was no significant impact on the review, on the concurrent review of these two topical reports.

As for ARITA, the staff did determine some concerns about doing a concurrent review and this resulted in Limitation and Condition Number 1, which we discussed towards the end of the presentation.

Next slide, please. The codes Framatome used to justify the increased applicability for the enrichment for their codes and methods include ARCADIA for the neutronics and thermal hydraulics analysis, GALILEO for fuel performance, ARITA for non-LOCA transient analysis and non-rod injection, AREA for rod injection, SCALE for decay heat, which includes TRITON and ORIGEN, and ORFEO-GAIA and ORFEO-NMGRID for critical heat flux.

This topical report serves as a supplement to each of these codes and does not impact the current functionality or applications of these codes in operating reactors.

Next slide, please. So some of the most important regulations considered in this topical report were 10 CFR 50.46 and 50.68. These are the ECCS acceptance criteria and 50.68 for the limit on increased enrichment. GDC-10 was also considered.

Additional regulations can be found in the

SRP sections as well as additional guidance. These SRP sections include fuel system design, nuclear design, thermal and hydraulic design, and transient and accident analysis methods review.

The final document on this list is not a regulation or a guidance, but is an Oak Ridge report that provided the staff with insight on trends associated with increasing enrichment in PWR fuel.

Next slide, please.

MEMBER KIRCHNER: You turned it off. Brandon, I don't think this is proprietary. I think it's more from NRC regulations and guidance. Is it 62.5, 62,500 megawatt-days per metric ton, is that the current limit that you use?

MR. WISE: That was --

(Simultaneous speaking.)

MEMBER KIRCHNER: In your earlier slide you said there is, you know, within existing burnup limits.

MR. WISE: That was not defined anywhere. I am uncertain. Maybe some of my colleagues could chime in.

MEMBER KIRCHNER: Well, okay.

MR. LEHNING: This is John Lehning from the NRC staff. So the burnup limits that are in place now they typically arise in connection with topical reports or other approvals like that and they are not typically coming from things like regulations basically, yes.

MEMBER KIRCHNER: Yes. Well you didn't list your Reg Guide on rod injection, which probably is the one that right now --

MR. WISE: That --

MEMBER KIRCHNER: What would be necessary for the NRC to raise the limits or would this be done on an applicant-by-applicant basis? Is there anything, so to speak, in regulation that would prevent any of the vendors from going beyond your nominal limits, I will call them that?

If there isn't a fast limit, I think it's 62.5 megawatt-days, 62,500 megawatt-days per a metric ton, whatever that is, 85 days, from the Reg Guide -- reactive answers an accident.

MEMBER BALLINGER: I think we're going to have a, we've got another report that we're reviewing on the burnup issue.

MEMBER MARCH-LEUBA: From Framatome, it's coming --

MEMBER BALLINGER: Sometime this summer. I forget when we're scheduled --

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: Later in the summer because it depends more heavily on the ARITA methodology than this one.

MEMBER BALLINGER: Yes.

MEMBER MARCH-LEUBA: And so they need to have ARITA approved first, which is happening I believe in June, I think thereabouts.

MEMBER KIRCHNER: But I guess what I am asking the staff is is there a de facto limit right now, what are you looking for from applicants to go on.

Obviously they are increasing enrichment, they've got an existing design, so they're not changing the core designs per se, they are looking at burnup, obviously, because that's where the economics come in.

So if you would just address that as to what the staff would be looking for for --

MR. WISE: Right now --

MEMBER KIRCHNER: -- for increased burnup.

MR. WISE: Right now we are considering everything on a case-specific basis. As more topical reports and applications come in that would lead the NRC to consider more wide-scale and generic changes to think like guidance and regulation. As you might aware, there is increased enrichment rulemaking going on. I think that sort of addresses your question.

As far as applicability of like guidance, like the rod injection, that same guidance, what we are looking for is the applicability of the limits stated in that guidance at higher enrichments done by the, we want justification from the vendors.

Right now that Reg Guide does have a limit of 5 percent. However, because there is no changes proposed to the acceptance criteria or the fuel damage criteria or anything like that, we have determined that it would be applicable at increased enrichments.

MR. LEHNING: This Is John Lehning from the staff again. Just to add to Brandon's good response to that I would just say that there are, even right now, I would say Framatome's report, I think the Subcommittee knows already that that's coming in the future.

There are other vendor reviews for increased enrichment that even underway now. We are not going to talk about those in this meeting. There are proprietary aspects to that.

But, you know, obviously, the dispersal of the fuel is one of the key issues. ACRS well understands, you know, the importance of that. So that is one of the key things of how to avoid that and how to avoid some of the other considerations where there is maybe not a full amount of information yet.

So there is no rule that says it can't, the enrichment can't be increased right now, even before this increased enrichment rulemaking, but it is a little bit more challenging and maybe vendors have to do different things in order to show us with the current knowledge that they are able to address what are the issues and operate safely.

So that's probably about what I could say in this session.

MEMBER KIRCHNER: Thank you.

MR. WISE: Okay. Moving into the neutronics section. Framatome's neutronics code is ARCADIA and the demonstrated applicability at increased enrichment for that code using three justifications.

The first was performing a criticality benchmark experiment comparison. The second was a colorset of calculated pin powers for multi-assembly problems.

These colorsets varied in enrichment, gadolinium loading, and burnups which span the entire range of increased enrichment as well as what would be expected for gadolinium loading and, again, current burnup limits.

Framatome determined that there is no significant change in uncertainty at these increased fuel enrichments for these parameters. Framatome also considered an evaluation on the effective increased enrichment for detectors and the detector lifetime and determined that there is no significant impact of detector functionality or lifetime. Next slide, please.

MEMBER BALLINGER: This is Ron Ballinger. I am going to ask a dumb question, which I thought was dumb when I asked it the last time but it turns out it's maybe not so dumb.

I cannot for the life of me find out where the word "colorset" came from. No matter what, I just could not -- Nobody could tell me.

MR. WISE: Unfortunately, I don't have an answer for you either. That was before my time.

MEMBER BALLINGER: Okay. Case closed.

MEMBER PETTI: That's a physics question.

MEMBER BALLINGER: Nobody can answer it.

MEMBER PETTI: Well I had someone explain it to me.

MEMBER BALLINGER: Oh, you did?

MEMBER PETTI: Yes.

CHAIRMAN REMPE: Turn on your mic and identify yourself.

MEMBER PETTI: Sorry. No, no, no, I just don't remember. I just remember him explaining -- You know when they do the color maps and the little boxes and like the burnups and they color code them --

MEMBER BALLINGER: Yes.

MEMBER PETTI: -- for ranges and someone coined the term colorset, but it's --

MEMBER BALLINGER: What's someone's last name?

MEMBER PETTI: Oh, he -- This person didn't tell me who did it, it was just done.

MEMBER BALLINGER: Okay. Urban myth.

MR. WISE: Next slide, please. When the NRC reviewed these comparison, the critical benchmark experiment comparisons and the colorset evaluations we found that the uncertainties were comparable to those found in previous submittals, specifically the ARCADIA topical report and its supplement, so there was no indication that there is any loss of predictive capability in the range of increased enrichment.

Additionally, we found that detector

functionality and lifetime is not significantly impacted by increased enrichment. This is primarily due to two phenomena which counteract each other.

The first is an increased importance of background signals and noise. This is relatively small at the beginning of life of a detector but increases as a detector ages, thus reducing the effective lifetime of the detector.

However, this is counteracted by a reduced reaction rate as the result of reduced flux and special hardening, which actually increases the life of the detector.

Overall there is no significant impact on detector lifetime and the overall detector functionality remains the same. Therefore, the NRC staff determined that the ARCADIA topical report maintains acceptable predictive capability at increased fuel enrichments.

Next slide, please. COBRA-FLX is Framatome's thermal hydraulics code which predicts departure from nucleate boiling using parameters such as pressure, flow, quality, and flux.

All these are clearly independent of Uranium-235 enrichment. Likewise, the CHF correlations are independent of increased enrichment and are acceptable for use in increased enrichments because there is no dependency on enrichment.

Therefore, the NRC staff determined that COBRA-FLX, as well as the fuel rod bow methodology and the CHF correlations, ORFEO-NMGRID and ORFEO-GAIA, all maintain acceptable predictive capability at increased fuel enrichments.

Next slide, please. For the mechanical evaluation Framatome found that component material performance is mostly independent of enrichment and tends to be affected more by fluence of burnup.

Framatome also provided data demonstrating the predictive capability of GALILEO and the range of increased enrichment.

Next slide, please. The Framatome mechanical codes and methods may be acceptable for use in increased enrichment if at least one of the following are true and if they are applicable and each of the Framatome topical reports listed in the mechanical section do fall under at least one of these three categories.

The first is that the code or method is independent of enrichment, so clearly it is applicable at increased enrichments.

The second category is the code or methods primarily fluence dependent. This is because the end-of-life or end-of-cycle fluence at increased enrichments is bounded by the end-of-life or end-of-cycle fluence at lower enrichments.

This is primarily due to a production in parasitic absorptions and a reduction in the amount of plutonium in the core as a result of increasing the enrichment.

Lastly, specifically for the GALILEO topical report, the data is provided demonstrating acceptable performance in the range of increased enrichment.

This data spans the entire range of increased enrichment and there is adequate coverage and there is no adverse trending that would suggest there is a loss of predictive capability of that methodology.

Therefore, the NRC staff determined that the methodologies related to component material performance maintain acceptable predictive capability at increased fuel enrichments.

Next slide, please. Framatome's non-LOCA codes are ARITA and AREA. They determined that these are acceptable for use at increased fuel enrichments and that their use and functionality at increased enrichments are unchanged.

The NRC staff determined that as a result of the ongoing review with ARITA that there are some parameters in their uncertainty treatments that could be affected by increased enrichments.

These were not adequately addressed in the increased enrichment topical report and the ARITA topical report is applicable only to 5 percent. This led to Limitation and Condition Number 1 which requires Framatome to provide additional justification for the use of ARITA at enrichments greater than 5 weight percent.

Otherwise, due to no changes in functionality of the AREA code the NRC staff determined that AREA maintains acceptable predictive capability at increased fuel enrichments.

However, ARITA is limited right now after it is approved to 5 percent until after Limitation and Condition 1 is addressed.

MEMBER MARCH-LEUBA: And this additional justification is related to uncertainties, correct?

MR. WISE: Yes. There are a large number of parameter uncertainty treatments as part of the ARITA topical report. The NRC staff reviewed these parameters and identified several that could be affected by increased enrichment.

These parameters are generic in nature and may be empirical or data driven, which is why the NRC would like to see additional information because there might not be adequate data justifying its applicability at increased enrichments.

MEMBER HALNON: Brandon, is the output of both of those codes the same, I mean relatively?

MR. WISE: We don't have specific data from ARITA because that topical report is ongoing and, likewise, for AREA because the guidance for AREA or for rod injection is going to be held to the same standard for above and below 5 weight percent.

MEMBER HALNON: Okay. So they are different, there are codes for different situations?

MR. WISE: Yes.

MEMBER HALNON: And the ARITA -- I mean I guess the point was is that AREA maintains acceptable predictive capability, does that compensate for not having ARITA in place or is it ARITA still has to have, have to be in there?

MR. WISE: So, first of all, the difference between ARITA and AREA, there is no overlap between them. AREA covers only rod injection and ARITA is all other non-LOCA transients.

MEMBER HALNON: So that is a different --

MR. WISE: Yes.

MEMBER HALNON: Okay. Thanks.

MR. WISE: Otherwise, as for the predictive capability of AREA, there is no changes to the code proposed so it's just small increase in enrichment.

MEMBER HALNON: Okay.

MR. WISE: So that's --

MEMBER HALNON: Negligible --

MR. WISE: Right. Right. Next slide, please. As for LOCA, Framatome identified no new phenomena associated with increased enrichment. Likewise, the codes and inputs used in the LOCA analyses have already been demonstrated to be acceptable at increased enrichments. These are the neutronics and thermal hydraulics codes discussed on the previous slides.

Additionally, the NRC reviewed the 10 CFR 50.46 ECCS acceptance criteria and determined that those limits apply at increased enrichments and that Framatome's codes and methods used in LOCA analyses do maintain acceptable predictive capability at increased fuel enrichments.

Therefore, the NRC staff determined that

Framatome's LOCA methodologies are acceptable for use at increased enrichments. There is one exception to this and that is discussed on the next slide for decay heat.

Next slide, please. Current decay heat models and standards remain applicable for Framatome methods at increased enrichments. That was Framatome's evaluation.

The NRC staff reviewed Framatome's models and their ability to accurately predict relevant decay heat phenomena at increased enrichments and found that they remain strictly conservative in the range of increased enrichment.

What we know about the relationship between decay heat and increased enrichment is that there is a small, about a 2 percent increase in decay heat initially after shutdown for about ten seconds and then the decay heat at higher enrichments and lower enrichments is roughly the same.

Overall there is a very insignificant impact of decay heat on evaluations. Therefore, the staff was able to conclude that the current decay heat models as used by Framatome methods maintain acceptable predictive capability at increased fuel enrichments.

MEMBER MARCH-LEUBA: And even though it's a very small difference everything in the transient for a few seconds the heat transferred to the coolant is controlled mostly by a stored energy, correct?

MR. WISE: That's correct.

MEMBER MARCH-LEUBA: So it's insignificant really.

MR. WISE: Yes. The impact of decay heat is essentially insignificant. Next slide, please. Now to discuss the limitations and conditions, there are two of them.

The first one is related to ARITA and that is the uncertainty treatment of 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 5 weight percent Uranium-235.

To implement ARITA with increased fuel enrichments the parameters listed below must have the applicability of their uncertainty treatment for other justified for use of fuel enrichments greater than 5 weight percent.

The list of parameters is not included here because they are proprietary, but they are mostly neutronics related.

This limitation and condition occurred

because of the ongoing review with ARITA and still some potential uncertainties that we had with the review.

MEMBER KIRCHNER: From a process standpoint, Brandon, what happens when you complete the review of ARITA? Do you go back and amend the SE and strip away this if they successfully address your concerns, then do you strip away this limitation and condition?

MR. WISE: So when ARITA is approved --

MEMBER KIRCHNER: Or do you have some kind of mechanism or whatever?

MR. WISE: Right now ARITA is being reviewed and when it is approved it will up to 5 weight percent only. So this limitation and condition will not be addressed in the current ARITA review.

We expect a supplement or some other licensing actions to resolve this limitation and condition.

MEMBER MARCH-LEUBA: And then will a future applicant be able to reference that new ARITA report for greater than 5 percent, like to claim that Limitation and Condition Number 1 is satisfied?

MR. WISE: Yes.

MEMBER MARCH-LEUBA: So they will not have to do an analysis every cycle?

MR. WISE: That's correct. And I'll restate the parameters associated with this limitation and condition are generic in nature so it is expected that they will be addressed once and then that's it, unless there are any plant-specific cases that would alter their generic nature.

Next slide, please. This is Limitation and Condition Number 2 of this increased enrichment topical report. It is applicable only to the following PWR fuel assembly designs, GAIA 17x17 and HTP 15x15 designs for Westinghouse plants and HTP 14x14 and 16x16 designs for combustion engineering plants.

The ANP-10353P may be used with other fuel assembly designs with sufficient technical justification for the applicability of this topical report to the assembly design.

This was the question that was brought up in the previous presentation and this is the licensing pathway for licensing additional fuel designs at increased fuel enrichments.

MEMBER KIRCHNER: So what does sufficient technical justification then require here? I mean you don't start over from scratch, you basically -- How do you determine this?

MR. WISE: We would look for applicability of the approved codes and methods to that fuel design. I have not specifically reviewed all of the codes and methods related to specific fuel designs.

So I will give an example of if a certain code is not applicable to GAIA 17x17 for any reason we would expect that to be addressed in the licensing action.

MEMBER KIRCHNER: Okay. By and large most of the changes are in the spacer grid design and that's thermal hydraulics, not an enrichment issue.

MR. WISE: Right.

MEMBER KIRCHNER: Okay. Thank you.

MR. WISE: We don't expect any major topics to really come up with licensing additional fuel designs unless there is a very significant change to how fuel is designed.

Next slide, please. And for the staff's final 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.

This is with the exception of ARITA as

discussed in Limitation and Condition Number 1. That will conclude my presentation. Thank you for listening. Are there any additional questions?

MEMBER MARCH-LEUBA: Thank you, Brandon. Any comments or questions from the members, including those out in the cloud?

Hearing none, I am going to allow comments by members of the public. If anyone out there -- I don't see any members of the public in the room. Anybody out there in the phone call wants to make a comment please identify yourself and make your comment.

CHAIRMAN REMPE: If you have a phone you may need to press star 6 to unmute yourself, it's just an added thing. If you are on a computer just unmute it.

(Pause.)

MEMBER MARCH-LEUBA: I don't see any comments. So, Ms. Chairman, you are in charge.

CHAIRMAN REMPE: Great. Thank you. Thanks for everyone's presentations. At this point we are going to go off the record for the entire meeting, Jim, and thank you for your support, okay?

(Whereupon, the above-entitled matter went off the record at 9:17 a.m.)

# ANP-10353P, Revision 0
## Increased Enrichment for PWRs

Morris Byram, Michelle Guzzardo

ACRS Committee Meeting

March 2, 2023

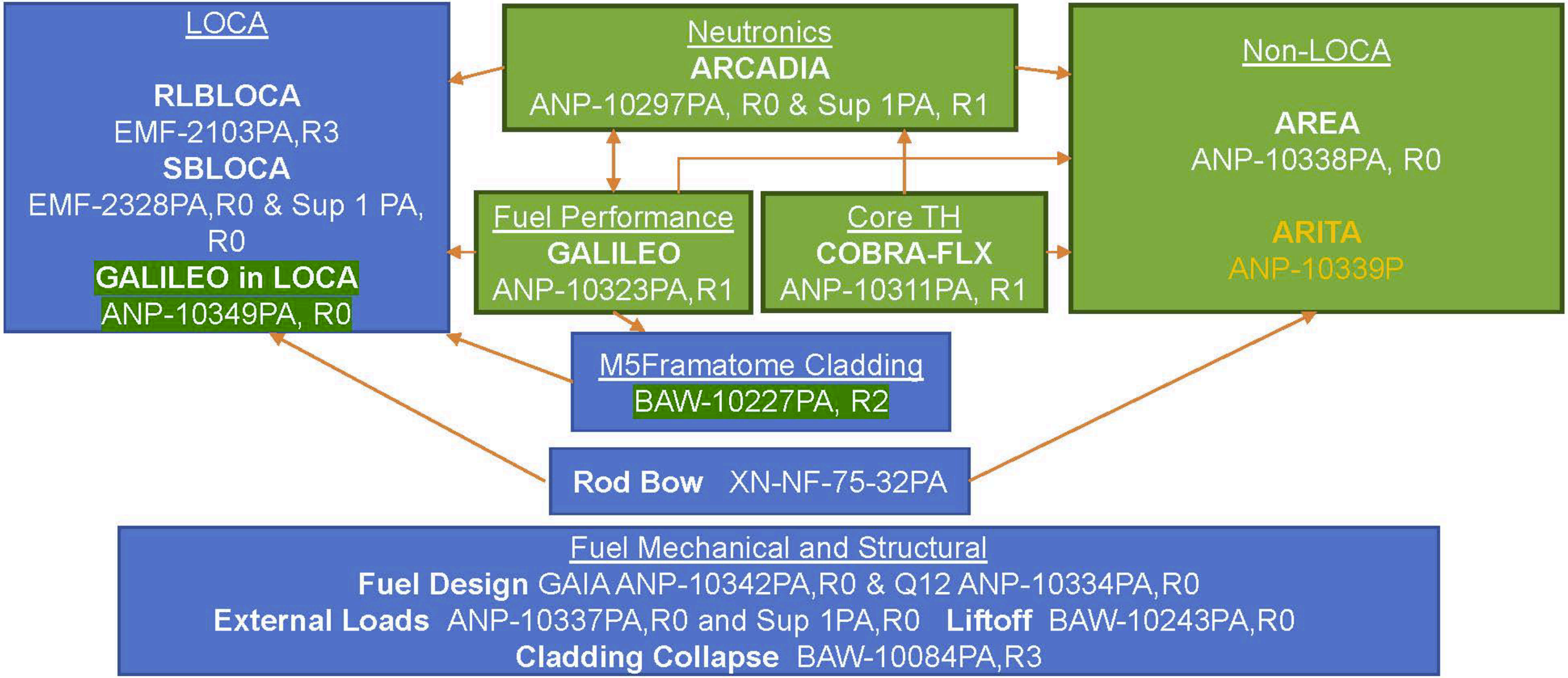
# Agenda

- Key Milestones
- Advanced Codes and Methods Topical Reports
- Approval Request and Applicable Fuel Designs
- Major Topic Evaluations
- Summary

# 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
- No change in current licensed burnup limits

# Supported Fuel Designs

- GAIA 17x17 design for Westinghouse plants
- HTP 15x15 design for Westinghouse plants
- HTP 14x14 design for Combustion Engineering plants
- HTP 16x16 design for Combustion Engineering plants

# Neutronics (ARCADIA)

- Additional critical experiment comparisons performed to extend range of enrichment
- Impact of Chromia Doped / Chromium-Coated Cladding
- Additional colorsets added using greater than 5 wt% U-235 fuel
  - Results combined with existing colorsets
  - ARCADIA uncertainty analyses remain applicable
- Detector behavior sensitivity and lifetime remain applicable

➡ ARCADIA code system is acceptable for use with fuel enrichments greater than 5 wt% U-235

# Thermal Hydraulics

- CHF Correlation
- COBRA-FLX
- Fuel Rod Bow

→ Thermal Hydraulic components are applicable to fuel with greater than 5 wt% U-235 since correlations and properties are independent of enrichment

# Mechanical

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

# Mechanical – (Continued)

- Materials and methodologies generally dependent on fast fluence
- Fast fluence decreases as U-235 enrichment increases
  - Current EOL fluences are bounding
  - Current fluxes are bounding
- Remaining parameters and methodologies are independent of U-235 enrichment, except GALILEO
- GALILEO benchmarks contain data that bounds the enrichment being requested

# Non-LOCA

- ARITA
  - ARCADIA, Decay Heat, COBRA-FLX, ARTEMIS FRM, GALILEO and S-RELAP5 were shown to be applicable to fuel with greater than 5 wt% U-235 or are not dependent on enrichment
  - Neutronics and thermal key parameters were reviewed and generation of these parameters are not affected by enrichment
  - An audit was held in August 2022 in which the uncertainties associated with some key parameters could be affected by increased enrichment
    - Limitations and Conditions (1) lists parameters for which their uncertainty treatment must be further justified for use with at fuel enrichments greater than 5 wt% U-235

# Non-LOCA (Continued)

- AREA
  - ARCADIA, GALILEO, COBRA-FLX and RELAP5 were shown to be applicable to fuel with greater than 5 wt% U-235 or are not dependent on enrichment
  - Neutronics and thermal key parameters were reviewed and generation of these parameters are not affected by enrichment
  - Methodology designed to be consistent with regulatory guidance
  - Regulatory guidance was found to be applicable for enrichments greater than 5 wt% U-235

# LOCA (SBLOCA and RLBLOCA)

- Rely on both GALILEO and S-RELAP5
- EMs were evaluated for important fuel-related phenomena
  - EMs remain valid for fuel with greater than 5 wt% U-235
- SBLOCA EM: enrichment specified in GALILEO input was updated to a generic value greater than 5 wt% U-235
- Relevant 10 CFR 50.46 limits remain applicable

# Decay Heat

- TRITON was used to determine best estimate effects of decay heat with U-235 enrichment
- Current decay heat models used in each of the methodologies remain valid for use with fuel having enrichments greater than 5 wt% U-235

# Summary

Codes and methods discussed in the ANP-10353 are acceptable for use with fuel enrichments greater than 5 wt% U-235

# 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

# Trademarks

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# 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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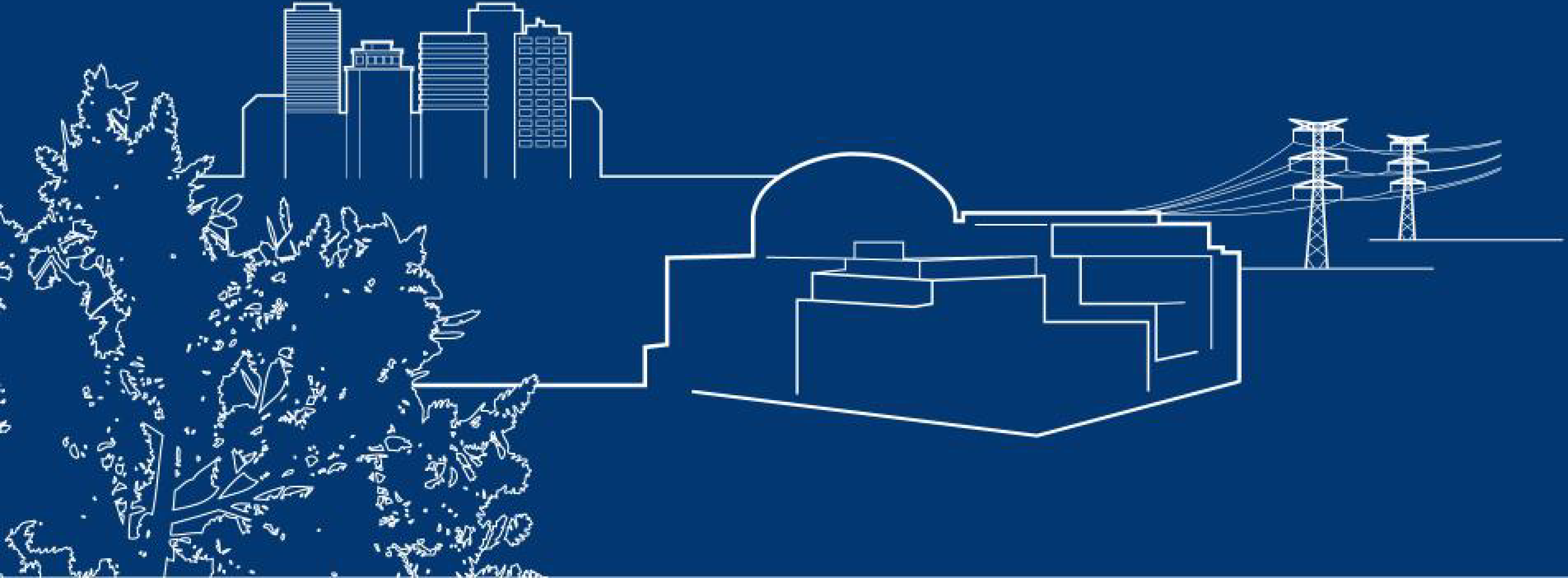

# NRC Safety Evaluation of Topical Report ANP-10353 Increased Enrichment for PWRs

## Open Session

Brandon Wise
Nuclear Methods and Fuel Analysis Branch
(NRR/DSS/SFNB)

ACRS Full Committee Meeting
March 2, 2023

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

# Presentation Outline

- Background
  - Concurrent TR Reviews
  - Codes Used
- Applicable Regulations and Guidance
- Neutronics
- Thermal Hydraulics
- Mechanical
- Non-LOCA
- LOCA
- Decay Heat
- Limitations and Conditions
- Conclusion

# 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 1
- 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”

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# Neutronics

- Framatome Evaluation
  - Needed to demonstrate applicability of ARCADIA at increased enrichments.
  - Performed a critical experiment benchmark comparison
  - 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
  - Evaluated effects of increased enrichment on detector lifetime

# Neutronics

- NRC Evaluation
  - The critical experiment benchmark comparison and colorset evaluation uncertainties are comparable to the uncertainties in the previously accepted ARCADIA TRs.
  - Detector functionality and lifetime is not significantly impacted by increased enrichment.
- 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.
  - Provided data demonstrating predictive capability of GALILEO in the range of increase enrichment.

# Mechanical

- NRC Evaluation
  - Framatome mechanical codes and methods may be acceptable for use at increased enrichments if the following, if applicable, are true:
    - The code or method is independent of enrichment.
    - The code or method is primarily fluence-dependent.
    - Data is provided demonstrating acceptable performance in the range of increased enrichment.
- 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 in the ARITA methodology that may be affected by increased enrichment were not adequately addressed.
- 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
  - Framatome models accurately predict relevant decay heat phenomena at increased enrichments and remain strictly conservative in the range of increased enrichment.
- 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