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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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FUELS, MATERIALS, AND STRUCTURES SUBCOMMITTEE

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OPEN SESSION

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TUESDAY

JUNE 20, 2023

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The Subcommittee met via hybrid in-person and Video Teleconference, at 1:00 p.m. EDT, Ronald Ballinger, Chairman, presiding.

COMMITTEE MEMBERS:

RONALD G. BALLINGER, Chair

CHARLES H. BROWN, JR., Member

VICKI BIER, Member

VESNA DIMITRIJEVIC, Member

GREGORY HALNON, Member

WALT KIRCHNER, Member

JOSE MARCH-LEUBA, Member

JOY L. REMPE, Member

MATTHEW SUNSERI, Member

ACRS CONSULTANT:

HOSSEIN NOURBAKHSH

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

ALSO PRESENT:

MORRIS BYRAM, Framatome

NGOLA OTTO, NRR

YUSEN QI, Framatome

ADAM RAU, NRR

JACKI STEVENS, Framatome

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

(1:00 p.m.)

MEMBER BALLINGER: Good afternoon. The meeting will come to order. I'm assuming everybody can hear me.

This is a meeting of the Fuels, Materials, and Structures Subcommittee of the Advisory Committee on Reactor Safeguards.

I'm Ron Ballinger, Chairman of today's Subcommittee meeting.

ACRS members in attendance are Jose March-Leuba, Matt Sunseri, Joy Rempe, Walt Kirchner, Vicki Bier, Charlie Brown, and I think Greg Hanlon -- yes, he's here -- Vesna Dimitrijevic is here, and that may be it. Yes, that's it.

Chris Brown of the ACRS staff is the designated federal official for this meeting.

During today's meeting, the Subcommittee will receive an information briefing on the staff's draft SER for Topical Report, ANP-10340P-A, Revision Zero Supplement 1. Revision Zero, Incorporation of Chromia-doped Fuel Properties, and Framatome PWR Methods.

Subcommittee will hear presentations and hold discussions with the NRC staff, Framatome, and

other interested persons, regarding this matter.

Part of the presentations by the applicant and the NRC will no doubt be closed, in order to discuss information that is proprietary to the licensee and its contractors, pursuant to 5 USC 552b(c)(4).

Attendance at the meeting that deals with such information will be limited to the NRC staff and its consultants.

Framatome and those individuals and organizations who have entered into an appropriate confidentiality agreement with them will be allowed.

Consequently, we need to confirm that we have only eligible observers and participants in the closed part of the meeting.

The rules for participation in all ACRS meetings were announced in the Federal Register on June 13, 2019.

Our NRC public website provides the ACRS charter, bylaws, agenda, letter reports, and full transcripts, of all Subcommittee meetings, including slides.

The agenda for this meeting was posted there, along with the MS Teams link. We have received no written statements or requests to make an oral

statement from the public.

The Subcommittee will gather information, analyze the relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full committee.

A transcript of the meeting is being kept, and will be made available.

Today's meeting is being held in person and over Microsoft Teams. There is also a telephone bridge line and an MS Teams link, allowing for participation of the public.

When addressing the Subcommittee, the participants should first identify themselves and speak with sufficient clarity and volume, so that they may be readily heard.

When not speaking, we request that participants mute your computer microphone by pressing star-six.

We'll now proceed with the meeting. Let's start by calling on Greg Suber from NRR, and I think Jackie Stevens from Framatome will provide opening remarks. So, Greg, are you out there?

(Pause.)

MEMBER BALLINGER: You should probably state your name and company.

MR. OTTO: Sure. Good afternoon, I'm Ngola Otto. I'm the project manager for Framatome Topical Report Reviews, and I'm the project manager for this particular topical report review.

Today, we're going to hear from the staff based on their review of the Chromia-dope topical report, which is a supplement to what was approved back in 2018. We did approve Provision Zero, which was based on PWR methods.

So, Adam, he's going to be presenting here today, based on his review on the Chromia-dope aspect of the PWR, and also we did use the ARITA methodology to analyze Chromia-dope.

So, the plan is that we will issue a final safety evaluation after completing the ARITA final safety evaluation. So, I wanted to mention that.

With that, I'll turn it over to Framatome.

MEMBER BALLINGER: Jackie Stevens, are you out there?

MS. STEVENS: Yes, I am. Thank you, Ngola. Can everyone hear me okay?

MEMBER BALLINGER: I think so.

MS. STEVENS: Okay, great. Good afternoon. Welcome to all who are attending our discussion today on Framatome's topical report, AMP-

10340PA, Revision Zero, Supplement 1P, Incorporation of the Chromia-dope Fuel Properties into Framatome's PWR Methods.

This topical report is the result of efforts of our fuel organization's Dr. Yusem Qi, Morris Byram, and others.

Their time and efforts resulted in a quality submittal to the NRC in June of 2021, and NRC's review of the report in approximately two years. Thank you, gentlemen, for your efforts.

I would also like to recognize Mr. Beaton and the other NRC reviewers for their detailed review of the report, and the timely and efficient manner of performing the review.

Framatome has found that the reviewers were well-prepared and had a full understanding of Framatome's responses, before each audit meeting.

The reviewers' commitment to understanding Framatome's PWR methodologies, before and during the audit, resulted in an efficient and effective review.

Framatome's objective is to bring innovation and improved performance methods to the industry. And when both our submittal and the NRC's review are as cohesive and efficient as the review on this topical report, then we were able to meet that

objective.

As we continue to work towards quality reports for all of our submittals, I'd like to encourage the NRC to continue to develop the reviewers to be able to perform these audits for understanding, that result in a draft SC during the audit, or in a 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.

Framatome is open to improving our own processes, to help the NRC reviewers become knowledgeable of our methodologies, and we continue to encourage open communication with the staff reviewers, while also assuring transparency for the public.

Again, thank you for your time today. We welcome your questions, feedback, and insights, throughout the meeting.

MEMBER BALLINGER: Thank you. I think, Morris, are you up next?

MR. BYRAM: Yes, I am.

MEMBER BALLINGER: Okay, you're on.

MR. BYRAM: Great. Can everybody see the slides okay?

MEMBER BALLINGER: Yes.

MR. BYRAM: Great. Okay, so as Jackie mentioned, this is AMP-10340, Rev. Zero, Supplement 1P, Rev. Zero, Incorporation of Chromia-dope Fuel Properties and Framatome PWR Methods.

I'm Morris Byram and I am manager for licensing for this topical report.

And on the agenda for the open session for Framatome today, we're going to talk about key milestones.

Backing up what Jackie said about the efficient review of this topical report, advanced codes and methods topical reports, we're going to go through where this topical report fits into the overall scheme of advancement that's in codes, and we're going to talk about approval requests and the limitations that were placed in issue when it was submitted, and for the draft SC on this topical report, and then go through a topical report outline.

Key milestones. Pre-submittal of meeting was held October 2020. The topical report was submitted for review in June 2021. It was accepted for review July 2021.

We had the audit for understanding with the NRC in November and December of 2021, and RAIs were received in December of 2021. We submitted the RAI responses in April of 2022, and the draft SC was received April of 2023.

Framatome PWR codes and methods. This is a depiction of all of the Framatome codes and methods will be used going forward, with ATF-type topical reports.

You can see in the blue that these are older methods, and the green are the newer methods which have been approved for use in Framatome PWR codes.

The main effect of this topical report, Chromia-doped fuel and PWR methods, is through the fuel performance code GALILEO.

You can see through the orange arrows that these are the connections between the methods that are used for licensing applications, and also note for the non-LOCA analyses, the area which is rod ejection, and includes the ARITA topical report.

The ARITA is in yellow, and that is the only one of these topical reports which has not been approved yet, but is very close.

So, I think that's the overview

discussion. And again, this topical report supplement that we are talking about today is mainly impacting the fuel performance code GALILEO.

And there are more connections between the codes and methods for Framatome, but this shows just the measure of connections.

To describe the topical report for what was submitted, this is a supplement, the base topical for PWR methods, which was approved in 2018. It uses the regulatory guidance from the SRP, NUREG-0800, Sections 4.2 and 4.4.

Generic parts of the base topical report, not repeating this supplement, but mentioned and addressed as applicability for the PWR methods, are materials properties, behavioral assessment, qualification database, and operating experience. And there are no changes required to currently approve methods to approve this topical report.

The approval request in the topical report was to extend the applicability of existing approved PWR methods, to include Chromia-doped fuel for licensing applications.

Limitations in the topical report and applied in the draft SC are consistent with the approval topicals.

Grain size for standard fuel is unchanged from GALILEO. Current burn-up limitations apply for UO2 fuel. Chromia-doped concentration range is consistent with the base topical report. And with the draft SC, applies additional limitation for burn-up on the Gad fuel.

And getting to the topical report outline, the applicability of the base topical report goes over and mentions, describes what is in the base topical report for materials, properties, behavioral assessment, accident behavior, and qualification data.

And the next section deals with the qualification of GALILEO, the GALILEO thermal-connectivity model, the fission gas release model, intergranular gas use swelling model, and the validation of the three rod tree volume and internal pressure.

Next section is the Qualification of Framatome Methods to Chromia-doped Fuel, and the following section is Qualification of Rod Growth to Chromia-doped Fuel.

And then the next section deals with the licensing criteria assessment for fuel rod thermal-mechanical evaluation, including cladding collapse, cladding fatigue, maximum rod internal pressure.

Safety analysis evaluations were performed to point out the changes due to Chromia-doped fuel for PWR methods in non-LOCA, using the ARITA methodology in LOCA, and for control rod ejection. And then the impacts of nuclear design requirements are also included.

And so, that is the end of the open presentation for Framatome. Are there any questions?

MEMBER KIRCHNER: Morris, this is Walt Kirchner. You gave a nice outline of what you're covering in your topical report.

Could you just, for the public record, say what the overall change or impact of Chromia-doped fuel is, and why it would change the methodology, without going into any proprietary descriptions?

Why are you doping fuel with Chromia? Just for the public record. And what would be the general mechanical or other material impacts on your methodologies?

MR. BYRAM: There are slight impacts on the methodologies, and the effects of the calculated evaluations.

The major impact and benefit of the Chromia-doped fuel is to increase grain size, and therefore impact in a positive way fission gas

release. That is the overall positive impact.

There are others. As pointed out, there are other model adjustments to the PWR Chromia-doped that will go into more detail with Yusen's presentation for the closed section. But that's the overall impact.

MEMBER KIRCHNER: So, when you say positive, with regard to fission product release, you're saying less fission product gases, fission product release. Is that correct?

MR. BYRAM: Correct. Correct.

CHAIR MARCH-LEUBA: This is Jose March-Leuba. See, we're talking generalities, again remember we're in the open session.

Clearly, chromium is a neutron poison which reduces the neutronic efficiency of the core. And my first impression is you are going to be discharging more U235 out of the core at the end of the cycle, simply because there's extra poison and you have to shut down earlier.

So, it has an impact on economics. Obviously, the thinking of Framatome is that a balance between more fission gas release and maybe spending a little bit more on enrichment, has some benefits. Can you discuss the economic impact of this? Again, we're

in open session, so don't disclose any proprietary.

MR. BYRAM: Right. Working with increased enrichment and increased burn-up for the fuel cycle, it should give good economic impact, as far as making the fuel more efficient.

But again, apart by itself, there is not a large economic impact. I don't believe that working with increased enrichment and high burn-up will yield a greater economic impact and a positive effect.

CHAIR MARCH-LEUBA: But to compensate for the drop in reactivity, because chromium is present in another cycle, you must discharge additional U235 before, in the form of its view, separate work units of the enrichment facility.

So, my question -- let me make it more succinct. Have you, Framatome, done a study and analysis, have you designed a core with Chromia-dope, and is it economical? Is it worthwhile for you or the licensees?

MR. BYRAM: Jose, I don't have an answer for you on that right now. Could I get back with you on that?

CHAIR MARCH-LEUBA: Sure. Yes, send it to Chris Brown.

MR. BYRAM: Yes.

CHAIR MARCH-LEUBA: But whatever you need to send, don't send it to me. Send it to --

MEMBER KIRCHNER: Yes. I think, Jose, I mean, the short answer is -- I was just trying to tease it out of Morris -- is that if you have better fission product retention, you can go to hard burn-up.

CHAIR MARCH-LEUBA: But still, at the end, you are going to discharge more U235, because you have to compensate for the negative reactivity. So, there has to be a balance.

Just curious. It has no safety concern, as Clea said.

MR. BYRAM: Yes.

MEMBER BALLINGER: Other questions from members?

MR. QI: This is Yusen speaking. Just add a little bit for Morris. The amount added is super-small. And also, PWR planned to -- actually, they're using the doped fuel. So, we do have core designs. Okay, thank you.

MEMBER BALLINGER: Now, do I understand that Yusen's presentation is not going to be given? Did I hear you say that you completed the open presentation?

MR. BYRAM: Yeah, for Framatome.

MEMBER BALLINGER: Okay, so my agenda is a little bit mixed up. So, I know got to go to add -- because that's done.

All right, sorry about that. Yeah, Adam, are you ready to go?

MR. RAU: Yeah. I'll pull up the slide. Thank you. I'll be ready when Ngola pulls up the slides.

MEMBER BALLINGER: Oh, okay.

MR. RAU: Thank you.

(Pause.)

MEMBER BALLINGER: While we're waiting, I might remind the Subcommittee that we had a very extensive presentation that included a lot of this, from Framatome during our recent visit to the facility in Richland.

So, for those that are looking for additional information, that presentation is part of the package, was very extensive, and the reason, the actual reason.

(Pause.)

MR. RAU: Can you all hear me?

MEMBER BALLINGER: Yeah.

MR. RAU: Okay. All right, so thank you very much. My name is Adam Rau, I'm a technical

reviewer in the Nuclear Systems Performance Branch. I need to thank Robert Beaton at the beginning of the presentation for carrying out the bulk of the topical report review. I came on later in the process, but I'll be presenting the safety evaluation for NRR today.

So, struck for the presentation to follow the form of the safety evaluation, so we'll start out talking about the specific licensing criteria that are intended to be met, the applicability of the base topical report as it's been discussed.

The report is about the addition of Chromia-dope into the fuel, and so the impact is primarily on the thermal-mechanical performance. And so, I've bolded number four because the bulk of the technical content is on GALILEO. Next slide, please.

So, we're discussion fuel thermal-mechanical performance. Relevant regulations are general design criteria ten for the SAFDLs for fuel. 10 CFR 5046 for emergency core cooling system design and loss of coolant accident, as well as general design criteria 28 requires analysis of the rod ejection accident.

These objectives are summed up fairly well in SRP 4.2, that the fuel system should not be damaged

as a result of normal operation and anticipated operational occurrences, but the number of fuel rod failures should not be underestimated for postulated accidents, and that coolability should be maintained, and for rod insertion should be possible. Next slide, please.

So, as has been stated, this is a supplement to an approved topical report. So, the goal of the supplement is to extend the applicability of Framatome pressurized water reactor methods to Chromia-doped fuel.

The topical report for boiling water reactor methodologies has been reviewed and approved, so there some common material between the two, as has been discussed.

The supplement that's under review contains code-specific implementations for Chromia-doped material property models, some additional measurement data, as well as a licensing criteria assessment for pressurized water reactors. Next slide, please.

So, discussion was provided for the behavior of Chromia-doped fuel during accidents, specifically for the loss-of-coolant accidents, and for the rod ejection accident.

The conclusion. Framatome provided information that the acceptance criteria for the loss-of-coolant accident and the rod ejection accident are still applicable when Chromia-doped fuel was used.

In general, the behavior of the doped fuel is similar to the standard U02, and where the behavior does differ because the properties of the doped fuel are different than the standard fuel, these changes are explicitly modeled in GALILEO. Next slide, please.

So, Framatome provided the implementation of the thermal-connectivity models for Chromia-doped fuel in the topical report. This implementation was supported by measurement data for unradiated fuel, as well as integral effects tests for radiated fuel.

NRC staff reviewed this information and found that it was satisfactory for both Chromia-doped urania fuel, and Chromia-doped urania-gadolinium fuel. Next slide, please.

Framatome also provided implementation of models for the fuel melting temperature. Again, similarly, information was provided for the Chromia-doped urania and urania-gadolinium fuel.

The NRC staff reviewed this information and found that it was consistent with the supporting

qualification data. Next slide, thank you.

For fission gas release, Framatome provided the implementation of fission gas release models for Chromia-doped fuel, as well as the basis and comparisons between measured and cryptic results.

And in addition to this, comparative analysis was provided for Chromia-doped urania-gadolinium fuel.

For standard U02, NRC staff was able to review the models, and found that it was consistent with experimental data for fission gas release fuel.

For Chromia-doped urania-gadolinium fuel, a limitation and condition was placed to ensure the appropriate therapies are used appropriately. Next slide, please.

So, rod growth models were originally reviewed and approved in the M5 cladding topical report.

For the Chromia-doped supplement, Framatome provided the specific information about what rods in the measurement database were Chromia-doped. NRC staff reviewed this comparative.

And there was some discussion about Chromia-doped gadolinium fuel rods, as well as the cladding type that's specific to these fuel types, and

NRC staff reviewed this and found this acceptable.

So, Framatome also provided the impact of the implementation on other safety analysis methodologies, including ARCADIA, AREA, ARITA, and LOCA, methodologies, obviously with the caveat that ARITA is still under review.

General conclusions from this evaluation were that the Chromia-doped properties are explicitly modeled in GALILEO. I threw a couple in with GALILEO for implementation of GALILEO as RELAP5, and that the use of the Chromia-doped properties don't alter the workflow of these calculations.

And finally, Framatome provided a licensing criteria assessment, both for thermal-mechanical evaluations and safety analyses. General conclusions for these were that the changes as a result of the doping were small, and consistent with the field property changes. And so, NRC staff was able to accept this as well.

So, conclusions. Material property changes were implemented in GALILEO, and these were consistent with qualification data. The impact of the doping on the field performance was adequately analyzed and the thermal-mechanical performance was addressed, and generally, the impact on safety

analysis was smaller than expected.

And I believe on the next slide, Framatome also discussed the limitations and conditions already. So, I won't repeat these here. But we can -- yeah, so. All right, thank you. Are there any questions?

MEMBER BALLINGER: Questions from members?

Okay, this concludes the open part of the meeting. So, we need to go out and ask if there are members of the public that would like to make a comment.

If you are out there and you would like to make a comment, please state your name first, and then make your comment.

Hearing none, thank you very much. This will close the open part of the session. Now, we need to transfer to the closed part, and that always entails a little bit of effort.

So, we'll take a ten-minute break and come back to the closed session, since it's now 1:32, let's try 1:45. That's more than ten, but I'm sorry.

(Whereupon, the above-entitled matter went off the record at 1:32 p.m.)

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ANP-10340, Revision 0, Supplement 1P, Revision 0 “Incorporation of Chromia-Doped Fuel Properties in Framatome PWR Methods” (OPEN)

Morris Byram

ACRS Subcommittee

June 20, 2023

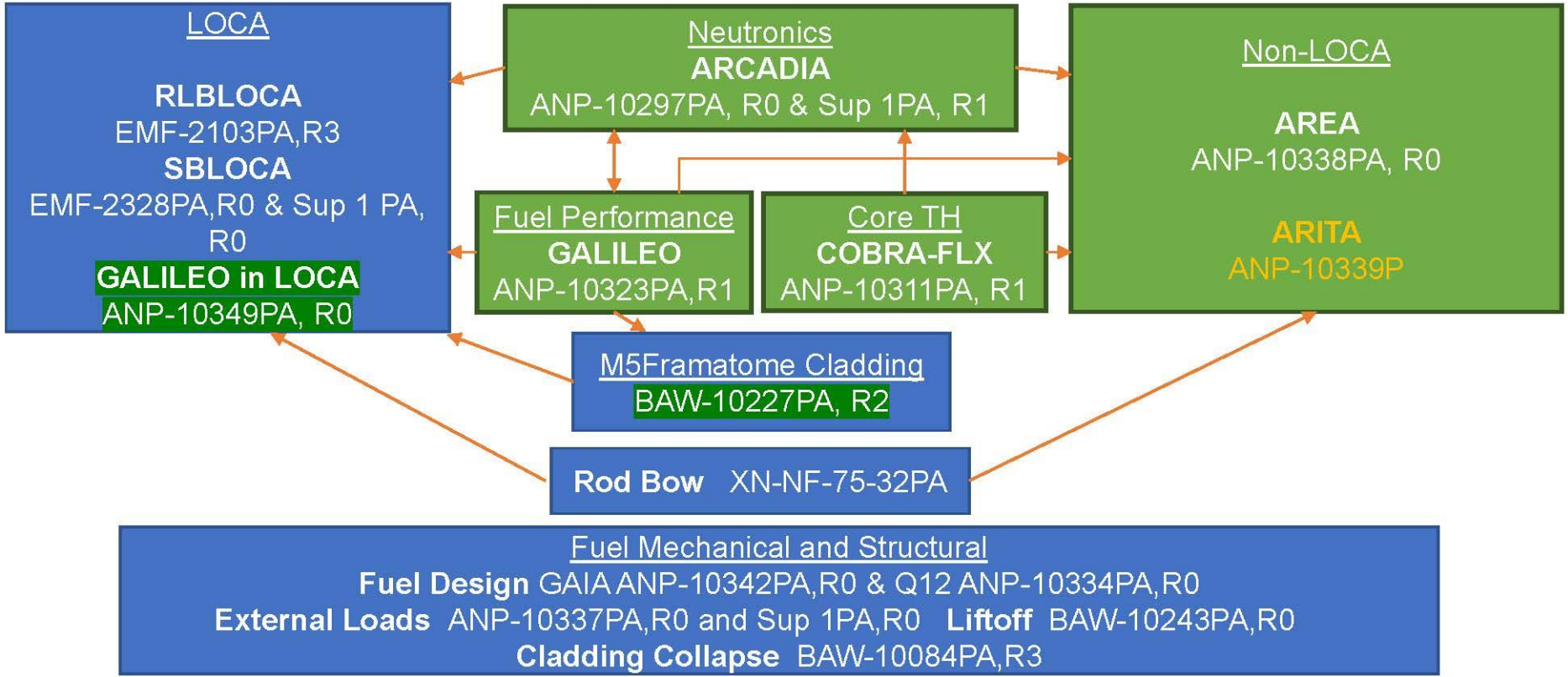
Agenda

- Key Milestones
- Advanced Codes and Methods Topical Reports
- Approval Request and Limitations
- Topical Report Outline

Key Milestones

- Pre-submittal meeting: October 2020
- Submitted ANP-10340, Supplement 1 for review: June 2021
- Accepted for review: July 2021
- Audit for Understanding: November/December 2021
- RAIs received: December 2021
- Submitted RAI Responses: April 2022
- Draft SE: April 2023

Framatome PWR Codes and Methods Overview



Only major methodology connections shown

Topical Report Introduction

- Supplement to base topical for BWR methods approved in 2018
- Regulatory guidance: NUREG-0800 Sections 4.2 and 4.4
- Generic parts to the base topical not repeated in supplement, but are addressed
  - Material properties
  - Behavioral assessment
  - Qualification database
  - Operating experience
- No changes to currently approved methods

Approval Request

Extend the applicability of existing approved PWR methods to include chromia-doped fuel for licensing applications

Limitations Consistent with Approved Topicals

- Grain size for standard fuel is unchanged from GALILEO
- Current Burnup limitations apply for UO_2
- Chromia-doped concentration range is consistent with base topical
- Additional Burnup limitation on UO_2-Gd_2O_3 (SER)

Topical Report Outline

- Applicability of base topical report
  - Materials properties
  - Behavioral assessment
  - Accident behavior
  - Qualification data

- Qualification of GALILEO
  - GALILEO thermal conductivity model
  - GALILEO fission gas release model
  - GALILEO intergranular gaseous swelling model
  - Validation of rod free volume and internal pressure

Topical Report Outline (Cont.)

- Qualification of Framatome methods to chromia-doped fuel
- Qualification of rod growth to chromia-doped fuel
- Licensing criteria assessment
  - Fuel rod thermal-mechanical evaluation
    - Cladding collapse
    - Cladding fatigue
    - Maximum rod internal pressure
  - Safety analysis
    - Non-LOCA (ARITA methodology)
    - LOCA
    - Control rod ejection accident
  - Impacts of nuclear design requirements

Acronyms

AREA – ARCADIA Rod Ejection Accident

ARITA – ARTEMIS/RELAP Integrated Transient Analysis

CE – Combustion Engineering

CHF – Critical Heat Flux

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

UO_2 – Standard Fuel

UO_2-Gd_2O_3 – Gadolinia Fuel

W - Westinghouse

DOE Acknowledgment and Disclaimer

Acknowledgment: “This material is based upon work supported by the Department of Energy under Award Number DE-NE0009034.”

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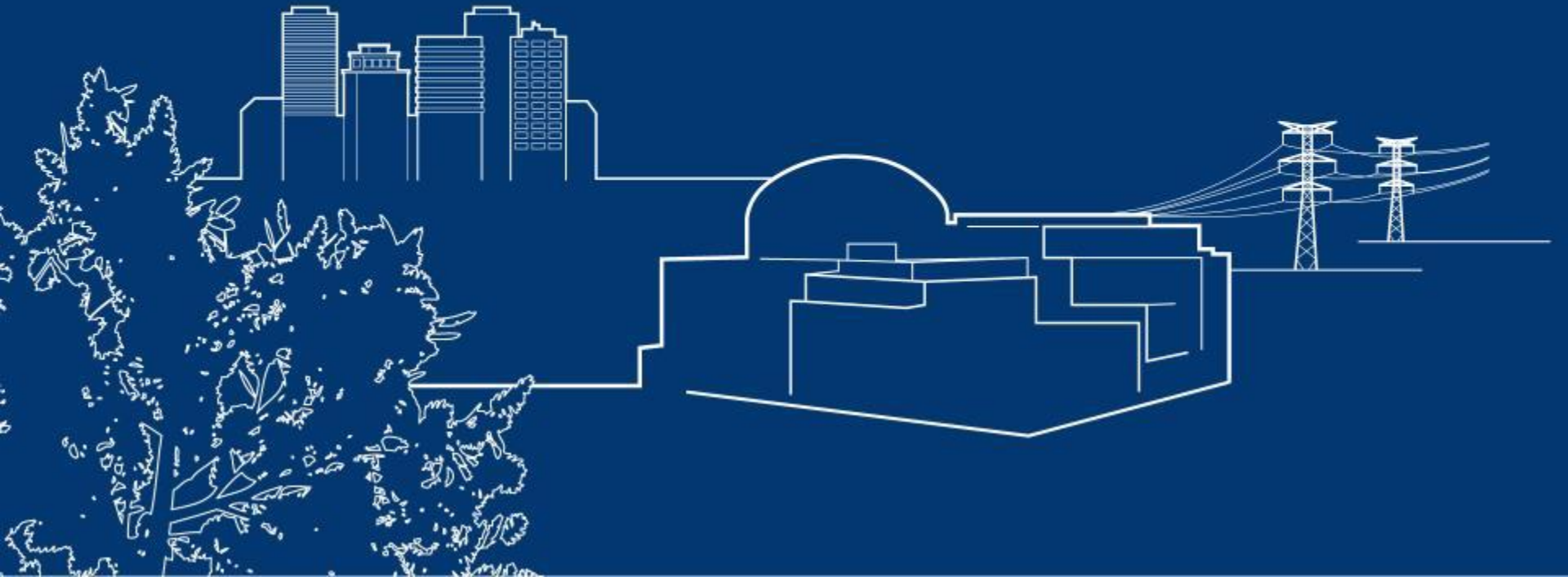


Staff Review of Supplement 1 to ANP-10340P-A Topical Report Incorporation of Chromia-Doped Fuel Properties in Framatome PWR Methods

Adam Rau, PhD

June 20th, 2023

Division of Safety Systems
Office of Nuclear Reactor Regulation

Presentation Outline

1. Licensing Criteria
2. Applicability of Base Topical Report
3. Impacts of Chromia-Doped Fuel During Accidents
4. **Qualification of Galileo for Chromia-Doped Fuel**
5. Qualification of Rod Growth to Chromia-Doped Fuel
6. Qualification of Framatome Methodologies for Chromia-Doped Fuel
7. Licensing Criteria Assessment

Licensing Criteria

- Regulations:
  - GDC 10 (SAFDLS)
  - 10 CFR 50.46
  - GDC 28 (Rod Ejection)
- SRP Section 4.2 Objectives:
  - The fuel system is not damaged as a result of normal operation and anticipated operational occurrences (AOOs),
  - Fuel system damage is never so severe as to prevent control rod insertion when it is required,
  - The number of fuel rod failures is not underestimated for postulated accidents, and
  - Coolability is always maintained.

Applicability of Base Topical Report

- Supplement Goal: Extend applicability of existing Framatome **PWR** topical reports to Chromia-Doped Fuel
- Base TR sections applicable to PWR/BWR Applications:
  - Material Properties
  - Behavioral Assessment
  - Qualification Database
  - Operating Experience
- PWR-Specific Supplement:
  - Code-specific implementation
  - Additional measurement data
  - Licensing criteria assessment

Impacts of Chromia-Doped Fuel During Accidents

- General conclusions
  - Use of Cr-doped fuel does not alter acceptance criteria
  - Similar behavior to undoped fuel
  - Impacts of chromia-doped fuel explicitly modeled by GALILEO
- Supported by review of material properties, sample accident analysis

GALILEO Qualification: Thermal Conductivity

- Framatome Evaluation
  - Good agreement demonstrated between GALILEO predictions and test data for 2006 and 2015 test campaigns
  - For irradiated fuel, REMORA2 test demonstrates validity of thermal models including thermal conductivity
- NRC Evaluation
  - NRC staff found the benchmarking of GALILEO thermal conductivity models satisfactory.
- Conclusion
  - The NRC staff determined that Framatome's thermal conductivity models for chromia-doped fuel and chromia-doped (U-Gd)O_2 are acceptable.

GALILEO Qualification: Fuel Melting Temperature

- Framatome Evaluation
  - Provided equations implemented in GALILEO and supporting qualification data
- NRC Evaluation
  - Reviewed GALILEO implementation for chromia-doped UO_2 and chromia-doped (U-Gd)O_2
- Conclusion
  - GALILEO appropriately captures the results of JRC-ITU experiments

GALILEO Qualification: Fission Gas Release

- Framatome Evaluation
  - Provided GALILEO implementation and basis, including comparisons of predicted and measured results
  - Provided comparative analysis for doped UO_2-Gd_2O_3
- NRC Evaluation
  - Reviewed data and found that FGR models for doped UO_2 are satisfactorily benchmarked to experimental data
  - FGR models for doped UO_2-Gd_2O_3 are suitable provided that a new limitation is met
- Conclusion
  - Finds that FGR models are suitable per use provided that limitations and conditions are met

Qualification of Rod Growth

- Framatome Evaluation
  - Compared rod growth model to experimental database
- NRC Evaluation
  - Reviewed measured to predicted comparison
  - Discussed chromia-doped gadolinia fuel rods, cladding
- Conclusion
  - Rod growth model is acceptable for use with chromia-doped fuel

Qualification of Framatome Methodologies

- Framatome Evaluation
  - Discussed implementation in ARCADIA, AREA, ARITA, W&CE LOCA Methodologies
- NRC Evaluation
  - Chromia-doped properties are explicitly implemented through coupling with GALILEO
  - Chromia-doped properties do not alter calculation methodologies
- Conclusion
  - Use of ARCADIA, AREA, ARITA, and W&CE LOCA methodologies to model chromia-doped fuel is acceptable

Licensing Criteria Assessment

- Framatome Evaluation
  - Provided sample fuel rod thermal-mechanical evaluations and safety analysis
- NRC Evaluation
  - Changes in results were small and predictable results of fuel property changes
- Conclusion
  - Results of the licensing criteria assessment are acceptable

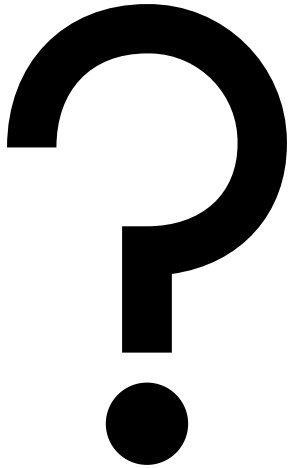
Conclusions

- Material property changes implemented in GALILEO and other Framatome PWR methodologies are supported by qualification data
- Impact of chromia dopant on fuel performance has been adequately analyzed
- Thermal-mechanical performance adequately addressed with the application of GALILEO
- Impacts on safety analysis are small and expected

Conclusions: Limitations and Conditions

1. The limitation imposed on grain size of standard fuel in Reference 7 (GALILEO TR, Rev. 1) is unchanged.
2. Chromia-doped fuel is limited to a specified rod average burnup limit.
3. Chromia concentration is limited to a specified range. The limit also applies to chromia-doped gadolinia fuel.
4. Limitation on chromia-doped UO_2-Gd_2O_3 fuel

Questions



Acronyms

AOO – Anticipated Operational Occurrence

AREA – ARCADIA Rod Ejection Accident

BWR – Boiling Water Reactor

FGR – Fission Gas Release

JRC-ITU – Joint Research Centre – Institute for Transuranium Elements

LOCA - Loss of Coolant Accident

PWR – Pressurized Water Reactor

REA – Rod Ejection Accident

RG – Regulatory Guide

RLBLOCA – Realistic Large Break Loss of Coolant Accident

TR – Topical Report

UO_2 – Uranium Dioxide (or Urania)

UO_2-Gd_2O_3 – Urania-Gadolinia