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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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WEDNESDAY

AUGUST 23, 2023

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The Subcommittee met in a hybrid meeting, in-person and video-teleconference, at 1:00 p.m. EDT, Ronald Ballinger, Chairman, presiding.

COMMITTEE MEMBERS:

RONALD G. BALLINGER, Chairman

VICKI BIER, Member

CHARLES H. BROWN, JR., Member

VESNA DIMITRIJEVIC, Member

GREGORY HALNON, Member

WALT KIRCHNER, Member

JOSE MARCH-LEUBA, Member

DAVID PETTI, Member

JOY L. REMPE, Member

THOMAS ROBERTS, Member

MATTHEW SUNSERI, Member

ACRS CONSULTANTS:

DENNIS BLEY

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

ALSO PRESENT:

MEG AUDRAIN, NRR

ALEX CHERESKIN, NRR

MATTHEW GORDON, NRR

SCOTT MOORE, ACRS

REBECCA OBER, NSIR

GREG OBERSON, NRR

DAVID RUDLAND, NRR

TABLE OF CONTENTS

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

(1:00 p.m.)

CHAIRMAN BALLINGER: The meeting will now come to order. 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 Charles Brown, Greg Halnon, Vicki Bier, Joy Rempe, Dave Petti, Matthew Sunseri, Jose March-Leuba, and Tom. And online I think --

MEMBER REMPE: Tom Roberts, just to help you.

(Laughter.)

CHAIRMAN BALLINGER: I know. Tom Roberts. I know.

And online, I think, are Vesna -- is Vesna there? Vesna --

MEMBER DIMITRIJEVIC: I am there. I am here.

CHAIRMAN BALLINGER: Thank you very much. And I think that's it. Oh, is Walt -- I don't see -- well --

PARTICIPANT: He will be joining us shortly.

CHAIRMAN BALLINGER: Yeah. I don't see -- oh, wait a minute. Well, I don't know how to tell whether he's on or not. Anyway, Walt Kirchner will join us.

We have our consultants, Steve Schultz and I assume Dennis Bley. Very good. If I have missed somebody, I apologize.

Chris Brown, who is also online, of the ACRS staff is the Designated Federal Official for this meeting.

During today's meeting, the subcommittee will receive a briefing on the staff's draft EANU-ISG2023-1 material compatibility for non light-water reactors. The subcommittee will hear presentations by, and hold discussions with, the NRC staff -- thank you very much -- and other interested persons regarding this matter as may happen.

The rules for participation in all ACRS meetings were announced in the Federal Register on June 13th, 2019. A U.S. NRC public website provides the ACRS charter, bylaws, agendas, letter reports, and full transcripts of all full and 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 relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the subcommittee.

A transcript of this meeting is being kept and will be made available. Today's meeting is being held in person over Microsoft Teams -- and over Microsoft. Sorry. There is also a telephone bridge line and an MS Teams link allowing participation by the public.

When addressing the subcommittee, the participants should first identify themselves and speak with sufficient clarity and volume that they may be readily heard. When not speaking, we request that participants mute your computer microphone or phone by pressing star-six.

I might add that for those of you who have not been in meetings here, these microphones are very direction -- directional, and you have to almost swallow the thing. You have to get very close to it, and it's important for the -- for the court reporter.

We will now proceed with the meeting, and I'd like to start by calling Greg Oberson -- yes, he

is -- Branch Chief in NRR for opening remarks.

Excuse me. Before we get started, the reason for this meeting is we are starting to receive applications and having presentations for a lot of non-light-water reactor designs. And this ISG is a complement to other documents which the staff put together to identify critical materials compatibility issues related -- that would relate to these non-light-water reactor designs.

All of the designers have to -- have to adhere to ASME Code and other standards. But related to materials compatibility with respect to corrosion and other kinds of things, a lot of these codes and standards basically say you're on your own. And so this ISG is helpful or will be helpful in that -- in that area.

So, Greg, sorry I interrupted you.

MR. OBERSON: Good afternoon, Dr. Ballinger and members. Thank you for the opportunity to present to the subcommittee this afternoon. I'm the branch chief for Technical Branch I in the Division of Advanced Reactors and Non Power Production and Utilization Facilities in the Office of Nuclear Regulatory Research.

As you already alluded to, our staff are

currently reviewing two applications for non-light-water reactors, the Kairos Hermes Test Reactor and the Abilene Christian University Molten Salt Research Reactor, while also the acceptance review is ongoing for the Kairos Hermes 2.0 test reactor, and three or more applications for commercial non-light-water reactors are anticipated within the next year to two years.

I begin with this to highlight the increasing workload for NRC staff on the non-light-water reactor licensing. And with that context, to emphasize the importance of clear, sound guidance that can be referenced by staff to support efficient and effective licensing processes.

Today we will present to you on one such example; namely, the Interim Staff Guidance, or ISG, on materials compatibility for non-light-water reactors. The ISG reflects differences in the materials fabrication methods, operating environments that will fundamentally distinguish component integrity and evaluations for non-light-water reactors from those from large light water reactors for which staff have abundant experience.

You'll hear further from the staff on the purpose, scope, and content of the ISG. A draft of

the ISG was issued for public comment in March of this year, and we will also discuss how the comments were addressed to prepare the final Interim Staff Guidance.

Finally, I'd like to acknowledge that the ISG was a collaborative effort. And in addition to my colleagues at the table presenting to you today, key contributions were made by additional staff in NRR as well as in the Office of Nuclear Regulatory Research.

We look forward to today's discussion.

And with that, I'll pass it back to you, Dr. Ballinger. Thank you.

CHAIRMAN BALLINGER: Thank you.

So I'm still not sure who is controlling the slides, but they're up there, so -- very good. Okay. So proceed, please. I'm not sure who the presenters are, but you might introduce yourself.

MS. AUDRAIN: Good afternoon. Am I close enough to the microphone?

CHAIRMAN BALLINGER: You're not that -- you're not close enough.

MS. AUDRAIN: Okay. Is that better?

CHAIRMAN BALLINGER: You've really got to

MS. AUDRAIN: Good afternoon. I am Meg Audrain, and I'm here today with Alex Chereskin and

Matt Gordon, as well as other members of the working group, both in person and online. We are presenting today on the ISG that we developed for materials compatibility in advanced reactor environments.

Today we are going to be going over the purpose and applicability of the ISG, the regulatory framework, qualification and performance monitoring, the technical content of the ISG, and our public comment and resolution, or our public comment resolution.

Next slide. We developed this ISG to assist staff in reviewing applications for construction and operation of non-light-water reactor designs, including power and non-power reactors. The guidance in this document identifies areas of staff review that could be necessary for a submittal seeking to use materials allowed under ASME Section III, Div 5.

Staff expects that most applicants will demonstrate their materials meet Div 5, which specifies the mechanical properties and allowable stresses to use for design of components in high temperature reactors. However, as stated in Div 5, code rules do not provide methods to evaluate and service deterioration caused by the environment, such as corrosion or radiation effects, but do state that these effects should be taken into account for the design

or component life.

This ISG provides the staff guidance in reviewing material areas that are not covered by Div 5. It identifies information the staff should consider in its review related to materials qualification. It also indicates where monitoring and surveillance may be appropriate to be relied upon to ensure component integrity.

Currently, there is no staff guidance on how to review materials qualification, performance monitoring methods, or surveillance for non-light-water reactors. This guidance is intended to ensure consistency across staff reviews and clarity on what to review in an application.

Next slide. Non-LWRs present environmental challenges to material performance that are not present in LWRs as the operating environments are different than those in our current fleet. The operating temperatures of non-LWRs may be significantly higher than those in current nuclear power plants, where temperature ranges corresponding to the creep regime in which deformation may occur with applied stress.

The coolants used in non-LWRs are significantly different from those used in LWRs as well. These coolants may be liquid metals such as sodium

or lead, liquid salts with or without fuel, helium, or possibly other coolants not yet considered. These different coolant environments may increase susceptibility to material corrosion, degradation mechanism, and radiation effects.

Studies have identified the gaps in knowledge that exist for some of these coolant types and the impact on the materials being considered in the construction and operation of these non-LWR nuclear power plants. Because of the current state of knowledge of degradation in these environments, and long test time, the staff will place a strong emphasis on ISG, on using mitigation strategies, performance monitoring, and surveillance programs to ensure SSCs continue to satisfy the design criteria where appropriate.

Next slide. This ISG is applicable to NRC staff reviews of applications for non-LWR designs, including both power and non-power reactors, for permits, licenses, certifications, and approvals under 10 CFR Parts 50 and 52.

As stated in the Commission's policy statement on the regulation of advanced reactors, advanced designs are expected to provide enhanced margins of safety; use simplified, inherent, passive,

or other innovative means to accomplish their safety and security functions; or both. Examples of advanced reactors include molten salt reactors, liquid metal reactors, and high temperature gas-cooled reactors.

The current regulatory framework for qualification of structural materials in non-LWRs is as follows. The 10 CFR regulations listed on the slide state that applicants must include PDCs for their facilities. Reg Guide 1.232 provides proposed guidance for the development of PDCs for non-LWRs.

Several design criteria in this reg guide relate to materials qualification for structural materials and state the importance of environmental compatibility, inspection, material surveillance, and functional testing.

Next slide. Before I begin a description of the technical content of the ISG, I'm going to define a few terms to make sure everyone has a common understanding. First, materials qualification includes testing conducted in an environment simulating the anticipated operating environment for the reactor, including chemical environment, temperatures, and radiation.

Performance monitoring includes inspections or examinations to confirm adequate

performance and to identify unacceptable degradation. It may also include aging management programs or post service evaluations.

And, finally, surveillance programs include examination of test coupons and components removed from the reactor over the licensed operating period.

CHAIRMAN BALLINGER: This is Ron Ballinger. I'm going to try to stick this in where I can. I see no -- in this ISG, I think there might have been or might be an opportunity to go after the issue of modeling and simulation as it relates to qualification of materials.

Over the years, modeling and simulation, especially in the materials area, has turned -- has really, really expanded. We oftentimes hear we want it to be a prototype, and things like that, and that's what this kind of performance and qualification monitoring kind of implies.

But I'm curious as to whether in developing the ISG folks considered somehow addressing the issue of the use of modeling and simulation as part of the overall materials qualification process.

Dave has pointed out to me that that was done in the fuels qualification area, but it's much

broader. So I'm curious as to whether or not there was consideration to including in the ISG something related to how you used modeling and simulation to -- I don't want to use the word "expand," but enlarge the data set, if you will, in quotes, because that's going to happen. It's inevitable. We're going to see applicants come in and make extensive use of modeling and simulation.

MS. AUDRAIN: I don't know that we specifically address that in the ISG. There's nothing in the ISG that prohibits the use of modeling and simulation.

CHAIRMAN BALLINGER: Yeah. There's nothing in the ISG, that's for sure. I'm just saying some -- have you thought -- did you think about including something like that in the ISG?

MS. AUDRAIN: So the scope of the ISG is really to focus on environmental impacts and considerations. So I am not entirely sure where we would address modeling and simulation. Do you --

CHAIRMAN BALLINGER: So it wasn't part of the plan, is what you're saying.

MS. AUDRAIN: Yeah.

CHAIRMAN BALLINGER: Okay.

MS. AUDRAIN: I think in doing the -- in

doing the review, you know, an applicant would likely propose using modeling and simulation of their data that they gather. So --

MR. CHERESKIN: Yeah. I think I would echo what Meg said there. And, in addition, you know, our guidance here I don't think got to the very prescriptive level of this is exactly how you review, you know, specifics for an application like modeling and simulation.

But, at the time, you know, if someone proposed it, we would obviously review it, you know, as appropriate, when we get those applications.

PARTICIPANT: You needed to state who you were for the court reporter.

MR. CHERESKIN: Sorry. This is Alex Chereskin.

CHAIRMAN BALLINGER: And I've got one other question, which I missed because I was writing something down. Did you look at -- with regard to materials and corrosion-related issues, did you look at API-579, which was converted into an ASME Code document, FF -- now I'm forgetting -- FFS-1, Fitness for Service, Chapters 7, 8, and 9, and that definitely has guidance on how to include environmental effects.

MS. AUDRAIN: I'm not sure. I don't

believe that anybody on the staff did.

CHAIRMAN BALLINGER: I would encourage you to take a look at that, because now it's an ASME Code document. It was an API document before, but the ASME just basically incorporated it and just took the title page off and put ASME on the front. Because environmental effects are a big deal in the oil and gas industries, but that API is not specific necessarily to the oil and gas industry.

MS. AUDRAIN: Okay.

MEMBER REMPE: So, Ron, just out of curiosity, what would you like them to do to talk about -- interpolation is generally okay if you have data to support something for material qualification. Do you want them to talk about how far you can extrapolate with modeling and simulation and say --

CHAIRMAN BALLINGER: I don't want these folks to do it.

MEMBER REMPE: No. But you want the ISG to say something about --

(Simultaneous speaking.)

CHAIRMAN BALLINGER: I'm suggesting that there might be ISG-2, or some other number in the future, where this issue of using modeling and simulation as part of the design process in the materials area --

MEMBER REMPE: So you want them to come up with some way that -- what's allowable to extrapolate, because extrapolation shouldn't be a problem.

CHAIRMAN BALLINGER: Dave and I have been going through some of this. There are techniques that you can use, which will also have limitations and conditions and all that kind of stuff, where if you meet those conditions, you can use modeling and simulation. You expand the uncertainty when you do that, but there is --

MEMBER REMPE: Sometimes extrapolation isn't so good, though.

CHAIRMAN BALLINGER: Extrapolation -- as long as --

MEMBER REMPE: I'm just curious.

CHAIRMAN BALLINGER: I'm saying, as long as J. Willard Gibbs is still working for us, extrapolation is okay. There are ways to extrapolate, but there are a lot of cases where you should not.

MEMBER REMPE: Yeah. Go ahead. Sorry. I just was curious.

MS. AUDRAIN: Well, I think for a lot of these areas, as we start to use the ISG, will identify areas of improvement for another iteration.

CHAIRMAN BALLINGER: You're trying to plant a seed.

MS. AUDRAIN: Yeah.

MR. OBERSON: This is Greg Oberson. And just along the lines of modeling and simulation, although it's not precise, speaking to that in the context of modeling and simulation for materials performance in the context of this ISG, of course you're aware that we do much in the way of modeling and simulation for neutronics, thermal hydraulics, and so forth.

So one of the things -- some of the things that would really be key to that evaluation would be looking at, for instance, the verification and validation of methodologies, and particularly if there's guidance, perhaps that would be needed in that respect as well as the confidence that the models accurately reflect the materials performance data.

So point well taken, and thank you for bringing it up.

MS. AUDRAIN: It looks like we have a few members of the working group that have their hands raised, too. Dave, do you want to go ahead?

MR. RUDLAND: This is Dave Rudland from the Division of New and Renewed Licenses in NRR.

To Ron's point, you know, the ASME Code has been spending a lot of effort beginning to investigate modeling and such to help in the qualification of time-dependent high-temperature materials. And the staff is actively following their development, as well as the development of the contractors in their work to do that, to be able to help quickly qualify these high-temperature materials. So we're very tied in with that.

And, of course, I think as Alex may have said, if something becomes approved through code, the staff of course will give it its full consideration.

As for API-579, you know, the differences in degradation behaviors between the information that's in API-579 and that that's in ASME Section 11, of course is different in the fact that, you know, ASME Section 11, Section 3, codes are focused on those degradation mechanisms that may be specific to nuclear-grade materials and their applications, where API-579 has a little different -- a little different focus.

And this ISG is mainly focusing on those behaviors that are expected at -- you know, for these advanced reactors. And while I think it's probably a good idea that we do a cross-check, I think that the stuff that's in the current guidance is covered for

API-579.

Thank you.

CHAIRMAN BALLINGER: Got it. Thanks. I think the operative word though, Dave, is "expected." I'm thinking that --

MR. RUDLAND: Of course.

CHAIRMAN BALLINGER: -- sooner or later when these -- with these new plants we might get what I would call surprised.

MR. RUDLAND: Oh. No, we always are. So -- and when -- and we do -- you know, we are as proactive as we can be, looking at the research that's being done, as well as the past operational experience, as well as any testing that is being done or test reactors that will be done. So the staff are staying very aware and on top of the issues.

CHAIRMAN BALLINGER: Don't retire, Dave.

MS. AUDRAIN: I think we can all second that one.

CHAIRMAN BALLINGER: Yeah. No comment on that one. Not saying anything.

Thanks.

MS. AUDRAIN: All right. An SSC's performance will be demonstrated through a combination of material qualification programs, supplemental

testing, and performance monitoring surveillance programs, which collectively provide assurance that a component will meet the design requirements over its intended life in the applicable operating environment.

This ISG identifies that the scope of materials qualification and monitoring program should include safety-related component materials, safety significant component materials, and, as needed, non-safety-related components whose failure could impact critical design functions.

The selection of structural materials for the reactor design should consider effects on the material properties and allowable stresses due to interactions with the operating environment. Materials qualification and monitoring programs should include testing conducted or use of historical data collected in an environment simulating the anticipated operating environment for the reactor, including the chemical environment, temperatures, and radiation.

Use of any historical data should be directly applicable to the plant design and environment. As seen in their historical data, it should account for uncertainties in the environment, material composition, fabrication methods, and operating conditions. Testing should be conducted to

determine if material properties and allowable stresses meet applicable codes and standards or other design requirements.

Next slide. Performance monitoring and surveillance programs are used in tandem to ensure that a component will continue to meet its design requirements. For components for which there is little data on performance in similar operating environments conditions, performance monitoring and surveillance programs could be an acceptable way to show that the component will maintain its intended function throughout the design life.

An example of this could be chemistry, temperature, flow monitoring, or wall thickness measurements. Surveillance programs could include test coupons or SSCs removed and tested during operation, data from which could be used to help predict degradation of components and service.

A component with significant design margin, or one that has demonstrated acceptable performance under similar operating environments and conditions, may require less rigorous performance monitoring and surveillance programs.

The staff review should include performance monitoring and surveillance programs for

SSCs that are not planning -- planned to undergo periodic inspections or functional testing.

MEMBER BROWN: Can I ask a question?

MS. AUDRAIN: Mm-hmm.

MEMBER BROWN: I'm not a materials person like these guys are, but when I was looking at this and what you just said, it gives the impression that you can embark on a new program of materials that are installed in the plant without prior experimental verification that they will actually withstand some of the conditions under which they are going to operate as long as you incorporate coupons and other performance monitoring.

Back in the old, old, old, old days, in 1950 and so when we started these programs, while we embarked on some of that similar-type stuff, there was some experimental data that was relied on to at least get the program started, but then there were test reactors that did what you would call accelerated experiments to try to characterize, you know, the radiation response and everything else.

And this seems to say we're not going to be as -- to me it says that we're not going to be as complete or as thorough as we did in the past. Is that -- it's kind of the way I read some of this.

MS. AUDRAIN: That was not the intention. The intention of this section was to say that we understand that, especially in some areas where there's a long lead time or challenges, especially with the radiation testing, that while that testing is being done, or in addition or supplementing that testing, you could do some other performance monitoring strategies to ensure that the component would say -- would satisfy its design criteria.

I think the bar for doing that versus having a testing program at all would be very, very high. The intention isn't to say that no testing would ever be required for these components. More that we would be more looking at materials qualification and performance monitoring holistically.

MEMBER PETTI: Charlie, my view on this is that there are some things you cannot do until you get to the reactor. And some of these inspections, they're integral effects tests, if you will. And some of the monitoring will get at things that no matter how good all your testing was outside of the reactor

MEMBER BROWN: I don't know what --

MEMBER PETTI: -- provide assure that --

MEMBER BROWN: I'm not arguing about the

you know, the in-plant performance stuff. It's just some information that says I can get through six months or maybe a year, but I may not have a complete story, but I can at least have some confidence that when I build something it's not -- it's going to be okay for more than a very limited period.

MEMBER PETTI: Yeah. No, that's --

MEMBER BROWN: That's not the way I read it.

MEMBER PETTI: That's not how I read it.

MS. AUDRAIN: That wasn't the intent.

MEMBER BROWN: But that's my brain.

MS. AUDRAIN: Yeah. That was not the intention of the ISG. It was more to show that for some of the more complicated testing that we wouldn't be preventing reactors from being designed and built, that there are other ways to ensure that the components would meet their design.

CHAIRMAN BALLINGER: This is Ron Ballinger again. Not to beat a dead horse, which I will keep beating the dead horse, and that is, to what extent do you think you would consider the substitution temporary, if that, of modeling and simulation for getting at this and satisfying it?

MS. AUDRAIN: I think that would be very

design- and materials-specific. It would be hard to give a generic answer to that.

CHAIRMAN BALLINGER: Well, but you're not slamming the door.

MS. AUDRAIN: No.

CHAIRMAN BALLINGER: Okay.

MEMBER BROWN: The reason I asked that question is based on that old, old, old experience back in the naval program, there was data taken and you could see nice progress over time of data points going along with an envelope, and all of a sudden it took off going in the wrong direction. And that's one of those surprises.

Now, you don't find five- or 10-year stuff, you know, with many programs, but you like to make sure that takeoff is not after three months or six months. You'd like to know there is a period that you've got enough experimental information that says, "Yeah. Temperature and radiation combined, whatever, at least gets you through some period wherein, you know, you can recover."

It seems that that's not incumbent in the ISG. That's all. And that was the way I read some of the paragraphs. So that's just -- that's me reading it, and I just wanted to make sure -- I don't think

you guys intend on going out to lunch. That's not the point. But it's the message sent via an ISG that licensees and other people who want to come forward, you know, see this. Oh, we can do a little bit less than we would have done, because it says they will consider it. That's all.

I will stop right there. It just was my thought process. That's the way I read it. I didn't have any problem with most of the rest of it.

MR. CHERESKIN: Yeah. So this is Alex Chereskin. The only other thing that I would add to, you know, what Meg and others have said is that the ISG is guidance to the staff on what to look for during the review. And so when we're having these discussions of where there might be potential tradeoffs or, you know, whatever the mitigation measures you need are, this is guidance to the staff to be able to then look at that when we actually get an application and evaluate it at that time, too.

So I don't think we're making the conclusive statements that, you know, there is one definitive way to do or not do something.

MEMBER BROWN: I understand that's the guidance, same as -- I mean, how you all review it. But notwithstanding that, the people that are going

to be doing things do know what you're going to be reviewing and look for ways so that they can proceed. It may be just nervous when we have lack of understanding. We've learned a lot, that materials do something strange after a while, as we have found out many, many times.

All right. I'm done.

MS. AUDRAIN: All right. The ISG has two sections on generically applicable materials issues, one for general degradation mechanisms and one for general materials issues. The general degradation mechanisms and material issues are likely to apply across different reactor designs, operating environments, and materials.

The ISG also has three technology-specific appendices. The technology-specific appendices developed were for molten salt reactors, liquid metal reactors, and high-temperature gas-cooled reactors. The topic areas in the ISG were identified by staff through a review of historical documents, NRC technical letter reports, industry gap analysis reports, and literature searches to identify materials topics and degradation mechanisms likely to occur generically and in the specific reactor designs.

The mechanisms identified in the ISG

reflect current state of knowledge. However, as additional operating experience and lab testing becomes available, the need to address each identified degradation mechanism or materials issue may change and new ones may be identified.

In the ISG, we identify degradation mechanisms that the staff should evaluate if they have been adequately addressed for various reactor environments. The ISG provides information to guide the staff's review for the degradation mechanisms listed on the slide. For each degradation mechanism, the ISG identifies the information to be considered in review, how the degradation mechanism could impact an SSC, and, where applicable, guides the staff to confirm that appropriate mitigation strategies, performance monitoring, and surveillance programs were considered.

This information is provided to guide staff review. However, the information required in the application for degradation mechanisms and specific mitigation, performance monitoring, surveillance programs would be design dependent.

We also identified the following general materials issues that staff should evaluate if they have been adequately addressed for various reactor

environments. The ISG provides information to guide the staff's review for advanced manufacturing technologies, metallic materials qualification, ceramic insulation, dissimilar metal welds, composite materials, and gasket and seal compatibility.

For each materials issue, guidance is provided on the areas to evaluate, the reason for the evaluation, and, where applicable, guides the staff to confirm that appropriate mitigation strategies, performance monitoring, and surveillance programs were considered. These material issues are, again, design dependent and would not be applicable for all designs.

The first appendix of the ISG offers details on the design or environment-specific aspects for molten salt reactors. MSR designs fall into two categories: liquid fuel and solid fuel. In a liquid fuel MSR, the fissile material is directly dissolved in the coolant. In a solid fuel MSR, the molten salt coolant has relatively small amounts of fissile material and fission products.

They are typically contained within a TRISO fuel particle, which could be in a prismatic graphic compact or a pyrolytic graphic sphere. The design of the MSR will have a large impact on how to review each materials issue identified on the slide.

For example, liquid fuel MSRs will have more material interactions with the fissile material and fission products. The ISG provides information to guide the staff's review for graphite compatibility, various materials considerations, such as degradation, cracking and corrosion, salt composition, and tritium production.

There is guidance on specific topics in each header for staff to evaluate. For example, under graphite compatibility, the staff has provided guidance to review graphite salt compatibility, salt infiltration, and abrasion erosion, in addition to other areas. Where applicable, the section guides the staff to confirm that appropriate mitigation strategies, performance monitoring, and surveillance programs were considered.

The second appendix to ISG offers details on the design and/or environment-specific aspects for liquid metal reactors, both sodium and lead-cooled. Liquid metal reactors are characterized by the operation at or near ambient pressure using a fast neutron spectrum in which the fuel with metallic cladding is cooled by liquid sodium, lead, or the lead bismuth eutectic.

The design and coolants at the liquid metal

reactor will have a large impact on how to review each materials issue. The specific topic areas listed in the ISG for each coolant type are on this slide. However, common areas to review include corrosion, coolant purity and flow rate, and temperature. The staff should evaluate whether applicants have adequately addressed these materials issues as -- including, as appropriate, plans to monitor, evaluate, and mitigate degradation.

MEMBER REMPE: I had a question. The ISG talks about safety-related and non-safety-related components, systems, and structures. And they talk about instrumentation you need to get this data to do all of this monitoring. But it doesn't distinguish whether more QA is needed for safety-related versus non-safety-related. Have you guys -- what are your thoughts about this, and how would the staff interpret this?

MS. AUDRAIN: It wasn't the purpose of this ISG to determine whether a component is or is not safety or non-safety-related.

MEMBER REMPE: But if the applicant has a safety-related or a non-safety-related component, do they need to have a better quality of data? And is it clear from the ISG what kind of quality of

instrumentation needs, performance monitoring data, are needed?

MS. AUDRAIN: We do have a section on quality assurance in our discussion section of the ISG. I forget the exact language, but the expectation would be that they use an approved UA program for safety-related.

MEMBER REMPE: So something that is safety-related needs higher fidelity data. It wasn't obvious to me when I read it, but I'll look at it more carefully.

MS. AUDRAIN: The third appendix to the ISG offers details on the design or environmental-specific aspects for high-temperature gas-cooled reactors. HTGRs can use helium or CO2 coolant. However, reactors that use CO2 as the coolant are not currently expected to be deployed in the United States, so ISG only addresses degradation considerations that are likely to apply to the helium cooled reactors.

The ISG provides information to guide the staff's review for creep rupture strength, emissivity, graphite, graphite dust, helium impurities and carburization, silicon carbide and composites, and lubricant considerations specific to the helium

environment.

The ISG identifies the information to be considered in a review for each topic, how the topic could impact the SSC, and, where applicable, this guides the staff to confirm that appropriate mitigation strategies, performance monitoring, and surveillance programs were considered.

As Greg mentioned, this ISG went out for a 60-day public comment period this spring. We received comments from eight different entities with a total of 57 comments. As part of the response to this, we made a few notable changes to the ISG.

First, we included additional evaluation of carburization and decarburization throughout the ISG for the different reactor designs. We included cladding in the metallic materials qualification section. And we included generic guidance for non-code-qualified materials in the background section rather than having references throughout the ISG.

MR. SCHULTZ: Meg, I'd like to make a comment. This is Steve Schultz.

I would have characterized the public comment period -- not the period, but the public comment process and its results somewhat differently. That is, it was a 60-day comment period, and you did receive

a substantial number of well-intended comments aimed at improving the document or its application.

And having reviewed them in some detail, there were a number of comments that the staff -- of those 57, a number of those that the staff did accept and integrate into the report to make fairly valuable changes to the document itself.

And then those that you didn't accept you had the opportunity to provide your additional rationale as to why you didn't do that, and in some cases how the comments didn't particularly apply to this document but could be utilized in other ways in the licensing process, and so forth.

So I would have -- I would have just characterized it differently in terms of the value of the process. I thought, as I said, the comments were very well intended and quite highly technically oriented to provide information that improve the document.

MS. AUDRAIN: Oh, yeah. It was not my intention to dismiss any of the public comments. There were a number of very, very good ones. It was more just to highlight the areas where we had major changes.

MR. SCHULTZ: Yeah. I just want to continue to encourage the public process and the comment

process. Thank you.

MS. AUDRAIN: In summary, we developed an ISG to develop -- to guide staff on reviewing non-LWR applications using materials allowed under Div 5. Changes were made to address the public comments received for the draft ISG. Our next steps are OGC approval and issuance of this as a final ISG.

Thank you.

MEMBER REMPE: I had another QA question. There were some documents related to AMT QA requirements that -- and I was wondering, I don't know if we've been involved in the review and what's the status of those documents. It basically said the NRC is in the process of developing both generic and AMT specific guidance for considering the QA of AMT components. Is that something that we'll see?

MS. AUDRAIN: I'm going to let either Dave or Rob Tregoning answer that question. They're still active participants on the AMT team.

MR. RUDLAND: I'm happy to make a quick comment on that. So, yeah, the staff of both NRR and Research have been working to develop guidance that is both technology-specific as well as generic over the last couple of years. And through that process, we have developed draft guidelines that pertain to those

-- to those topics that have been sent out for public comment, and such like that.

At this particular time, we're continuing those efforts. I think the overall goal is to wrap that into some overall guidance. The timeframe of that I think is relatively -- is relatively short term, but I know the staff is still currently working on that. And if ACRS is interested, of course when that time comes we'd be happy to bring that to you guys.

CHAIRMAN BALLINGER: I think you can assume that's the case.

MR. RUDLAND: I'll pass that on to the team.

CHAIRMAN BALLINGER: Questions?

MEMBER DIMITRIJEVIC: This is Vesna. I have something that I want to support in one of Joy's comments just before where she asked about the safety classifications and are the requirements different for the -- you know, the different safety class.

And I notice in your guide that you actually -- that was also part of -- I think of some questions which I saw. But, anyway, I notice in your guide that you say that this applies to safety-related, safety-significant, and non-safety components whose failure could impact critical design function.

So certainly you have here three categories, because usually there is just, you know, two -- three different categories. Essentially, you have four categories, because then we're going to have non-safety components which don't impact, you know, the critical design function.

So this is slightly different than the usual safety classification which we see. So is -- do you have an intent for this to be risk-informed? You know, when do you need to start the old degradation mechanisms, and things like that? And why do you have these classifications which are slightly different than, let's say, NEI-0804?

MS. AUDRAIN: Well, our intention was to because the likelihood of designs being so different for advanced reactors versus the light water reactors was to make sure that any component that would be relied upon for safety, whether it was classified as non-safety or safety, would still be reviewed by staff to ensure that the component would meet its design criteria.

Does that answer your question?

MEMBER DIMITRIJEVIC: But you understand my question. You have a little -- you have added this category, non-safety, whose failure could impact control design function. And that will mean

non-safety, non-risk-significant, but impacts critical design function.

So, you know, I mean, I don't know, but I will bet non-safety-significant. But, anyway, this is some additional category you are adding, and basically do you want to cover everything? I mean, or -- I mean, as you said, you just want to make sure that they address everything which is done.

But I just want to say that your classification is not really consistent with classifications we see for the non-light-water reactors in the, you know, classification process.

So this is just my comment. Just, you know, take it with a grain. On one of the comments, which you get from the public, you said that you -- you know, you had to three categories, and you don't intend to change this.

CHAIRMAN BALLINGER: Other comments from the members or consultants? Okay. We're rapidly approaching a world's record, a presentation to the ACRS which is less than an hour long.

Yeah, that's right. By materials people.

(Laughter.)

CHAIRMAN BALLINGER: We're encroaching on thermal hydraulics territory.

So we need to go out for public comments. If there are members of the public that would like to make a comment, please state your name and your organization, and please unmute yourself and make your comment.

Hearing none, this is a very short meeting, but the purpose of the meeting was to make sure that the members are all familiar with this issue, because we're going to be constantly dealing with new materials as submittals come through, and to have this available and this knowledge will serve us well I think.

So I'll --

MEMBER HALNON: Ron, what are they using now, like, for instance, the reactor we heard this morning and the reactor we'll hear this fall?

CHAIRMAN BALLINGER: I'm guessing that they're using this. I can tell you that the Kairos people are.

MEMBER HALNON: Okay.

CHAIRMAN BALLINGER: For sure. I mean, if you read their --

MS. AUDRAIN: Just a point of clarification. The Kairos review was done for the topical reports prior to this being issued publicly.

CHAIRMAN BALLINGER: Okay. I get your

point. But if you read it, there's a certain familiarity with the topics and things in there, and the order.

MR. CHERESKIN: Yeah. I understand that. There are a lot of common staff working on both the Kairos project and this project as well. And so I -- you know, I think we can --

CHAIRMAN BALLINGER: I mean, that's a testimony to the efficacy of what you're doing. I mean, people are starting to use them.

MEMBER HANLON: All that informed what we see here, anyway. I mean, because there is a lot of material here. You just didn't make this up over the last three months. I mean, this is a lot of stuff.

MS. AUDRAIN: No. We've been working on this ISG for a couple of years. We just want to make very clear that Kairos did not get a preview of this document before anybody else, but it was --

MR. CHERESKIN: Very smart.

MS. AUDRAIN: -- similarities are because the same staff worked on both projects.

MEMBER HALNON: So would it be considered a backfit to impose this guidance on, like, Kairos and some of the reactors that have already been somewhat designed but maybe not submitted?

MS. AUDRAIN: This is staff guidance. It's not guidance for applicants.

MEMBER HALNON: Yeah. But we all know what staff guidance means.

MS. AUDRAIN: I think it's fair to say that because the same people who developed this guidance have been working on the advanced reactor applications --

MEMBER HALNON: That's a very iterative process. I mean -- thanks.

MR. CHERESKIN: One other thing I would note, that I was just talking about, you know, the timing of this and what the staff -- you know, kind of our knowledge base, you're right, this wasn't developed, obviously, in a matter of days or months.

But, I mean, even if you look at some of the references going back, we cite technical letter reports from the NRC Office of Research that were, you know, from 2020, 2021, and so this is a couple of years I think kind of in the making, with us crediting that. And a lot of the staff that worked on these things are familiar with the work our colleagues in Research have been doing as well.

So, yeah, and it kind of also has, like, a common source for, you know, the reviews and us putting

together this ISG.

CHAIRMAN BALLINGER: I mean, it's very timely. I'm surprised it took this long.

Okay. If there aren't any other comments, and I could ramble along for another 10 minutes and make it an hour, but I won't do that. So -- we're good at that.

Anyway, thank you very much for spending the -- I did. What, do you mean to do it again?

Okay. Thank you very much again, and we are adjourned.

(Whereupon, the above-entitled matter went off the record at 1:50 p.m.)

Interim Staff Guidance on Materials Compatibility in Advanced Reactor Environments

Meg Audrain, Alex Chereskin and Matt Gordon
Office of Nuclear Reactor Regulations
August 23, 2023
ACRS Subcommittee Meeting

Agenda

- Purpose and Applicability of Interim Staff Guidance (ISG)
- Regulatory Framework
- Qualification and Performance Monitoring
- Technical Content
- Public Comment Resolution
- Conclusions and Questions

Purpose for Development of ISG

- Anticipate non-light water reactor (LWR) applicant use of ASME Section III, Division 5 (Div 5), “High Temperature Reactors”
- Account for environmental effects in assessment of service life for structures, systems and components (SSCs)
- Address lack of existing staff guidance on the review of materials qualification, performance monitoring methods, and surveillance for non-LWRs
- Ensure consistency and clarity for application reviews, including identification of:
  - Information related to materials qualification, and
  - Appropriate monitoring and surveillance programs.

Non-LWR Environment

- Corrosion and other materials degradation phenomena may significantly differ from LWR environments
- Lack of test data and operational experience gives rise to knowledge gaps for the materials-environmental interactions in non-LWRs
- Use of appropriate mitigation strategies, performance monitoring, and surveillance programs will be emphasized by staff to ensure SSCs continue to satisfy the design criteria

ISG Applicability

Staff reviews of non-LWR power, research or test reactors that propose the use of materials allowed under Div 5

- Part 50 - construction permit and operating license
- Part 52 - design certification, combined license, standard design approval, or manufacturing license

Current Regulatory Framework

- Staff evaluate performance of SSCs with reference to the facility principal design criteria (PDCs) required by 10 CFR 50.34(a)(3)(i), 10 CFR 52.47(a)(3)(i) and 10 CFR 52.79a(4)(i)*
- ISG addresses staff review of materials qualification, performance monitoring, and related issues to ensure conformance with PDCs.

*See also Regulatory Guide (RG) 1.232, “Guidance for Developing Principal Design Criteria for Non-Light Water Reactors”

Qualification and Performance Monitoring - Terminology

- Materials qualification
  - Testing conducted in an environment simulating the anticipated operating environment for the reactor, including chemical environment, temperatures, and irradiation
- Performance monitoring
  - Inspections or examinations to confirm adequate performance and to identify unacceptable degradation such as chemistry temperature or flow monitoring, or wall thickness measurements
  - May also include aging management programs or post-service evaluations
- Surveillance programs
  - Examination of test coupons and components removed from the reactor over the licensed operating period

Qualification and Performance Monitoring

- Purpose: Demonstrate that a component will meet the design requirements over its intended design life in the applicable environment
- Scope: Safety-related and safety-significant component materials, and as needed, non-safety related component materials whose failure could impact critical design functions
- Testing: Determine if materials properties and allowable stresses meet applicable codes and standards or other design requirements

Performance Monitoring and Surveillance

- Expected scope of programs will depend, in part, on availability of testing data
- Robust monitoring and surveillance programs may provide appropriate confidence when:
  - There is a limited set of testing data
  - Periodic inspections and/or functional testing of SSCs is not planned

Technical Content of ISG

- Degradation issues
  - Generically applicable
  - Technology specific
- Technology-specific appendices
  - Molten salt reactors
  - Liquid metal reactors
  - High temperature gas reactors

Represents current state of knowledge – subject to change based on evaluation of further test data and operating experience

Generally Applicable Degradation Mechanisms

- Carburization
- Corrosion
- Environmental effects on creep and creep fatigue
- Environmentally assisted cracking
- Flow induced degradation (abrasion, erosion, cavitation)
- Flow induced vibration
- Irradiation effects
- Stress relaxation cracking
- Thermal aging, thermal emissivity, thermal fatigue and transients
- Coolant Flow, wear, and fretting

Other Generally Applicable Materials Issues

- Advanced manufacturing technologies
- Metallic materials qualification considerations
- Ceramic insulation
- Dissimilar metal welds
- SiC, C/C, and SiC/SiC composites
- Gaskets and seal chemical compatibility

Molten Salt Reactor Appendix

- Graphite compatibility
- Materials considerations (degradation, cracking, corrosion)
- Salt composition
- Tritium production

Liquid Metal Reactor Appendix

Sodium-cooled fast reactors

- Caustic stress-corrosion cracking
- Exothermic reactivity with water
- Sodium impurity effects on corrosion
- Liquid metal embrittlement
- Carburization and decarburization

Lead-cooled fast reactors

- High temperature corrosion
- Effect of flow velocity
- Liquid metal embrittlement
- Nonmetallic materials
- Oxygen control

High Temperature Gas Cooled Reactor Appendix

- Creep-rupture strength
- Emissivity
- Graphite
- Graphite dust
- Helium impurities and carburization
- SiC and composites
- Lubricants

Public Comment Period

- 60-day public comment period: spring 2023
- Received comments from 8 entities, total of 57 comments
- Only a few notable changes:
  - Additional evaluation of carburization/decarburization
  - Addition of cladding in “Metallic Materials Qualification”
  - Addition of generic guidance for non-code qualified materials in background section rather than references throughout ISG

Summary

- NRC staff developed an ISG to guide staff on reviewing non-LWR applications using materials allowed under Div 5
- Limited changes were made to address public comments received for the draft ISG
- Next steps – OGC approval and issuance as final ISG

Questions?

Full Name	User Actio	Timestamp
Christophe	Joined	8/23/2023, 12:33:20 PM
Larry Burk	Joined bef	8/23/2023, 12:33:20 PM
Thomas D	Joined bef	8/23/2023, 12:33:20 PM
Kent Howa	Joined	8/23/2023, 12:35:55 PM
Walt Kirch	Joined	8/23/2023, 12:45:15 PM
Walt Kirch	Left	8/23/2023, 12:52:17 PM
Walt Kirch	Joined	8/23/2023, 1:01:55 PM
Court Rep	Joined	8/23/2023, 12:45:53 PM
Shandeth	Joined	8/23/2023, 12:46:08 PM
Greg Obei	Joined	8/23/2023, 12:46:56 PM
+1 707-31	Joined	8/23/2023, 12:47:24 PM
Rebecca C	Joined	8/23/2023, 12:47:46 PM
Zena Abdu	Joined	8/23/2023, 12:52:01 PM
Robert Da	Joined	8/23/2023, 12:53:46 PM
Dennis Ble	Joined	8/23/2023, 12:54:09 PM
Tammy Sk	Joined	8/23/2023, 12:54:55 PM
Alexander	Joined	8/23/2023, 12:55:08 PM
Derek Wid	Joined	8/23/2023, 12:55:21 PM
David Rud	Joined	8/23/2023, 12:56:11 PM
Vesna B D	Joined	8/23/2023, 12:57:30 PM
Gregory H	Joined	8/23/2023, 1:00:00 PM
Robert Tre	Joined	8/23/2023, 1:01:01 PM
Eric Reich	Joined	8/23/2023, 1:03:21 PM
Trace Orf	Joined	8/23/2023, 1:04:54 PM
Jamila Per	Joined	8/23/2023, 1:05:24 PM