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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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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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X-ENERGY XE-100 DESIGN-CENTERED SUBCOMMITTEE

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WEDNESDAY

AUGUST 21, 2024

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The Subcommittee met via Teleconference, at 8:30 a.m. EDT, Robert P. Martin, Chair, presiding.

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DEREK WIDMAYER

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P R O C E E D I N G S

(8:30 a.m.)

CHAIR MARTIN: This is a meeting of the Advisory Committee on Reactor Safeguards X-Energy's Xe-100 Design-Centered Subcommittee. I am Robert Martin, Chair of today's subcommittee meeting. ACRS members in attendance include myself, Ron Ballinger, Craig Harrington, Tom Roberts, and Vicki Bier. All right, and members attending virtually via Teams, and I will definitely navigate the screen here, I see Greg Halnon, Matt Sunseri --

(Audio interference.)

CHAIR MARTIN: Is there a live mic? Please mute. If you have a live mic, please mute. And I see Scott Palmtag, and Walt Kirchner, and Vesna Dimitrijevic.

All right, and we have one consultant participating in person. To my right, we have Steve Schultz, and we have a couple of consultants, at least one, I saw Dennis Bley online, and I'm not seeing anyone else, but if I indeed missed somebody, either members or consultants, please speak up now. I'll give you a few seconds. Okay, thanks.

Derek Widmayer of the ACRS staff is the designated federal officer for the meeting today. No

member conflicts of interest were identified for today's meeting.

During today's meeting, the subcommittee will receive a briefing on the topical report and staff's draft safety evaluation for X-Energy's principal design criteria for the Xe-100 non-light water small modular nuclear reactor.

Regarding principal design criteria, which I expect we'll refer to by the acronym PDC many times, we expect to focus today's meeting on X-Energy's process to develop PDCs for the Xe-100 high-temperature gas-cooled reactor.

Consistent with the NRC's historic reliance on general design criteria for light water reactors, the PDCs proposed by the applicant and accepted by the NRC are requirements that will influence X-Energy's Xe-100 design and final safety analysis report content.

The PDCs are therefore integral to the review of the unique aspects of an advanced nuclear power plant. We are reviewing this topical report because it serves as the foundation for the safety design approach of the Xe-100 advanced reactor.

For the record and to provide some context for anyone less familiar with the PDC process, there

are a couple documents that we'll hear mentioned during today's meeting that are publicly available on NRC's website.

These are Regulatory Guide 1.232, Guidance for Developing Principal Design Criteria for Non-Light Water Reactors, and NEI 18-04, Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development, and we'll add -- I'm sure there's a couple other documents you'll bring up, but those are the obvious two. The subcommittee will hear presentations by and hold discussions with the NRC staff and X-Energy regarding this matter.

A portion of the presentation by the applicant and the NRC staff may be closed to discuss information that is proprietary to the licensee and its contractors pursuant to Title 5 U.S. Code, Section 552b(c)(4).

Attendance at the meeting that deals with such information will be limited to the NRC staff and its consultants, X-Energy, and those individuals and organizations who have entered into an appropriate confidentiality agreement with them. Consequently, we will confirm that we have only eligible observers and participants if there is indeed a closed portion of the meeting. We've only allocated about 20 minutes if

that's necessary.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, or FACA. The NRC implements FACA in accordance with its regulations found at Title 10 of the Code of Federal Regulations, Part 7. Per these regulations and the committee's bylaws, the ACRS speaks only through its published letter reports.

We hold subcommittees like this one to gather information and perform preparatory work that will support our deliberations and final decisions of whether to issue a letter report at the full committee meeting, which I believe we'll be doing in two weeks.

All member comments should be regarded as the individual opinion of the member only, not a committee position. The rules for participation in ACRS meetings, including today's, were announced in a June 13, 2019 Federal Register Notice.

The ACRS section of the U.S. NRC public website provides a charter, bylaws, member guidance, subcommittee structure, agendas, letter reports, and full transcripts of all full and subcommittee meetings, including the slides presented there. The meeting notice and agenda for this meeting were posted there and can be easily found by typing About Us ACRS

in the search field in the upper right corner of the website. Now, the word easy may be subjective.

The ACRS, consistent with the Agency's value of public transparency in regulation of nuclear facilities, provides opportunity for public input and comment during its proceedings. We have received no written statements or requests to make an oral statement from the public.

We have also set aside time in the agenda at the end of this meeting for any comments from members of the public listening to this meeting. The subcommittee will consider all public comments as appropriate.

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

A transcript of today's meeting is being kept and will be made available. For the convenience of our members and staff, NRC staff, advocates, and members of the public, our meeting today, of course, is being held both in person and over Teams, Microsoft Teams. The Teams link information with a telephone bridge line was placed in the agenda on the ACRS public website.

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 participants mute your computer microphone on Teams or on the phone if you are on the bridge line. This happens all the time. I'll just reiterate if you're not speaking, please be on mute, as we, of course, had a demonstration right at the beginning.

Please do not use any virtual meeting chat feature, that is the chat feature that's in Teams, and this happens a lot too, to conduct sidebar discussions related to the presentations or just to say hi to the friend you see online. Limit this to just reporting on IT problems such as inability to hear speakers or see presentations, or for our staff to communicate generally to all participants that are on the line.

Also, for everyone in the room, please put your electronic devices in silent mode, including muting your speaker, microphone, or your laptops. In addition, please keep sidebar conversations in the room to a minimum since the microphones in the ceiling are live.

Finally, for the presenters, your microphones at the table are uni-directional, so

you'll have to speak in front of the microphone in order to be heard online.

Okay, after all of that formality, we will now proceed with the meeting, and I will call on, so I have Stephen Philpott, okay, you're over here to the right, of course, of the NRC to begin today's presentation.

MR. PHILPOTT: My name is Steve Philpott. I'm the acting chief of one of the advanced reactor licensing branches in the Office of Nuclear Reactor Regulation. And as Dr. Martin mentioned, the purpose of this subcommittee meeting is to discuss X-Energy's principal design criteria or PDC topical report for their Xe-100 design.

As you're aware, X-Energy is an awardee of the Department of Energy's Advanced Reactor Demonstration Program, and they are an early implementer of the Licensing Modernization Project or LMP technology in their licensing approach.

This PDC topical report describes X-Energy's development of the principal design criteria for the Xe-100 pebble bed high-temperature gas-cooled reactor. X-Energy developed these PDCs using guidance from, as Dr. Martin mentioned, from Regulatory Guide 1.232, which we commonly refer to as

advanced reactor design criteria guidance, as well as the technology-inclusive content of application guidance for non-light water reactors for applicants using the LMP methodology as found in NEI guidance 20-07, as well as Xe-100's specific safety functions and design elements. This topical report is intended to support future licensing applications for X-Energy's Xe-100 design.

I'd like to start by thanking, expressing the staff's appreciation to the ACRS for your interest and time to review this important topic. I also want to thank the NRC staff and the X-Energy staff that are here for their time and preparation for today's meeting, and for the presentations that the ACRS is going to hear today. So, I look forward to the conversation today, and if there are no questions now, I'm just going to quickly turn it over to X-Energy.

CHAIR MARTIN: Okay, the floor is yours.

MR. VAUGHN: Thanks, Steve. So, an introduction, I'm Steve Vaughn. I'm the licensing director at X-Energy. To my left, I have Kyle Metzroth. He's the deputy director of Xe-100 systems development. To my right, we have Drew Nigh. He's our manager of risk-informed safety analysis, which also includes PRA.

We'll go ahead and get started. As Steve mentioned though, X-Energy did get an award from DOE, the Department of Energy, the advanced reactor demonstration program.

PARTICIPANT: Yes, now X-Energy, Steven Vaughn is speaking.

MR. VAUGHN: Yes, there are two Steves, my apologies. So, again, X-Energy was awarded the Department of Energy advanced reactor demonstration program award, so here is just a disclaimer of that acknowledgment.

So, agenda and objectives, we just did introductions. First, we'll go over at a high level the Xe-100 principal design criteria development process, then we'll focus on general differences from Reg Guide 1.232, which was just mentioned. That's just a short slide.

The majority of the content are examples of how we took the MHTGR, which I'll get into in a little bit, and converge with the NEI 18-04, which conformed to the Licensing Modernization Project effort, and then questions throughout obviously, and we can always end with questions and any closing remarks.

As mentioned before, we started with Reg

Guide 1.232, though again, just a quick history of that, that effort was extremely important for non-light water reactors since the general design criteria is based on large light water reactors, and created advanced reactor design criteria, and then lucky for X-Energy, at the high-temperature gas reactor Appendix C, that Reg Guide had design criteria based on the MHTGR.

So, we were given a set of specific design criteria based on our technology. So, we started with that, and then 18-04 came along shortly after. We had a risk-informed performance-based way to develop design criteria based on functions we'll get into in a bit, so those are the two key documents.

NEI 21-07, that wasn't mentioned before, but effectively that document took, or provided the industry with guidance from the NRC on how to actually develop a safety analysis report based on 18-04 methodology. So, we looked at it as a practical guide to develop, you know, the chapterization of a SAR.

And, of course, the NRC's ARCAP guidance, Advanced Reactor Content of Application Project guidance, was issued a couple of years ago, and we also used that as well because it does describe how to address principal design criteria in that.

And the one down below, it's an Xe-100 X-Energy document and it's a first example of how we implemented, I'd say, the NEI 18-04 methodology. Drew, myself, and Kyle, and a couple of others were the ones who actually developed this document and styled required safety functions and PRA safety functions, Revision 5. And obviously, there was Revision 1 three or four years ago and we're up to Revision 5, so we're iterating through the functional hierarchy of the Xe-100 safety case.

And this is just a picture really that kind of describes what we've already discussed. We start with Reg Guide 1.232, which, you know, I will say it might have some risk-informed elements to it, but was historically maybe more deterministic when it comes to design criteria, and then we bring along 18-04 and 21-07 methodology and framework. That tells you kind of what you need to do, but not how to do it.

So, that document I just mentioned, that Xe-100 document, that's how we did it is we developed essentially the functional hierarchy from the top down and then from the bottom up, so we decomposed the functions at a high level down to a detailed level.

And then when you get here in the green box, the yellow, and blue, and mixed green, our Xe-100

PDC, so the topical report you see, I look at it as the convergence of those two paradigms, if you will.

CHAIR MARTIN: I'm going to interrupt you just for a second. I noticed that you don't really have like one slide that kind of presents Xe-100, and for the record, you know, you haven't visited the ACRS since before I was on. Just real quick at a high level, kind of explain what the Xe-100 is for anyone that may be less familiar?

MR. VAUGHN: Yeah, I'll take a shot at it as the licensing director, although I'll refer to the one in design and safety analysis. So, a high-temperature gas reactor, our primary coolant is helium. It's a pebble bed reactor using TRISO fuel, and so it's online refueling.

So, we have a fuel handling system. As pebbles go through the bottom of the core, they are transferred back up to the top of the core. We have a once-through steam generator, and that's, at a high level, the main power system.

The helium is forced through the system via two helium circulators. That's how we move the helium through. And other key safety features are our heat removal system reactor, RCCS, reactor --

CHAIR MARTIN: Reactor Cavity Cooling

System.

MR. VAUGHN: Reactor Cavity Cooling System, there you go. It has both an active and passive capability. And I'm probably missing some other key features, but those are the high level ones.

CHAIR MARTIN: Graphite-moderated, I don't know if you said that one.

MR. VAUGHN: Oh, yeah, graphite-moderated, yeah.

CHAIR MARTIN: So, I wanted to make sure you said the three key things that were assumptions in Reg Guide 1.232, which of course, was the graphite-moderated, the helium, and of course, the TRISO.

MR. VAUGHN: Yeah, so we do have, in between the pebble bed and the core barrel and reactor pressure vessel, there are graphite blocks that provide moderation.

CHAIR MARTIN: All right, thank you. You can go on.

MR. VAUGHN: I do want to point out that we added some definitions to expand on the 18-04 methodology. The ones you see in blue are what we added to the topical report. The ones in black are already defined in 18-04 and 21-07.

And so, you know, the first question, why do you even feel the need to define a term? Well, the SSC classifications of safety-related, non-safety related special treatments, non-safety related window special treatments are defined at an SSC classification level, but they actually didn't define how they tie to the functions.

The only one that 18-04 did was the required safety function, which has a very clear delineation to required functional design criteria and safety-related design criteria, but the others didn't.

So, you see if you added an NSRST class, SSC classified as NSRST, 21-07 shows there's a direct correlation and it's complementary design criteria, but that term right there, NSRST, wasn't a defined term, and we used basically the language in 18-04, used what was there to define that term.

CHAIR MARTIN: And I believe you made a point early on that the reg guide came before the NEI report, so clearly there's some language, you know, that didn't get captured because, of course, the chicken came before the egg in this case.

So, you have, you know, taken the work that's been done and deliberations on NEI 18-04, you know, with the benefit not only of just the year or

two that passed between the reg guide, but also the last five years, and have worked it into the language of NEI, excuse me, the Reg Guide 1.232. That was my interpretation as I was reading through your material, correct?

MR. VAUGHN: Correct, yeah, and then even within 18-04 itself, they didn't define these terms when we felt the need to. So, for NSRST PSF, what 18-04 did do is they described there are two ways to get a classification for NSRST, and that's for specific function or necessary for defense-in-depth.

So, we defined this term, defined it functionally essentially, and we did the same thing with non-safety related with no special treatment PSF. And one of the reasons we did that for the one below, the NST PSF, is to draw a direct correlation to this owner-controlled design criteria, which is a term that, you know, we didn't make up, we added, but it's based on 18-04 language.

That owner-controlled, owner design requirements, owner-controlled design requirements is a term used in 18-04. We just changed the requirements to criteria just to show that there -- we wanted to make sure it's very clear, the delineation between functions and design criteria throughout,

across the entire plant.

CHAIR MARTIN: They're not necessarily, just as a clarification, not necessarily design criteria that have a safety aspect to it, yes or no?

MR. VAUGHN: They're not safety significant, which is a defined term in 18-04. Safety significance includes safety-related in NSRST. Now, those systems that are classified as NST PSFs, you know, the PRA itself is going to model all functions, including NST PSFs, but those functions aren't safety significant, again which has a very clear definition in 18-04.

CHAIR MARTIN: Meaning that there could still be value from a defense-in-depth perspective? Even though it can still be complementary, your complementary design kind of covers some of that, but maybe this is kind of clarifying the delineation, the lines. You're crossing the line a little bit to really kind of maybe later in safety analysis prove they're not, you know, they're not really that important to safety for instance.

MR. VAUGHN: I mean, there's --

CHAIR MARTIN: You're going a step beyond.

MR. VAUGHN: It plays a role in defense -- they play a role in defense-in-depth, or the need for

sufficient defense-in-depth, no, right. That's the assertion that we made is NSRST is sufficient for defense-in-depth, but they do play a role. The NST ones do play a role in defense-in-depth.

CHAIR MARTIN: Of course, but ultimately, it's the required functional design criteria, the complementary design criteria that really have the safety role.

MR. VAUGHN: And just a terminology thing too, I mean, one of the things we found challenging communicating to our own team is technically everything in the PRA is a PSF, and so like it's a bunch of nested terms and they weren't mutually exclusive, and so this was the attempt to create a set of mutually exclusive terms so that we could clearly communicate which ones we were talking about.

CHAIR MARTIN: All right, thank you.

DR. SCHULTZ: This is Stephen Schultz. I have a question associated with these new definitions. Is there any reason why this was done specific to your design? The second question is have you been communicating with NEI or others in the industry or in the same position you are with regard to moving forward with their designs to perhaps adopt this same approach?

MR. VAUGHN: Great question. I wouldn't say specific to our design. It was, I guess, specific to, if you want to take the LMP construct and then take the Reg Guide 1.232 construct and merge them. Having these definitions just help keep the accounting clear.

So, it wasn't specific to a technology. I think anyone could use it. Have we discussed this with NEI? No. That's a great suggestion and I'll make sure they're aware that we did this and see if other vendors, other folks in the industry want to use it.

DR. SCHULTZ: Thank you.

MEMBER ROBERTS: Yeah, this is Tom Roberts. What I thought I heard you say is that everything modeled in the PRA is tracked in one of these three categories. Is that right?

MR. VAUGHN: Correct, the --

MEMBER ROBERTS: That's a lot of functions.

MR. VAUGHN: Yes, every function modeled in the PRA is technically called a PRA safety function, right, because it plays some role in responding to events, and so we just made these definitions to help delineate all of those things in

the PRA.

MEMBER ROBERTS: Did you use some sort of metric like a risk achievement worth or something to determine which ones are more important and show up in a CDC?

MR. VAUGHN: Yeah, the metric piece risk significance is the definition from NEI 18-04, so I won't repeat it here, but it's consistent with guidance in NEI 18-04.

MEMBER ROBERTS: Yeah, I think about important to defense-in-depth. Some things that are important to defense-in-depth might be complementary design criteria. Everything in the PRA helped you model. Therefore, it's important to defense-in-depth. I'm just wondering how distinguished between the two things.

MR. VAUGHN: Yeah, so there are two criteria that get you to NSRST. One is risk significance, which is a quantitative criteria, and then the other one is defense-in-depth, which is a blend of qualitative and quantitative criteria outlined in Table 5-2 of NEI 18-04.

And when it comes to the qualitative guidelines, you know, we have to interpret those in a certain way to determine which functions are necessary

for adequate defense-in-depth versus providing defense-in-depth.

MEMBER ROBERTS: Okay, thank you.

MR. VAUGHN: So, moving onto general differences from Reg Guide 1.232, so the first three are fairly straightforward, especially the first two. So, we replaced important to safety with the NEI 18-04 definition of safety significant. So, again, safety significant has a very clear definition, whereas important to safety did not have such a clear definition in regulatory space.

We did remove single failure criterion from all PDC given that NEI 18-04 does leverage the defense-in-depth evaluation approach, which I just mentioned. That's when you go through the DID evaluation for the entire plant, one of the last steps in LMP before you enter it again, and during that process, you kind of solidify the SSC classifications and your defense-in-depth posture.

CHAIR MARTIN: Excuse me, question. Regarding the single failure criterion, do you feel like that the single failure criterion could play a role in any LMP or NEI 18-04 approach to the safety case or do you think that NEI -- I mean, I think my read is that it obviously heavily weights, you know,

reliability, which is -- but do you think it excludes the use of single failure criteria?

MR. VAUGHN: I wouldn't say it excludes it, and I'm sure Drew has some thoughts on this, but I would say the defense-in-depth approach, because you're looking at the entire plant and then LMP, you do your required safety functions, PRA safety functions, you do your SSC classification, you do special treatments effort, and then you do your defense-in-depth evaluation.

That, like, say, four-step process ending with the DID evaluation, I feel like is a holistic, integrated approach that I think gets you to a better safety case than just applying single failure criterion multiple times, right. I think you can miss something if you just apply the single failure criterion in isolation.

CHAIR MARTIN: Okay, I appreciate your answer. Maybe it will come up again here.

MR. VAUGHN: And we did replace, again, the terminology. We want to keep them as consistent as we can. We replaced postulated accident and accident conditions with the NEI 18-04 defined licensing basis events or LBEs, so AOO, TBE, and DBA.

So, the fourth one was, you know, new. As

we went through the process, we realized that the MHTGR DC you see there, 18-32, 36, 37, 45, 46 to 72, all talk about essentially monitoring inspection and testing surveillance, and they're all system-specific essentially.

And what we did is we took all of those and really distilled it down to the essence of what those criteria were really trying to get at. And it's when you design a plant, you want to design for the ability to monitor, inspect, test, and surveil through the life of the plant, which is a great design criteria to have.

What we did is we consolidated it down into one and made sure we didn't leave anything out, and then applied it to every system that is classified as safety-related or NSRST. So, to me, it gave more flexibility in language and we didn't miss anything with it, so that's one thing we did to kind of consolidate.

CHAIR MARTIN: Yeah, I thought it was one of the bolder things you did in deviating from the reg guide, but, you know, again, the committee expresses their opinion, but I thought you caught something there. You know, there's a lot of overlap, right, and certainly by including statements related to testing,

surveillance, and the other ones, I mean, you're covering everything, but I think what you did by bringing in C-6 and really elevating it in the sense that we have a design criteria that addresses all of those things.

You know, I think it's unnecessary to repeat and it allows you to focus maybe more specifically on what all of the other DCs are really saying. So, I don't know. It would not be unique to X-Energy there, but I did think it was an interesting observation you all must have had as you went through that.

And I almost felt like it's elevating monitoring, inspection, testing, surveillance by having kind of the one central one as six as opposed to kind of spreading it out and kind of reminding everybody oh, yeah, you've got to do all of that.

MR. VAUGHN: Yeah.

CHAIR MARTIN: Right? So, I don't know. That's something for the staff obviously to consider in other reviews for sure, but actually my opinion, I think it was a good move, that it does provide more focus by having the one. All right, you cover it and it covers for all of those things.

MR. VAUGHN: I appreciate that because it

does force you to critically think for every safety-significant system, what do I need to do in this space? And it makes sense that the general design criteria, the plants were already designed, right, so they already kind of knew what the systems were, so it's hard to not bring in system-specific criteria because the designs were already there. So, we wanted to, again, take a step back and get generic to force you to think about it.

And now we're getting into the details. So, again, you know, I selected these. I selected the examples really based on -- because they're good examples of how we took the 18-04 approach essentially, but obviously in a PDC and a topical, we can discuss. I kind of went in order starting at 11. Well, I think PDC 10 describes SARRDL. The --

CHAIR MARTIN: Just for the record, define SARRDL.

MR. VAUGHN: Yeah, SARRDL is specified acceptable radionuclide release design limit. For those familiar with SAFDL, it's the HTGR version or TRISO-X version of a SAFDL. So, in essence, it's described in PDC 10. So, I didn't bring that up because it's not functional.

I guess one thing I should point out, when

navigating through and converging the 232 design criteria and 18-04, we were realizing all of the design criteria are actually functional, and you really had to think about them. Is there a function here or just design criteria?

And the ones I'm showing here are the ones that truly were functional, and that's why they blended so well to the 18-04 method. So, PDC 10 describes SARRDL. We didn't change any words from what was in Reg Guide 232, but really that's the first place you see that limit, which is a really important one for us, SARRDL.

So, I mention that because it is using the CDC down below, but we did take PDC 11 and 12, so reactor protection and suppression reactor power oscillations, and again, combined them, made sure we didn't leave anything out, and decomposed them into two PDCs, so there's an RFDC 11 and a CDC 11.

And one thing to point out here, you know, this RFDC 11 is also really important and it ties into our RFDC 26, which we'll get into in a little bit. So, it is one of the two means to supporting controlled reactivity because our reactor inherent protection is by core design, the strong negative temperature coefficient reactivity, that's how you

control reactivity during LBEs.

So, this, and coupled with what we'll see in RFDC 26, collectively have those two means. So, it is a little bit awkward that you need to take 11 and 26 to support a function called control reactivity, but that's, at the end of the day, that's what we're left with. There might be an opportunity in the future to consolidate those.

And then the last line there is showing that it does align with RSF, required safety function, 1.1.1, controlled reactivity within the inherent reactivity feedback.

And I guess one thing to point out here, between RFDC and CDC, you'll see something common where RFDC align design basis events to design basis accidents, and CDC align with anticipated operational occurrences.

All right, PDC 13, instrumentation control, this one was a tough one to break out on its own into RFDC, CDC, and OCDC, but it does contain all -- the RFDC here aligns with control reactivity with moveable poisons, so it obviously has a tie to control reactivity, and the RSF isolate water steam ingress.

You know, maybe we should have spent some time to go over not just the design, but some of our

required safety functions, but there's a functional tree, that document shown down below, that energy implementation of 18-04. There's a decomposed tree of functions. So, you know, 1.3 is control water steam ingress. Under 1.3, there's a 1.3.1, isolate water steam ingress, right, so you can see the decomposition. We don't show that in these slides.

I do believe that the previous, the only other time we briefed the ACRS was Kyle Martin, right. They described all of that. I think in those slides, I think there's a picture of those functions.

CHAIR MARTIN: And you're referring to your visit in May of 2023, correct?

MR. VAUGHN: Correct, yeah, I believe we did break down at some level the functions there, but without that kind of decoder ring, it's hard to kind of see all of this, but I just wanted to point those out. And then on a CDC level, it's really similar to control reactivity, the moveable poisons.

There's an NSRST PSF associated with that, and then controlling heat removal with active means, and then maintaining helium pressure boundary, pressure during transients. Those are some other PSFs that align with the CDC.

And on the control design criteria, this

is instrumentation control needed to keep the plant just at a normal operating state, so the I&C obviously supports that. The challenge with this one is to -- you'll see later in DC 34, it was more straightforward to create an RFDC CDC and OCDC, but this one with the wording, it was really hard to compartmentalize them into three separate phrases, so, you know, they all have their own elements to it. Any questions on this one?

Moving on to PDC 15, again there's no RFDC element to this, but I did want to clarify that the helium pressure boundary design doesn't provide a required safety function for the HTGR or Xe-100, so it aligns with a CDC, not an RFDC, and specifically, the function aligns to prevent loss of the helium pressure boundary integrity, and down below, it aligns with normal operations and anticipated operational occurrences.

Moving on to PDC 16, it essentially defines from a design criteria perspective our functional containment. The RFDC portion of it is retain radionuclides in our fuel particles and pebbles, that RSF 1 is at the top of our hierarchy of our required safety functions.

That is the start, and in the picture down

below, that retain radionuclides in the fuel particles and pebbles is to control reactivity, control heat removal, and control water steam ingress.

Those are the three, and then tangentially, you have, you know, maintain core geometry, which kind of, you know, it's kind of, it's crosscutting of all of them, but at a high level, that's our functional hierarchy, and then down below, those three, you know, you can decompose it further.

CHAIR MARTIN: Real quick, the language you use there in your required functional design criteria, to ensure that the functional containment design limit. Now, could you have used SARRDL there and said the same thing or is there expectations of something more than SARRDL?

MR. VAUGHN: Great question. Currently, the thought is that the functional containment design limit at a high level is the frequency consequence target in 18-04, that chart.

CHAIR MARTIN: That's SARRDL.

MR. VAUGHN: SARRDL is a little bit different because SARRDL, you need to maintain SARRDL during normal operations and anticipate operational occurrences, yeah, but beyond that, SARRDL can be exceeded.

CHAIR MARTIN: But the SARRDL would cover the whole spectrum from 10 CFR 20 through evaluation guidelines for DBAs and even beyond design basis, that whole frequency consequence.

MR. VAUGHN: It's tough to describe. Maybe we could talk about this during the closed portion if we can, but at a high level, yes, SARRDL, if you brought up PDC 10, the SARRDL limit does not need to be met during design basis events or design basis accidents, similar to SAFDL for DBA. You know, you expect SAFDL to be exceeded during a design basis accident. So, likewise for SARRDL, they kept the same.

CHAIR MARTIN: Okay, we'll just table that and keep on going.

MEMBER ROBERTS: Yes, Tom Roberts. There's a requirement in 18-04 to look for cliff edge effects. Does that factor at all into CDC and functional containment? Because it seems like cliff edge effects may require assessment of scenarios that are beyond design basis or design basis accidents, and yet you still want to have resilience in the functional containment particularly. Is that a factor here and how is that accounted for?

MR. VAUGHN: I mean, so the fact is when

we implement our 18-04 methodology, we will look for cliff edge effects, and I would say that if we -- you know, this whole process is iterative, right? So, if we go through and we identify something that comes out of that evaluation, there's the potential to add something to this to be able to account for it, but, you know, right now, we don't have anything that covers it explicitly, but in going through our 18-04 methodology, we will evaluate cliff edge effects.

MR. METZROTH: And I'll add that the PDC pertain to design basis events, and AOOs, and design basis accidents, whereas cliff edge effects, in my opinion, generally pertain to beyond design basis and lower frequency events than that. So, yes, we will still get requirements for our design from evaluating cliff edge effects through the 18-04 approach, but not necessarily through the PDC.

MEMBER ROBERTS: Okay, thank you.

MR. VAUGHN: The RFDC portion of this is focused on the fuel particles and pebbles, whereas the complementary design criteria focuses on maintaining a pressure boundary. That's the third barrier where the particles and pebbles are the first two, meaning that aligns with the previous one where the helium pressure boundary integrity isn't a required

functional design criteria that aligns with the CDC.

All right, so PDC 26 was a challenging one to align all of the wording, but we did break it down into not only an RFDC CDC and OCDC, but also a PDC, and this, you'll recall that we didn't change the wording much, but that's the fourth. If you look at the GDC currently, the like four pieces to it, the fourth one is that bottom one, and we just did maintain that.

CHAIR MARTIN: Yeah, I mean 26 always comes up with a new design. It seems like you're focusing a lot of it on an active system requirements. You're using the words moveable poison to attempt to, say, credit passive response, or that comes in -- I mean, it exists in your design because we're all familiar with high-temperature gas reactors and their performance with, you know, large negative feedback with temperatures, but there's -- how does that play into satisfying the design criteria? Because it seems like you have like the implication that the statement is that, you know, you have two active systems basically.

MR. VAUGHN: Well, so RFDC 11, the reactor inherent protection, is the passive means of controlling reactivity, and then this RFDC up here is

the, you know, the moveable poison.

CHAIR MARTIN: So, it's completely separate?

MR. VAUGHN: Yeah, and they're separate, so that was that, two independents, but that was the challenge of, unfortunately, you have to look at both RFDC 11 and RFDC 26 collectively.

CHAIR MARTIN: Those were the two, yeah, okay.

MR. VAUGHN: That's the challenge, and again, for our design, it's a removal of power gravity drop is the, sort of that active -- that would be the poisons portion.

CHAIR MARTIN: Okay.

MR. VAUGHN: And if you look at the CDC notes, they're not too off, but one focuses on -- again, CDC focuses on AOOs and the OCDC focuses on normal operations.

PDC 30, at the top, it is integrity of the reactor helium pressure boundary. So, the RFDC focuses on, this is again controlling water steam ingress, in this case, isolating the water steam source, and that's the event sequence that our design needs to protect against and it's a required safety function, so that's what this RFDC focuses on.

CHAIR MARTIN: Yeah, you're kind of getting into the section where, again, I'm noticing from the staff's review, and of course there's limitation and condition related to events.

MR. VAUGHN: Right.

CHAIR MARTIN: I know you haven't presented events yet. I mean, the PDC is the very first topical reports, and nominally you would consider -- nominally when we refer to light water reactors and other designs, a loss of coolant accident, or in this case, the depressurized loss of coolant circulation event where you could have area risks. And so, PDCs like this and maybe the next one kind of touch into events, okay.

Now presented events, that's been acknowledged by the staff in their review, so, you know, it's kind of a TBD, but certainly that is something that, you know, an external stakeholder might look at kind of going, you know, okay, it's a little different, but we know there's kind of an eye-opening on that anyway.

MR. VAUGHN: And this was often formed by our PRA and our initial set, and so that was to try to bring the technology --

(Simultaneous speaking.)

MR. VAUGHN: Yeah, exactly. And PDC 34 is about residual heat removal. I think the MHTGR DC just said passive heat removal, but like that definitely applies to us. The reactor cavity cooling system has a passive mode. That ties with the required principal design criteria. So, we have two active means of removing heat.

The CDC focuses on one system to address AOOs and the other system is internal operations, so it aligns with owner-controlled design criteria. This PDC was definitely more amenable to compartmentalizing the three separate criteria as opposed to the I&C 11 and 13.

We have two more. So, at the end, we get to the reactor vessel and reactor system structural design basis. This is where we get into maintaining core geometry. So, this is a required functional design criteria to maintain core geometry, and some things you'll see, we did that.

You know, core internal structure is here too. That was one addition we made to add more clarity from what we inherited from the MHTGR design criteria. Other than that, we didn't change too much.

CHAIR MARTIN: 70 was something that GDCs don't have, but obviously, there's a uniqueness to

high-temperature gas reactors. You know, we're relying on heat removal, passive heat removal, kind of inside-out reactors if they've got a cavity cooling system, and something like this, a design criteria that focuses on everything else besides the fuel is very, very important, so that's really more for maybe people that are not as familiar, but that's really a very key one there.

And we've come from other, you know, safety analysis programs, and applications, and, you know, other design centers. There's still the expectation that you maintain thermal limits of, you know, core internals and what have you, oftentimes in particular, water.

You know, the margins are huge with gas reactors and things are high temperature, so you don't always know what component is being threatened. I mean, in doing fuel, I've done a lot of research. There's probably a lot of margin on that, so it might be something else, so 70 is particular important.

MR. VAUGHN: Exactly, and then likewise, this is focused on the reactor pressure vessel and the core internals, and then you take a step back. We also need to protect what's supporting the actual reactor pressure vessel and the core, and again, the

reactor building.

So, obviously, you need to maintain the structural integrity here to maintain the core geometry. So, 70 and 71 kind of double to maintaining core geometry. So, 1.42 is, I would say the structure itself, and then 1.4.1 is the maintaining pressure boundary and the actual core itself, so.

CHAIR MARTIN: But them I'm just going to be nosy to Kyle, and this puts a bit more of a burden of your safety analysis, but eventually you'll come to us or come to the staff, and maybe you've already done some of that. Are you going to have a true like integrated safety analysis which kind of looks at normal limits and all of these things all together and your transient analyses?

MR. METZROTH: Yeah, sure, I mean, we have to look at, you know, events that consider challenging the structural capacity of the building. We have to look at events which, you know, it brings all of those things together. So, yes, it is -- we have a very integral safety analysis that considers all of those factors.

CHAIR MARTIN: Yeah, it's certainly a lot more complicated --

MR. METZROTH: Right.

CHAIR MARTIN: -- you know, maybe than a light water reactor in some ways, meaning you're tracking so many more things.

MR. METZROTH: Well, I'm not sure that it ends of being -- I mean, you do have to do containment analysis in a light water reactor. You know, we don't have containment. We're not doing --

CHAIR MARTIN: Yeah, but are you integrating that all together with your --

MR. METZROTH: It doesn't have to necessarily all be integrated. I mean, it's integral in the fact that we have a tool set which spans the spectrum of all of the things that have to be covered, and that could be done by analysis one, feed things into analysis two, and get the right boundary conditions, et cetera. I think at a high level, it's consistent.

CHAIR MARTIN: They are still segregators.

MR. METZROTH: Yeah, correct.

CHAIR MARTIN: And there are objectives.

MR. METZROTH: Right, it's a different interpretation of integrated, but yeah, it's still integrated in the fact that we're considering it all, but it's not one giant analysis that has to factor in everything.

MR. VAUGHN: That's the end of the presentation.

CHAIR MARTIN: All right, I'll turn to my fellow members. Are there any further questions, consultants? All right, I don't see any.

MEMBER ROBERTS: Yeah, one question. Greg, 1.232 has a requirement to evaluate any unique design features of your plant and determine if there's any additional design criteria required for that. Now, you've got a MHTGR, which you've got the benefit of an appendix since it was basically written from that.

So, it would seem reasonable that you would have included it. You know, it covers you, but the point is, is there anything unique about your plant design or are you thinking about adding a design criteria or do you consider you don't have to by the reg guide?

MR. VAUGHN: The water steam was discussed in the MHTGR DCE. I think I changed the wording a little bit, but that was the only -- we didn't find anything new, like a new licensing basis event we needed to withstand to create a new design criteria.

MEMBER ROBERTS: Right.

MR. METZROTH: We utilized our early

version of our PRA to basically systematically evaluate whether that was the case, and in going through it, we found that, you know, all of the events that considered the technology was pretty well covered. We had to rearrange some things, but pretty well covered by the PDC that were there.

MEMBER ROBERTS: Okay, thank you.

CHAIR MARTIN: Any further questions?

MEMBER KIRCHNER: Bob, this is Walt, yes.

CHAIR MARTIN: Hi, Walt.

MEMBER KIRCHNER: Could we go back to 16, functional containment design?

MR. VAUGHN: What's your question, Walt?

MEMBER KIRCHNER: I'm just looking at that and wondering versus what is in the reg guide, whether this is meant to be as expansive as the reg guide. The reg guide emphasizes multiple barriers. Obviously, we have the different layers in the TRISO particles and the fact that they're in pebbles. Is that -- I'm just looking at the choice of words versus what was used in the reg guide.

CHAIR MARTIN: Yeah, I think my comment at the time was related to this, the language of functional containment design limit. What all does that mean? And I was looking for, you know, maybe

something more narrow. It seems like for me, it hasn't been completely defined, you know, but it could mean a lot, right, and it seems to me that that was your -- it's kind of your answer. It's not just --

MEMBER KIRCHNER: Yeah.

CHAIR MARTIN: It's something called functional containment design limit, so it can kind of create a much larger box.

MR. VAUGHN: Effectively, the dose limit is what we are aiming for, but that may derive back to other criteria on SSCs that we would then create specific limits for after we do all of the iterations of the analysis.

CHAIR MARTIN: Sure, we still have thermal limits. You know, you still got to look at, say, 1600C and TRISO limits --

MR. VAUGHN: Exactly.

CHAIR MARTIN: -- and stuff like that. There are still kind of SAFDLs. You know, they're kind of buried under all of that.

MR. VAUGHN: But we have to make sure to derive it because, you know, it's not as -- TRISO isn't as discrete as other, you know, in how it exhibits radionuclide release as other fuel forms, and so it's a little continuous, and so that's why we sort

of look at okay, we meet dose limits, and then we make sure we want to derive back from that, you know, because our safety analysts maybe want to have, well, give me a number to shoot for and we want to derive that back from the dose limit, and so there's just a myriad of things that we could evaluate, but we haven't got all of that in detail defined. We're focused on the dose limit.

MEMBER KIRCHNER: What I'm tripping over here is the second half of this where the pressure boundary, the helium pressure boundary is not exceeded during AOOs. Could you just elaborate on that? That seems to me rather restrictive or less expansive than the actual reg guide. And I understand why you're partitioning, but I want to hear why you -- what's the -- what AOOs? Why is it limited to AOOs?

MR. VAUGHN: So, I think what we're trying to do here with PDC 16 is emphasize the different between the SSCs performing the required functional design criteria piece and the complementary design criteria piece.

And the point of 16 is that the criteria related to the RFDC or the requirement coming from the RFDC is only applied to the fuel particles and pebbles, whereas the requirement coming from the CDC

links back to, I guess, creating defense-in-depth and AOOs and the requirements from that CDC.

MEMBER KIRCHNER: Why just AOOs?

CHAIR MARTIN: Well, you have the required functional design criteria that covers the design basis events, right. You've segregated -- and earlier, when you said, you know, AOOs and CDCs go together, you were almost begging for a question it seemed like.

(Laughter.)

CHAIR MARTIN: This is a little bit novel there.

MEMBER KIRCHNER: Well, here is the question.

MR. VAUGHN: So, it relates back to the basis for the classification of the functions. So, for -- within NEI 18-04, Table 5-2 provides qualitative guidelines for evaluating if you have sufficient plant capability for defense-in-depth, and there's a guideline in there that pertains to AOOs and it says that you should minimize challenges to safety-related SSCs and AOOs.

So, as a result of that guideline, it leads to a safety classification on the helium pressure boundary. There are events, there are AOOs

where we challenge safety-related SSCs, the fuel, such that we need to have a requirement on the boundary to create adequate defense-in-depth for those specific events.

CHAIR MARTIN: Right, I mean, typically, the limits associated with AOOs are more restrictive, right, to the point you made. I guess my curiosity is couldn't these CDCs just be part of the required functional design? I mean, there's no less rigor, I mean, for the work you do.

I mean, in some ways, the language maybe deceives us, but terms like required functional design criteria versus complementary design criteria, I think it's trying to say there's some kind of secondary importance associated with a word like complementary, but it's not, right? I mean, when you go in practice, you don't do anything different than --

MR. VAUGHN: This really derives from the fact that these functions are performed by systems based on a certain classification, right. This is bringing in the 18-04 piece of it, right, and so in the fact that we have identified there are things that satisfy NSRST PRA safety functions. For the Xe-100 design, that's all based on defense-in-depth.

We don't actually have risk significant --

we haven't identified risk-significant SSCs that would get you to NSRST that way. We get to NSRST purely through defense-in-depth, and so a lot of the CDC thinking that goes into here is because we've gone through the PRA, we've done an initial classification.

All of the NSRST SSCs come out through defense-in-depth, and as Drew mentioned on the Table 5 through guidelines and how it talks about AOOs, that's how that language gets in there. So, it's a reflection of the function we're asking it to perform in a defense-in-depth capacity based on how NEI 18-04 points you in that direction. So, that's where some of that language comes from.

MR. METZROTH: And I can just expand. I'll give kind of like a counter-example here where let's say like in design basis accidents, we were relying on the helium pressure boundary to retain radionuclides, to perform that required safety function in those design basis accidents. If that were the case, the second part of this PDC would actually be an RFDC.

That required functional design criteria would relate back to a required safety function. In this case, since it's a defense-in-depth function, NSRST PSF, it has a CDC. Bob, your point is well

taken. What's the difference between calling it RFDC or CDC? The point is just to trace back to the origin of the requirement.

MR. VAUGHN: And when you talk about rigor, I mean, we still have to apply special treatments. When we have an NSRST system, we'll apply special treatments. That means design codes and standards. We select those based on, you know, how they play into the safety case, and so you can still get to a certain level of rigor on that based on, you know, the special treatments that you select. So, you're right, it doesn't necessarily mean a difference in level of rigor because we still have special treatments to select for those systems.

CHAIR MARTIN: Walt, did you have anything else to add on your question, original question?

MEMBER KIRCHNER: I'll wait for the staff. Thank you.

CHAIR MARTIN: Okay, yeah, I think it does kind of present some questions for the staff too.

MEMBER ROBERTS: Yeah, Walt, I think your question is related to the one I asked about the cliff edge effects assessments and how that might be part of the outgrowth of the design requirements, because the original PDC said that there will be, where are the

exact words at, multiple barriers internal and/or external to the reactor. So, what they seem to have done is define what those multiple barriers are for all three classes, AOOs, design basis events, and design basis accidents, and so what they've done is made the requirement more specific, but it seems to track to what it says.

But what neither one says is there should be defense-in-depth for events that are beyond, you know, what's modeled design basis events and design basis accidents, and whether there's some element of the multiple barriers that that will spawn. It sounds like that's future work.

And, I mean, another idea to sit in is when you look at the reasonable but beyond design basis categorization and you come up with well, I've just blown through all of my barriers that I had, so I no longer have multiple barriers, maybe I need to add one more for that. It sounds like that would be a reasonable outcome, what you get there. Is that right?

MR. VAUGHN: That's correct and there's also a barrier beyond the helium pressure boundary, but we don't have it listed here because it's not necessary for defense-in-depth, and that would be the

helium pressure boundary and the reactor coolant. That is a barrier functional containment.

But based on our design and what we've done in 18-04 space and the PRA, we'll have to obviously support this with associated stage analysis and does it rise to the level of a NSRST PSF and staff-associated complementary design criteria? But it is still part of the defense-in-depth picture. It's just not necessarily sufficient for it.

MR. METZROTH: And I think when you think about something like -- you know, we actually debated this quite a bit. And when you look at something like the reactor building, we sort of thought about some of these functions and the criteria that were coming out of it. It's like what design requirement am I giving a designer, right, like that's really what this has to flow down to.

You know, and so the building is kind of there, correct. It's there. It's part of defense-in-depth. It's not needed for adequate defense-in-depth. We will still evaluate it as part of the defense-in-depth philosophy, but I'm not going to hand the designer a requirement that says, right, you know, provide this much on defense-in-depth.

These were things were there were specific

requirements that we could hand down and actually provide the designer versus it's there and we're going to evaluate it as part of it. So, you're right, it doesn't probably capture all of that picture, but there are other SSCs that are contributing that are modeled in the PRA.

MR. VAUGHN: Tom, I just want to make sure we're answering your question though. Are you wondering why beyond design basis events aren't like mentioned in the topical report?

MEMBER ROBERTS: No, it was more follow-up on Walt's point about the multiple barriers verbiage was taken out and replaced with some specifics about what your design does, and so that takes, you know, a principle and replaces it with a specific design, and, you know, whether that risks losing what the principle actually is when you do these more detailed analyses and find that maybe you're still achieving this standard design criterion, but not the underlying principle, and you need to go back and make sure you're covering that, and so I think you've answered that question.

MEMBER KIRCHNER: Could you go back then to your last criterion, your last illustration? This is Walt again. I think it's number 70 for the

building, excuse me, 71. That's it. Now, since you've brought it up with regard to giving your designers some criteria for the building design basis, what about controlling unmitigated moisture and air ingress?

Assuming you have a rupture in the primary helium system boundary, are you going to provide a functional requirement for the reactor building to actually play a role in terms of a confinement function?

MR. VAUGHN: So, well, hold on a second. So, confinement and, and air ingress.

Let me address the air ingress piece of that first.

When we look at our PRA and we look at the events that are in the, you know, down at the DBE region and the DBAs we derive from it, we don’t have credible scenario that leads to air ingress; right? So, this is why we’re not, we’re not including that in here because this isn’t even informed by our initial PRA.

That’s why we don’t have a specific criteria on it.

MEMBER KIRCHNER: Wait a minute. Stop.

You classified your helium pressure

boundary in a separate category only for AOOs. So, that suggests that you could have a failure in your pressure boundary, possibly a large failure.

MR. NIGH: This is Drew.

I think what Kyle's trying to say is there's no scenario that could lead to a significant amount of air ingress such that it affects the radiological consequences. Like, yes, a breach in the pressure boundary eventually leads to some amount of air ingress.

CHAIR MARTIN: Thank you.

MR. NIGH: I believe analyzed all those scenarios occur, and the impact of air ingress as a result, and it basically showed that, the physics, that there is no significant amount of air ingress for, for those events that would alter the radiological consequences of an impact.

MEMBER KIRCHNER: Okay. All right, thank you.

CHAIR MARTIN: Yeah, I think that's one of the challenges of us looking at the PDCs at this stage because we've not seen your, like, you know, your safety analyses and we haven't seen the PRA. And I think it puts more burden on staff, you know, to kind of recognize, you know, this is coming first, and

there's only so much information. It really is otherwise ready for primetime.

And I'll probably bring it up in a second here when we talk to the staff.

At the end of the day there can be no limitations in conditions more than likely; right? I mean, all of this has to be resolved. I mean, there is no limitation in conditions on the GDC; right? They are what they are.

And so, this is still kind of a work in progress. Anything could change. You could learn something in the next few years that drives, you know, a tweak to what you have today.

It really puts more responsibility on the staff to stay on top of that and keeping -- you know, you see a lot more than we do. You see a lot more than the public sees. And you should be sensitive to that because otherwise you're going to get questions that maybe in your mind have already been answered but that haven't been answered for the rest of us.

And so, you see some of that even from, say, today's conversation. But, you know, I think it's good to air out this, you know, for the record that this is something that will continue.

I think, you know, my personal opinion

since we provide this, you know, you've done a pretty good job. I think you've taken the task of integrating it before, and the Reg Guide 1.23 together very seriously, and there might be value to from other design centers.

So, this involves designs, the first one through does a lot of work, you know, could very well be to the benefit of other people who get it for free. Thank you from 16th Street.

But I don't have any further questions. I know we are, like, way early on the schedule. And I'm going to need a little help on how do we manage schedule and how we should.

MR. SNODDERLY: So, I think the first question -- this is Mike Snodderly from the ACRS staff.

Right now the agenda calls for breaking. This is a logical time, but it is early. So, I think the question is break or do you want the staff to come up?

CHAIR MARTIN: I would say let's go ahead and have a 15-minute break. Again, this keeps us pretty, pretty early on all things considered. But I'm up for tea, so.

So, how about, you know, I hate to have a

long break, but how about till 10:00 o'clock? Is that okay? Anybody have any heartburn with that?

MR. SNODDERLY: You're the chairman.

CHAIR MARTIN: All right. There you go.

We'll recess until 10:00 a.m.

(Whereupon, at 9:40 a.m., the above-entitled matter went off the record, and reconvened at 10:00 a.m.)

CHAIR MARTIN: We're going to reconvene our hearing here this morning.

We have heard from X-Energy. And we're going to move into staff's presentation of their evaluation. I believe Adrian Muniz will be leading our discussion for the introduction part at least.

Go ahead.

MR. MUNIZ: Thank you.

Good morning. My name is Adrian Muniz Perez. I am the lead product manager for the review of the X-Energy Xe-100 design.

Sitting right next to me is Ian Jung, a senior reliability and risk analyst, and lead tech, technical leader for the X-Energy design.

And right next to him is Dan Beacon. He's supporting their view on his integral part of the core team design team, design review.

We are all staff members of the Office of Nuclear Reactor Regulation, NRR, Division of Advanced Reactors and Non-power Production and Utilization Facilities, also known as DANU.

We are here today to present on the NRC staff review of X-Energy's principal design criteria topical report.

Next slide. Thank you.

As presented during X-Energy's presentation, the topical report describes their process for developing the principal design criteria, or PDC, for their design and the resultant PDCs coming off this process.

The staff's evaluation documented review and regulatory approval of their proposed PDCs, the NRC staff found this is acceptable to support design and licensing process associated with X-Energy's design, subject to limitation applications stated in the safety evaluation.

We'll provide additional details in some of the slides.

In our review of our X-Energy's proposed PDC started in July 2022 with the initial submittal of their topical report, during the review of this topical report the staff issued questions to X-Energy

and engaged in an RFI associated with this effort.

This resulted in greater understanding of their proposed PDCs and X-Energy provider of the topical report as a result of this engagement.

The NRC staff safety evaluation is based on Revision 3 of X-Energy's topical report that was submitted on June 17, 2024.

Now I'm going to turn it over to Ian Jung who will cover the next slides.

MR. JUNG: My name is Ian Jung, Senior Reliability and Risk Analyst. I have the honorable position of technical lead, but I feel like it's more of a punishment.

(Laughter.)

MR. JUNG: So, with that, I can begin and I'll cover these slides.

In addition to us, we have engaged other staff members as necessary to get insights and inputs in our evaluation.

So, as you know, 10 C.F.R. Parts 50 and 52 contains requirements on PDCs. It doesn't say, the requirements doesn't say a lot but it's simply principal design criteria must be submitted for a staff review and approval.

And just one note to 10 C.F.R. Part 50,

Appendix A on GDCs. It is not, it's a requirement for light-water reactors but it contains some important information about the scope and content of PDCs. The language there it says that PDCs establish necessary design fabrication, construction, testing, and performance requirement for SSCs important to safety.

And that is SSCs provide reasonable assurance that the facility can be operated without undue risk to health, to the health and safety of the public.

So, the reason I highlight this portion is that when you apply licensing modernization project at NEI 18-04, there's a set of information, critical elements of LMP needs to be executed that provides a reason for us to obtain a finding. I think there's some difference between light water reactor side and the risk-informed (audio interference) side.

It's going to come up later when we, when I'm talking about the scope of the PDCs regarding licensing basis events like, you know, beyond-design-basis not being included in the PDCs for X-Energy.

This conversation led to imposing limitation on condition because under the LMP beyond-design-basis is best if they show it to be

important which leads to classification, appropriate requirements and so on, which could lead to safety significant SSCs, which may require potential principal design criteria.

Based on the current design that X-Energy has, they have not identified any risks significant beyond-design-basis events and so on. So, we are going with that. I think that we are still imposing a limitation to condition. The rest of the LMP process has to be executed as well as their design, currently being preliminary, has to be finalized.

Next slide.

As was mentioned earlier by X-Energy, several regulatory guides are very relevant to our review. Reg Guide 1.23 -- 232 provides items on PDCs for non-light water reactors, non-LWRs.

Reg Guide 1.233 provides guidance for risk-informed and performance-based methodology to inform the licensing basis and content of classifications. It endorses NEI 18-04 with certain clarifications.

Regularly Guide 1.253, which has been -- which was issued a few, a couple months ago, it provides additional guidance on PDCs as its related to PDCs when you implement the LMP. So, required

functional design criteria and so on, CDCs and so on, those start showing up in NEI 21-07 document.

So, staff approved the NEI 21-07 with additions and clarifications.

Next slide.

CHAIR MARTIN: Just real quick.

MR. JUNG: Yes.

CHAIR MARTIN: It was first amended two years ago. And it was noted on your slide one or two back. And, of course, now you're mentioned regulatory guidance.

Two years seems kind of a long time for a topical report like this. Is it because of all the newness, you know, their approach to, I mean, you know, opinion, questions from staff that kind of led to keep it from the more traditional assumptions that appeared in the Reg Guide 22-52?

But, nonetheless, this integration of new and possible suitable, was that really what most of your questions through the different revisions and maybe required an extra iteration about the design evolving fast enough to support where it's influenced the overall?

MR. JUNG: The answer is yes. Overall, we found that the modular high-temperature test records

and criteria are very similar. So, we knew going in that it wasn't going to be a huge challenge. Yet, implementation of LMP led to additional conversations.

And the reason it took a little bit longer is that, actually, X-Energy suggested for the staff to perform an audit so that we, the staff, can see some of the implementation documents of the LMP relevant to PDC developed, required function of design criteria, classification, and so on.

So, we benefitted a lot from that which led to another several months of delay. Overall, the review of this topical report has gone very smoothly. Our conversation with X-Energy was very cordial and very professional.

CHAIR MARTIN: Okay, thank you.

Who asked for an audit?

MR. JUNG: X-Energy volunteered and we accepted.

So, X-Energy design, key design features, I'm not going to repeat it. Steve Vaughn at X-Energy did it. And the report, MHTGR mostly, very similar design. There are some differences, of course, but, you know, the fuel design being, you know, prismatic, fuel block versus pebble being one of those.

But, overall, there's no significant

design differences.

DR. BLEY: Excuse me. This is Dennis Bley.

Can you say a little more about the audit, what kind of things you learned and maybe what difficulties you might have had if you hadn't had the chance for that audit?

MR. JUNG: So, there's an audit report that's a part of our safety evaluation. And so, I was reading through it. X-Energy made available several LMP implementation documents. So, development of the required safety functions, PRA safety functions, similar documents. I can refer to it.

CHAIR MARTIN: Safety classification documents, like that?

MR. JUNG: Yes. I'm just going to go, there's five documents: preliminary SSC classification list; special treatment of reactor protection system; integrate decision-making process into implementation guide; and the PRA Phase 1 event sequence analysis document.

So, these are the documents that X-Energy provided staff. Also was engaged in find which documents might be useful for us.

And it led to a conversation that if some of them led to actually modification to the topical

report and later revisions of the topical report.

DR. BLEY: Okay. Thank you.

I'm just wondering if some of these documents they developed about how to implement NEI 18-04, if any of that suggested that there might be more general guidance from the staff to other applicants who might be following the general approach?

MR. JUNG: I think my, my sort of observation at the time on the subject has been into X-Energy's implementation of these, these documents are still preliminary in nature. I think it might be more beneficial to go through the process and then bring back the lessons learned into, into more broadly to other stakeholders.

DR. BLEY: Okay, thanks. Because that, yeah, I think some of the guidance in 18-04, predict's not the right word, but might be difficult for some applicants to implement. And this may have given some clarity on how to go through that process.

MR. JUNG: I think, personally, I fully understand that. And at the same time X-Energy implementing, for even X-Energy it's very challenging even now. We see that. And so I think all the lessons learned we're going to get.

Of course, for the staff members we are learning, using these Reg Guides we are learning a lot of lessons. We are already applying lessons learned on documentation of the NEI 18-04 into our task.

So, those are being actually discussed even among staff members on how to bring back the lessons learned, and document that and bring back into the potential revisions to future LMP guides and guidance documents. That's already being useful.

DR. BLEY: Okay, thank you.

CHAIR MARTIN: And I'll add, you know, I started to write my letter, my draft letter. And focusing mostly on what we talked about Xe-100 PDCs. But there is for me a temptation to talk about this generically.

And, you know, given that we've, you know, seen a couple of PDCs, you know, come through, and, you know, maybe after the third one we have a better idea maybe how, how to report with that, how to consider these sort of things.

And so, I'm trying to decide in my head whether I should add some content to my letter related to the generic application of PDCs. Because I think, you know, I'm learning a lot. Sounds like you all

have learned a lot over the last two years about implementing.

You know, the Reg Guide itself has been, you know, was focused on non-light water reactors. That just feeds right into, you know, the technology-inclusive philosophy of the subsequent Reg Guides.

Maybe one day we see a little tighter coupling between, you know, those subsequent Reg Guides and kind of revisit Reg Guide 232 in light of what we've learned from multiple design center meetings like this one.

But this one I think is, particularly mostly because I'm chair, the keeper, but I think there's a lot to learn here, a lot of lessons learned, I think. And certainly as you compile and we're compiling some ourselves, that I think that it might lead to further improvements, process improvements that we can do here.

Anyway, proceed.

MR. JUNG: Understood.

DR. SCHULTZ: This is Steve Schultz.

Let me ask it a little differently. You've spent a lot of time going through this portion of the process. And Revision 3 as you've gone through

this evaluation and your review, are you for X-Energy, has it prepared both you and X-Energy, put you in a position to move forward more rapidly because of the time you spent here?

Do you have a better understanding of what needs to be done in the next steps of the licensing?

I would hope the answer would be yes, but if you could answer from your point of view on that I'd appreciate it. Thank you.

MR. JUNG: The answer is yes. Not just because of this topical report. Because there are several multiple topical reports that are currently under review, and audits are ongoing on several of those topical reports.

Overall, safety analysis there are four, four topical reports that are currently under review and audits ongoing. There's the training qualification topical report, and graphite topical reports are coming soon.

We are performing our audit, actually, right now, pre-application readiness assessment on that.

So, putting all these together it does take a challenge. It's new and novel. But I think, I think X-Energy's working hard and we can see that.

They have their own milestones. And staff's been entertaining quite a bit of expense learning about the design, learning about the LMP process.

So, ARCAP, advanced reactor content of application and technology-inclusive content application guidance finally issued a few months ago with the endorsement from the committee. We are all learning and implementing, I think it's to some degree having a construction, Part 50 construction permit application process allows gradual process to go further into the final design. And the operating license application will be coming out.

So, feel comfortable where we are. But I think there's a lot more to be done.

DR. SCHULTZ: Thanks for your perspective. Thank you.

MR. JUNG: So, next slide.

So, just a recap. Overall, PDC the approach for us is that based on the fact that these are, these PDCs are based on Appendix Charlie of the Reg Guide 1.232, substantially similar in design, allows us to be a little more efficient. And there's some modifications made to the Appendix Charlie based on the X-Energy-specific design.

Also, PDCs are, X-Energy PDCs are also

based on LMP implementation, which was talked about.

Marriage of Reg Guide, deterministic Reg Guide 1.232, a bit more risk-informed and performance -based Reg Guide 1.233, is not yet, not a clear cut. So, we struggled a little bit trying to marry those things, two things together, and the terminologies and so on.

And then new expressions of LMP require safety functions, require safety function of the criteria, PRA safety functions, and so on.

I think the staff wants me to hurry up.

MEMBER HALNON: This is Greg. Can I jump in here real quick?

I just wanted to, on that previous slide you mentioned it wasn't as clear as what you had hoped. Are you guys keeping notes so that -- one of my questions I was going to ask you all, if you were happy with the guidance statutes through both reviewing, and I should have asked the applicant about developing the PDCs, are you all keeping notes and are you planning on a future lessons learned type revision of these, or maybe another Reg Guide that roadmaps you for the right way to go, or the better way, more efficient way of getting through this using LMP?

MR. JUNG: The answer is yes. It would be

we have a contract with the Idaho National Lab who's been supporting the development of many of this LMP guidance.

So, one of the new task items is actually collection of the lessons learned. And I think a couple weeks ago there was a discussion of developing a Excel spreadsheet where this information is documented, lessons learned are documented and questioned in the future.

Also, that lessons learned is somewhat important from the perspective of Part 53 guidance development because we, if possible, we want to include those lessons learned into the Part 53 guidance documents that has to be developed based on the past.

Some of those guidance under Part 53 is going to be also based on the LMP guidance we do have right now under Part 50 and 52.

MEMBER HALNON: Okay. That's excellent. Thank you.

And perhaps when we get into the Part 53 interactions we can walk through some of the lessons learned that you're capturing to see how it might make things more efficient down the road.

But I'm glad you've got that task going

on. Thank you.

CHAIR MARTIN: A follow-up to Greg's question. You mentioned an Excel spreadsheet. Will there be a document, public domain document kind of capturing your work with the lab, work with DOE? I would think that --

MR. JUNG: I know it's internal. At some point those lessons learned will probably need to circle back with industry.

CHAIR MARTIN: Sure. It will go public at that point.

MR. JUNG: Exactly.

CHAIR MARTIN: Okay.

MR. JUNG: Yeah. Even during that meeting, interactions with X-Energy, X-Energy already has expressed some of the lessons learned and some of the, actually, improvements that can be made to NEI 18-04 and so on. It's already showing up.

CHAIR MARTIN: Okay.

MR. JUNG: So, I'll be very quick. So, the key differences are discussed here.

Overall, the significance of these items are not super complex. And I would say I've seen enough to emphasize some of these areas in our safety evaluation. So, these are some of the areas that we

focused on.

So, I'm going to, just like X-Energy did, I'm going to go through some of the examples of these areas.

Next slide.

So, to my knowledge, X-Energy is proposing to replace important safety with safety significant. And the safety significant, the terminology is well defined in NEI 18-04, a lot more clearly than traditional important to safety definition.

So, the reason I think that terminology is very important to be part of these PDCs is that under the LMP your terminologies and definitions and so on are quite different in some of the areas. So, even Reg Guide 1.233 talks about if you are following an LMP you are, you know, it is expected that terminology under LMPs is supposed to be used.

So, I think X-Energy is being consistent with that.

So, I think overall, overall, you know, there are some areas that in LMP safety significance you can access these being safety-related and NSRST SSCs, and also LMPs, it's a score of these focuses on normal operations, AOOs, and design basis events, DBEs, and design basis accident, and

beyond-design-basis events.

But there was a notion that, that in NEI 21-07, as well as ARCAP roadmap I have a sheet on the screen, talked about there may be cases where important to safety SSCs may not be fully captured in safety significant SSCs under the NEI 18-04.

So, finally, follow the Reg Guide 1.232 that brings some of these concerns to use, because when you -- if you look at the Reg Guide 1.232, Appendix Charlie, as well as X-Energy PDCs, it addresses some of the PDC 60. I think, for example, it talks about normal radiological releases, like gas and that. Also, fuel handling and fuel storage systems are discussed.

And, also, some of the normal operations that was discussed by X-Energy, normal operation is also included in the Reg Guide. So, I think that we felt that there is no gap.

Next slide.

Yeah, I briefly touched on this on the scope of the LBEs. And, so, X-Energy replaces the terms in Reg Guide 1.232, such as postulate accident and accident conditions with a terminology used in the LMP. Postulated accidents and accident conditions, those terminology has a certain meaning in the light

water reactor space.

Also, those are not used in LMP. So, I think it's good to translate those terminologies into LMP language.

One other area that we looked at was how come there's no beyond-design-basis events discussed here? Because under the LMP beyond-design-basis events are one of the LBE categories which may contribute to risk-significant or defense-in-depth functions, as well as, as well as it can lead to a safety-significant SSC, for example.

So, based on the current design, X-Energy indicated that they have not seen any significant, risk-significant SSC for the beyond-design-basis events. And so, one, and also there it is one of those marriages between Reg Guide 1.232 and 1.233.

They are generally equating these postulated accidents and accident conditions to AOOs and DBEs and DBAs. Yet, we, the staff did not really have full confidence in that. All the current preliminary design and current implementation of LMP may lack the full benefit of LMP process: PRA, defense-in-depth evaluation, and so on.

We felt that there is room that there possibility of beyond-design-basis events showing up

to be potentially risk significant, for example.

And, also, if you look at the LMP process and turn to some of the external hazards, or certain sites may with the external hazard characteristics, if these PDCs are applied you may also have some challenges.

So, we felt that I think it's good to impose the limitation of application based on preliminary design and preliminary implementation of the LMP. Future applicants may find these PDCs applying to their design by verifying that their LMP notification confirms this. That's the limitation provision (audio interference.)

CHAIR MARTIN: I know from historical context the GDCs design basis as, well, almost 60 years ago weren't as sensitive to beyond-design-basis events as we are today.

But I do agree that the language in NEI 18-04, you know, when you acknowledge that certainties associated with liability always in frequency of events you are looking, you will look at events that are considered beyond design basis.

I guess as I was reviewing the material, reconciling the maybe lack of, you know, specific mention of beyond-design-basis in the proposed PDCs,

the fact that they're going to do it anyway. I mean, that's if you're, if you're following LMP in a rigorous manner you will be, you know, considering the, you know, safety significance of the SSCs in all these contexts.

So, it is currently there. And indication of LMP may be considered a little more restrictive than the tradition of GDCs for light water reactors. It comes down to whether the language appears there or not.

Now, what we don't have is, like, the flip-end events, and that's a little bit beyond, well, you know, beyond 5 times 10 to the minus 7th, in that space. So, that effect remains excluded even under, you know, inevitable marriage of the Reg Guide with NEI 18-04.

But I do think it's covered elsewhere in the NRC safety framework documents.

MR. JUNG: Yeah. And I fully agree. And it's sort of in the nature of where we are in the whole process. And, also, if we did have the complete design, final design, there might be a lot better clarity on some of these things.

But, historically, equating postulated accidents and so on are traditional DBAs. But

historical also it's these GDCs and so on came around 19 late 60s and early '70s. Maybe before my time, but I was told.

But as we learned many lessons learned since then, that two additional regulatory requirements on what we call beyond-design-basis accidents. It could be debated depending on the frequency and consequence, sure this could have been, you know, beyond-design-basis events or just been DBEs. But at the time the decision was more a traditional framework.

So, it could be a long story there. But I think that we are covered clearly for ARDP as well as commitment for X-Energy to follow the LMP, provide the assurance to help continue to PRA, and they'll still go through and make sure what can go wrong, you know, comprehensive evaluation of what could go wrong is evaluated for PRA standard requirements as well as LMP implementation through integrated decision making panel process that will be subject to future NRC review.

CHAIR MARTIN: Till we get more information, particularly on the LBEs and first response, do you have that LC, limitation condition, associated with this TR.

MR. JUNG: Yes.

Next slide.

MEMBER ROBERTS: The applicant talked about how making qualitative and quantitative factors will figure out the beyond-design-basis events, what parts of the system need to be credited or what parts of the system are, you know, dismantled for PRA modeling.

For the containment part specifically they took out the words about multiple barriers. And so, what they defined is a system that they think had multiple barriers from a standpoint of specifically what they put in as opposed to the generic, you know, have multiple barriers.

The committee six years ago wrote a letter on functional containment where one of the recommendations was to always have multiple barriers in functional containment systems. And I'm just wondering if that gets lost taking the words out of the PDC? Or is your expectation that the subsequent evaluation will ensure there's multiple barriers because that's just what the PRA and the judgement will produce, something that's needed?

Just wondering what your thoughts are on that? Because maybe not the words, multiple barriers just means that, you know, the conclusion was what

they specify doesn't contemplate multiple barriers beside beyond-design-basis event, you know, what hope do you have to get multiple barriers?

MR. JUNG: Member Roberts, can I, can I speak, respond to that by the time we get to the functional containment slides?

MEMBER ROBERTS: Sure.

MR. JUNG: So, staff also looked at the area of normal operations and the use of owner-controlled design criteria. X-Energy went through owner-controlled design criteria pretty well.

The reason that we got established looked at the normal operations is it's partly because LMP scope does not include, NEI 18-04 scope does not include the normal operations.

So, there was a notion, and NEI 21-07, as well as NRC staff guidance that talks about there may be cases where safety-significant SSCs may not equate to important to safety, that I discussed earlier. So, we looked at the area that was kind of, we thought that was important to consider some normal operation aspects of that.

So, X-Energy includes those normal operations, normal operations were at normal conditions these PDCs, some of them are related to the

OCDCs in particular SSCs is not performing -- is performing non-safety related functions.

But, also, as I mentioned earlier, X-Energy PDCs 60 through 64 discussed some of the normal operational releases, gas, liquid, and solid waste, and then also fuel storage and handling, design criteria in 61 through 64 and so on. So, those are captured.

So, overall, we felt that the overall action of PDCs covered this area.

And then the use of OCDCs, although they may not be the design basis of the plant, but it clearly provides a clarity in terms of separation between safety-significant SSC design criteria versus those that are not. Or as we discussed earlier, the PRA models, all these SSCs.

So, I think it's all being handled and having this distinction is useful for this.

Next slide.

So, replacement of single failure criterion with the reliability criterion was discussed by X-Energy. We felt that this is consistent with the staff guidance in Reg Guide 1.233.

The concept was approved by the Commission earlier.

In NEI 18-04 we also recognized that, that safety-significant SSCs would be, would have a reliability target and capability targets as well. And then also defense-in-depth evaluation is needed for us during the assessment of the event sequences.

So, we felt that this replacing -- replacement is not lost.

But we also recognized that single failure criteria is in some cases good industry practice. So, I took the 603 for I&C, for example, gets us the criterion. Some of the active systems have to be able to establish the redundancy and overall reliability redundancy. And we found that diversity play a critical role, in doing so apply a single basis criterion is a good practice, theoretical practice.

CHAIR MARTIN: If they had kind of kept an either/or kind of statement, single basis criteria for reliability, would it materially change anything to the PDC?

You know, my experience is doing safety analysis for, you know, for other projects, I mean having to address the reliability or, you know, pinpoint design inputs in the decision-making process, it counts; right? And we're dealing with new plants.

Now, when you get down to, you know, some

very specific parts, well, then maybe there are, there is data that supports, you know, the design inputs for PRA. Maybe not. Maybe there's some novelty associated with designs both TRL, technology readiness level, to SSC, that really are hard to pinpoint in reliability.

And as a practitioner in the single failure criteria, while oftentimes terribly conservative, versus why it was introduced 60, 70 years ago could be valuable and really help with the regulatory engagement. It has had a long history and a very successful history.

I perceive a possibility that, you know, when you were starting to -- I know you've audited, you know, the PRA, you know, this early PRA. But, maybe not to the degree that you will down the road. You know, might you find maybe a need to revisit this one should you not be able to really make a conclusion on some reliability numbers for maybe some, oh, TRL aspect of the design.

So, that was kind of two questions. You know, the first simple one, would it, you know, be included just in your statement whether that would have any problem with that? Or and then second, a what if kind of question.

MR. MUNIZ: Personally, I think, I think it may not hurt to use the or. That gives them more flexibility. So, I don't think there's an issue with that.

But I think to me it's more at a function level. I think if we look at the term reliability it brings a lot. I think it captures the intent of why certain design techniques would show up.

So, during the LMP implementation when you set reliability terms, and capability terms, and defense-in-depth, and all that, and as you classified SSCs, at the time you start helping define what are special treatments you want to identify about, it leads to codes and standards, depending on the significance of the functions these SSCs are performing, I'm not surprised that you get to stand, stand up to frame specific techniques. That helps use of failure criterion or something.

So, personally, I'd rather leave that choice to the designers rather than putting a single failure criterion up front may actually be too narrow, too specific, which may lead to potentially unnecessary conservatism that we wanted to avoid. So, that's my thought.

CHAIR MARTIN: I do think, along with

opinions, the process, maybe it's August, applies more on the PRAs. And it suggests that the quality of PRAs are going to be higher than when it agrees with the Part 52. Of course, that's pretty high standard already.

But, you know, the operating plant, 40, 50 plus years of experience, you know, the qualities are very, very high. The plants that are still on paper, you know, there's a question mark there. And, of course, LMP accommodates that. But I think from a practitioner's standpoint it actually might be hard to implement. You might want to have the "or" statement in there to, you know, solve certain problems.

But I do think scrutiny on PRAs would be a little bit higher. I'm sure the staff here is sensitive to that.

But to the extent that criterion is a way out, you know, and can be sticky areas, again, more to the benefit of the applicant but certainly from the engagement with the staff.

I saw Dennis. Dennis' hand. Go ahead, Dennis.

DR. BLEY: I did put it up because this is a thing I've worried about for a long time.

But the truth is, unless you've got a

really lousy PRA, if a single failure is significant in its impact it will surface very clearly in the PRA.

And, separately, speaking of it being conservative, well, not quite. There are quite a number of double or even higher order failures that can be more likely than a particular single failure. So, it's not always giving you what you're hoping for.

Back when it was formulated we didn't know how to do the reliability approach thoroughly, so it was kind of a cover to make sure we had enough redundancy to at least have some protection. But I don't see the value in it today.

CHAIR MARTIN: Okay. We all have opinions.

So, thanks, Dennis. Perfectly fine that way. But I do appreciate, obviously, being given the details of PRAs. You know, there's a lot of insights that come from that.

My principal concern is the uncertainties associated with those design inputs, particularly for a plant that has never been built. Those uncertainties are, you know, going to be and pretty, pretty challenging I think for everyone.

But, Tom, you look like you have a question.

MEMBER ROBERTS: Yeah. I just wanted to

follow up on what Dennis just said.

I think you made an important point, which is that for some designs, specifically I&C as an example, there are decades, you know, of experience with designing a single failure criterion as one of the inputs. And throwing that out would have a whole lot more baggage that you would have to figure out, okay, how do I get the equivalent of that in terms of my reliability assessment?

And so, at least for some areas, just keeping a digital alternative single failure criterion, at least the applicant level, not necessarily at the safety analysis or the NRC staff level, it might be important just to ensure that the reliability analysis that's needed by the -- if, you know, the approach is sufficient.

So, I don't know if you want to comment on that. But that's what I understood you to say.

MR. MUNIZ: I think this is a conversation we are having with an applicant and also internally.

I still believe that whether a single failure criterion exists or not, the applicants are right now accident significant and the PRAs speak about it. They understand uncertainties. They have a challenge of addressing potentially areas, so less

expense, less data, and so on.

But I think, personally, I do believe that LMP is designed to deal with that. And that's why there's a difference in that element. Defense-in-depth, one of the main purposes is to deal with uncertainties.

DR. BLEY: This is Dennis again.

I agree with Tom here, especially when you start looking at digital I&C, which is an area where we haven't got especially the reliability models these days. So, you need some alternative to protect you there.

I think in most of the places where we're, you know, talking pumps, valves, that kind of stuff, there's plenty of pages for the other opinion.

MR. MUNIZ: I think we all are recognizing that same challenge. I think there are going to be some areas with passive system failure modes or digital system reliability for common failures and things like that.

So, what I'm trying to get at is that there are requirements and expectations that present that, as well as uncertainty being considered as part of the integrated system making process as well. And then PRA, even TR review process we endorse will have

a tremendous requirement there and responsibility to address how you are you addressing the uncertainties, lack of operating experience. Which may lead to some of this decision point.

This is important, if applicant or designer choose to, I'm going to say, hey, we've done this code always for the reactor protection system, actually 603s, apply that. Give it to the vendor and generate it.

That can be one of the options. But still there's going to be some question. Do you want to follow single failure criterion and then still have a challenge here, like you have some of the sequences, I&C system is involved, we'd like to understand always the PRA model. What PRA model in terms of frequency of consequences?

So, I just want to share that. The provisions are there. But at this point I want to give X-Energy to have an opportunity to decide on what brings the reliability in sufficient quantity, in their own choice.

CHAIR MARTIN: Certainly appreciate that.

I think one of my points is that we have kind of two approaches for some decisions, you know, even at a low level design process. And that's a good

thing.

You know, we've been living off single failure criteria for a very long time. And it's been very successful. And now we have elevated the role of risk in our decision making and development of safety cases. Now we have kind of a different approach. They can complement each other. They can use them to verify each other, you know, should you need that, you know, level of rigor.

My only, you know, concern might be that, you know, we start moving past what has been successful, you know, up to 2024, and not recognize that benefit and try to go into the other, other direction.

Right tool or the, the right problem, you know. And that's what, you know, this language, you know, maybe just take the PDCs offering. You cut one out, well, maybe you're really, you know, cutting off your arm, you know. Because there may be situations, we've heard an example or two that, you know, you may want to go the other direction.

I just want to comment real quick. Walt, I did notice just briefly your hand went up and then went down. Did you want to say something?

MEMBER KIRCHNER: Well, I would have just

concurred with Dennis. One would hope that a good PRA would flesh out very early on single points of failure in terms of impacting the overall robustness of the design.

I would observe, though, that applying single failure criteria to the defense-in-depth audit may be a useful way just to test the completeness.

I felt that early in the LMP process the defense-in-depth exercise was the least well fleshed-out aspect of the NEI 18-04 and LMP. And certainly for a simple desktop audit of the defense-in-depth exercise, looking at single failures and, one would hope, as Dennis observed, those would have been identified very early on, but it is a way, Bob, to test out whether to have a robust design for the particular system in question.

That's all I wanted to add.

CHAIR MARTIN: Well, thanks, Walt. That kind of accentuates my point there that there's value for verification testing.

All right, thanks. Go ahead.

MR. JUNG: Next slide.

PDC 16 uses, the language and Reg Guide 1.232 made certain changes. So, it came up at the X-Energy presentation, they are dividing the PDC into

two, on RFDC 16 and CBC 16, and consistent with the NEI 18-04 and Reg Guide NEI 21-07.

So, for DBEs and DBAs, these are multiple, right, the barriers and fuel particles.

That is, essentially, X-Energy is relying on these fuel particles and pebbles, their main three layers there as multiple barriers or as a function for CDC in the area for helium bound before AOOs.

And then next bullet has they're placing design conditions within importance to the design limits. A little bit more clear, more clear that design limit is established.

And so, overall they feel that the function of containment is approved by the Commission a few years ago. And the intent of the MHTGR 16 is met.

So, with that, you know, remember Robert asked me about the question of what do you think about the, you know, multi-layer approach? I, to me I still go back to the LMP process. So, there's a functional requirements that are placed or functional categorization, requires safety functions and PRA safety functions, and so on.

So, for more significant elements are related --

CHAIR MARTIN: Please mute.

MR. JUNG: So, from an overall LMP perspective we feel that even the intent is, I think the intent of the Reg Guide is met. There's no question about the fuel failure, fuel particles.

For helium coolant boundary aspects of the layer, if I remember correctly, even in Reg Guide 1.232 there's a, there's a table that showed what was in the GDC and what was what the staff resolution is. Even the staff at the time had some discussions on it. And, actually, they had a discussion and it could be a layer or more.

So, there is a little datapoint for that.

But I think, you know, also X-Energy has indicated that there are other SSCs, right, you know, in the actual building and so on. X-Energy has determined that this is sufficient criteria to meet the functional requirements that they identified.

If they needed additional layers for defense-in-depth perspective, it would have shown up. That's what we saw.

So, we felt this is reasonable approach.

Yet, the whole process to still go through. That's why there's the imposition of the limitation in condition, it has to be still

demonstrated.

CHAIR MARTIN: Okay. Walt, I see your hand's up.

MEMBER KIRCHNER: Yes, thank you.

This is an area where it's more for the staff, than the applicant. I see what the applicant is doing here.

But my assessment is that this definition actually dilutes what the Reg Guide provides for, and let me explain.

The Reg Guide takes a much more expansive view of what functional containment means by basically stating multiple barriers, internal or external to the reactor and its cooling system, shall be provided to control the release of reactivity to the environment, and ensure that functional containment design conditions important to safety are not exceeded for as long as the postulated accident conditions require.

Now, postulated accident conditions earlier was redefined as licensing bases events.

This is not, this is a rather narrow, more narrow interpretation in my opinion, of what is in the Reg Guide under functional containment, PDC 16.

And, my concern is that it's the Commission policy that multiple barriers to form a

robust containment system, to prevent unmitigated radionuclide release is the intent here of this.

And, that's why I asked the question about the (audio interference), and whether that was going to be credited or not, as one of those barriers earlier.

I just think in this case, I know it's been tailored by the applicant for their particular analysis based on going through the entire NEI 18-04 cycle.

But it leaves the perception perhaps to the public, that this isn't quite the robust multiple barrier system that the Commission and Agency had in mind, when they drafted the Reg Guide.

So, that's a personal opinion and observation. It's a problem, we've seen this with other applications as well, particularly on this particular PDC.

And, my sense, how an applicant implements it is a lower level thing. But retaining that basic philosophy that the Commission laid out, is important.

And so sometimes just an observation, this multiple, this dissecting of the PDC and the ascribing in this case, the helium pressure boundary only for AOOs, well, you need it during normal operation anyway

because you depend on the purity of the helium to protect the pebbles, and the particle fuel.

So, it's a little bit, I know that's addressed also in an earlier PDC in 15 about, I think it's number 15, about unmitigated moisture control on access in particular, is a concern for an MHTGR using a steam Rankine cycle.

But when these PDCs get parsed like this, I wonder whether they're losing the overall intent that was initially determined in the Reg Guide.

So, any observation from the staff would be welcome. But I've seen this in a number of the PDCs.

They were getting into actual specific design detail, rather than having an overlying, or overarching is the better word, PDC for the particular safety function that's in question.

MR. JUNG: Member Kirchner, I appreciate your thought and it brings up your insights, something to think further.

But I think at least my logic and the review is that my trust in the (audio interference) process, right?

You mentioned, there was mentioning about Section 5 of the NEI in 04, which has a extensive

discussion of the defense-in-depth adequacy evaluation.

And, there's a certain criteria that comes along. For example, no single features, or no single element is relied upon in demonstrating defense-in-depth adequacy.

So I'm not sure exactly how this particular AOO sequence may satisfy that element.

And also, if you look at the reason there are steps in a kind of little bit challenging situation, is the lack of the helium permutation itself.

If you look at the construction permit stage defense-in-depth evaluation, the NEI 21-07 talks about because of the preliminary nature of the design, and the lack of a programmatic elements, then that's going to come down the road.

It focuses more on plant capability defense-in-depth, not based on a programmatic element that will come along, as well.

So, that limits also the scope of the defense-in-depth to be plant capability, based on the preliminary design.

So, NEI 04 allows the consideration of both, at the end, both capability as well as

programmatic elements in demonstrating overall defense-in-depth.

I just want to mention that to kind of express my trust in the process that's undergoing. But I think it's more at the end is the language of multi-layer.

I do worry about a little bit, having the language imposed on the designers at this juncture, may potentially impose a unnecessary conservatism that may, that may actually negate the potential benefit of a LMP permutation.

CHAIR MARTIN: We've spent a lot of time talking about this.

MEMBER ROBERTS: Yes, I was going to make the exact same comment as Walt. But one thing I might add is if the ACRS reviewed the functional containment approach back in 2018, the recommendation, I'll just read it verbatim.

The functional containment should contain multiple barriers as defense-in-depth features that should be minimally dependent upon each other, and adverse of nature.

And per the ideals in the letter, that was because of a concern that containment is more important, ultimately the safety, than probably any

other feature.

And so, the idea of thinking you're smart enough to rely on one barrier as sufficient, is cause to concern to the committee 6 years ago.

I just wanted to make sure you're aware of that, that precedent.

MR. JUNG: Yes, and another challenge is the unique nature of these fuel pebbles, and fuel particles.

Again, can we say on the language of are they really independent, how that in a same, same, under the same pebble things like that.

And, but there's an even interpretation of a LBE sub right, if you want a really original intent of the functional containment.

Is it really related to design basis accident in a traditional sense. It's really the original containment design is based on DVAs.

And so, we are in this somewhat unique situation with the AOOs where we don't expect the fuel to exceed the subtle temperature, things that we count upon, there's going to limitation for that.

So, it appears that where DVEs and DVAs, which is a significant, potentially more significant consequential event, event sequences, if we equate to

those events, I think the multiple barriers are really articulated in here.

Even without multi, but barriers of plural. So, I see that.

CHAIR MARTIN: Well, certainly we have between the required functional design criteria and the complementary design criteria, there are certain barriers (audio interference) that are acknowledged whereas the corpus of the Reg Guide just has the one kind of statement.

Because obviously in this discussion kind of falls back to kind of the historic discussion that led up to the Reg Guide, about containment versus confinement for high temperature gas reactors.

And, the Reg Guide is clear that TRISO is kind of a key assumption in the preparation of these PDCs.

But it's certainly something to keep on considering, particularly and I'll bring up another point.

They have a proprietary TRISO, the TRISO-X. We're all familiar with EPRI's, I just call it the TRISO topical, but obviously the staff reviewed that in 2023 timeframe.

And, obviously came to a pretty strong

conclusion about the particular TRISO that was tested out in Idaho.

But they had something a little different and I know you have reviewed the fuel qualification topical, and have some L&Cs associated with that.

But all that kind of plays into the functional containment story. And, at least I had a question and I got some help, when I was reviewing, got some help from Derek Widmayer.

Because he's federal officer for this organization, or staff was supporting and he pulled up that topical and it answered a number of questions kind of related to what commitments that you already have with X-Energy supporting this obviously very key barrier.

Or maybe another word, tri-structural that implies multiple barriers, obviously at the kernel, around the kernel.

So, I do think given that little bit of history, it really supports my own personal comfort level with the functional containment story that you already have reviewed some of this.

Have L&Cs already kind of on record about where they need to go ultimately with demonstrating the fuel performance.

So, given how much time we've spent on this, I didn't, I wanted to give you the same question I had for X-Energy on this one related to SARRDLs versus functional containment, but I'm going to let that one go.

Believe it or not, I think we're getting more and more on time. So, why don't we go ahead and proceed to the next one.

DR. SCHULTZ: I've got one more comment.

CHAIR MARTIN: Okay.

DR. SCHULTZ: One more comment.

In the safety evaluation, you indicate that the required functional design criteria and the complimentary design criteria, they have been accepted by the staff.

But then you also remark that with regard to the specific functional containment design limits, those have not yet been reviewed.

And, I think you had just indicated that the limitation in condition 1 may cover that, but I didn't really see that being applicable to your statement in the SE, and thought that perhaps expanding that limitation and condition would be appropriate.

MR. JUNG: I think the way we added that is

just more of a expectation. So, just like any other PDC, like even PDC 2, environmental qualification type of things.

DR. SCHULTZ: Everything would --

(Simultaneous speaking.)

MR. JUNG: Everything --

DR. SCHULTZ: -- sort of get to that same category in terms of what needs to be done, given the more detailed design information?

MR. JUNG: Yes, it didn't have to get the NRC, but I think it's just the emphasizing that that work -- demonstration of conformance to the PDC design our staff to carry through by having the design limits established, which will be subject to NRC's review perhaps during the construction permit application.

DR. SCHULTZ: As well as any other changes that may affect the design criteria, as well?

MR. JUNG: Right.

DR. SCHULTZ: Thank you.

MR. JUNG: Next item is PDC 6, which was discussed earlier by X-Energy, as well. It combines, you're proposing a one single criterion for this area. We felt that it's actually a better idea.

I think as you know, the LMP brand new design, it's a clean sheet approach on things. So,

identifying this one criteria that covers broadly to all safety significant access, is a great idea.

Actually, it simplifies not limiting, but, not limiting just particular systems but having a design criterion that applies to all safety significant assets. We felt it was a (audio interference).

So, PDC 11, Dan, can you cover that? Dan wasn't really feeling well earlier, so.

MR. BEACON: It's been a rough morning.

MR. MOORE: Could we take a short break? This is Scott Moore, from ACS. Could we take a short break for about 5 minutes?

CHAIR MARTIN: Oh, if we need a break, let's go ahead and do it. I mean, 5 minutes, let's get back at 11:20.

(Whereupon, the above-entitled matter went off the record at 11:14 a.m. and resumed at 11:21 a.m.)

CHAIR MARTIN: Okay, so we were moving on to PDC 11. You may proceed.

MR. MUÑIZ: Dan Beacon is not feeling 100 percent, so I'm going to take a shot. But Dan's still here; he might try to answer some of the questions.

So, PDC 11 on reactor inherent protection,

TRISO fuel plays a significant role there. X-Energy exposed its plan this morning so I don't want to belabor this.

And, PDC 11 both captures MHRDC 11 and 12, and also inherent protection of the TRISO fuel is one of the two means that's discussed in PDC 26.

It's a unique design in the sense that instead of two active means, there's one inherent protection along with the record, the trip system that poison and to come along down the road.

There is a, we put a little one limitation condition regarding the expression of the indoor power range, power operating range, where the staff because of the design stages we are in, as well as the LMP permutation, there might be a possibility beyond the power range there might be some potential oscillations and other issues.

So, we are proposing a limitation on that. That the designers and applicant's referencing that would verify that there's no such issues in other ranges.

CHAIR MARTIN: Okay, that power oscillation was actually was it 12 or, right? Oh no, you didn't have it because it probably that's kind of all goes together with it.

But I believe there is a separate PDC specifically about power operation. But, or excuse me, power oscillation. Obviously it plays into what you're saying here about the totality of the power operation range.

Okay, so just wanted, if anybody was looking at the topical, you might want to look at also, I think it's 12.

MR. MUÑIZ: Appreciate it.

So, limitation 2, yes, as Dr. Martin mentioned, it has relationship to the MHTGR-DC 12.

Next.

CHAIR MARTIN: So, they say subsumed by PDC 11. Okay, so they integrate the two.

MR. MUÑIZ: Right.

CHAIR MARTIN: Okay, I guess my bad. I mean, obviously the 12, 12 has always been there in Reg Guide, but that's what they did kind of the same way they used PDC 6 and just propagated its role.

MR. MUÑIZ: Yes, so PDC 11 captures both 11 and 12.

CHAIR MARTIN: I see.

MR. MUÑIZ: PDC 14 reactor helium pressure boundary, and testing considerations are removed and integrity part is captured by PDC 70.

If you look at the PDC 70, it talks about the integrity of the reactor helium pressure boundary. PDC 6 as discussed earlier, it covers all testing provisions for all the safety significant assets is covered.

There is a, I'm trying to read through it. Yes, what I was going to mention is that is ingress of moisture, air, and secondary coolant to other fluid is replaced with a moisture ingress, based on current their design.

But I think staff is proposing the limitation and condition that needs to be verified, depending on the LMP implementation and the design.

We just couldn't see without the detailed design, whether the moisture ingress simplification is sufficient or not.

So, we are imposing a limitation of that.

MR. METZROTH: And, does this somewhat imply that they don't believe, they don't, reliability frequency of event data, that you can't have a double guillotine break that when you consider the characteristics of the most serious breach of the pressure boundary, that it just falls outside of the likelihood range.

And as a consequence, they're looking at

the next one up that is the moisture ingress. Is that a basis for excluding mention of airing?

Because obviously you've captured it as the limitation condition because there's more to be said about it, I'm sure.

But is that the way you interpreted it?

MR. MUÑIZ: It doesn't ring me a bell the specifics of this. Can I call up X-Energy to kind of chime on that?

If you can speak up?

MR. METZROTH: Could you repeat the specific question?

CHAIR MARTIN: Actually, Kyle, could you just stand over here to make sure that everyone can hear you.

MR. METZROTH: So, the gist of the question was the statement that you provided here, which effectively excludes the European press.

Because it's fine that you've kind of excluded the largest breaks based on your PRA model.

(Simultaneous speaking.)

MR. NIGH: It's based on an evaluation of the design, and looking at the frequency of various break sizes.

Including that there are certain break

sizes that fall in the design basis event region; and certain fall outside of that.

So, the size that we have, we don't have --

(Simultaneous speaking.)

MR. METZROTH: If you pressurize enough --

MR. NIGH: -- to have a significance. We mentioned earlier we evaluate any possibility of that occurring, but it's not enough, it's not break size where we have a significant amount that gets in such that it's a big concern.

MR. METZROTH: Yes, and you got to kind of where you said there's no possibility for like a double heat guillotine break, for example.

MR. NIGH: Right.

MR. METZROTH: Like, we did look what if two holes open up in the helium pressure boundary. And, that event is sufficiently unlikely that it wouldn't be covered by this PDC.

PARTICIPANT: Can you identify yourselves again for the court reporter, please?

MR. METZROTH: Oh, sorry, Kyle Metzroth.

MR. NIGH: Drew Nigh.

CHAIR MARTIN: It seemed obvious connecting the dots, but I just wanted to hear it from you two.

MR. NIGH: Thank you.

MR. MUÑIZ: That's how I was going to answer, but.

(Laughter.)

MR. MUÑIZ: I'm saved. PDC 26 next slide.

It was discussed earlier a little bit, PDC 26. There are several requirements the provisions, we evaluated each one of them.

The key one being in the event and diverse means to achieve, they shut down and a puncture rod is one of the method. And the other one is inherent reactivity feedback I discussed.

And, I'm not going to go through it. There's RFTC and CTC related to DVEs. And DVEs and DVAs, and AOOs.

And, yes, so we felt that the underlying intent of the Reg Guide 1.232 is achieved by this PDC 26 proposed.

MEMBER KIRCHNER: This is Walt Kirchner. Could you elaborate? I'm not following the logic here. This is a moderated, a gas-cooled graphite moderated TRISO fueled reactor.

As you cool down the plant, it adds reactivity. So I'm not getting the logic that certainly that characteristic is desirable to prevent

reactivity insertion accidents, or overheating. And suppression of reactor power oscillations.

But as you cool down this system, you will be adding reactivity. So, I don't understand the logic of saying the inherent feedback effect is part of the means, diverse means of achieving shutdown.

You're going to need control rods and shutdown, and an independent shutdown mechanism to achieve a cold shutdown condition.

MR. MUÑIZ: I'm going to call upon Dan or X-Energy. I'm not a reactor engineer, but my understanding is, is that the inherent reactivity feedback mechanism demonstrated by the sum of the task team, and to be further demonstrated a by fuel qualification.

It demonstrated that the negative reactive feedback is sufficient enough to reach a shutdown condition.

That's an interesting --

(Simultaneous speaking.)

MEMBER KIRCHNER: No, no, the negative feedback protects you against overheating reactivity transients. It doesn't shut you down.

It adds reactivity as you cool down the system. So therefore, you need sufficient reactivity

in the control systems, likely control rods, some designs, smaller designs may use drones.

But, and then you'll need two independent mechanisms to satisfy the overall intent of PDC 26. But the inherent reactivity feedback, which is desirable for overheating and reactivity insertion transients, doesn't work to your advantage when you're cooling down a reactor like this.

You're adding reactivity as you cool down the system.

CHAIR MARTIN: I will add, I noticed, I have to check but cold shutdown is not used here, right?

MEMBER KIRCHNER: No, it isn't. The condition already issued back, it was cited by the applicant in one of the -- no, sorry.

It was cited in the Reg Guide 1.232 of the conditions position on achieving shutdown. And not requiring a cold shutdown, realizing that the mass, the inventory, the thermal inertia for lack of a better description of such a system, doesn't allow you to achieve a cold shutdown condition like is possible in a LWR system, in a reasonable period of time.

So, the condition recognized that and the Agency made provisions for that. But what I'm

objecting to is that the inherent feedback that you get out of this kind of reactor design, protects you against overheating transients, protects you against reactivity insertion accidents.

But it doesn't help you shut down. You have to compensate for the fact that as you shut down this system and it cools down, that that adds reactivity and hence, the reactor control systems, reactivity control systems need to be designed accordingly.

Then, to have a diverse means, you have usually control rods and then shutdown rods. And for most MHTGR designs that I'm familiar with, so that you can actually have a means to ensure that you don't return to criticality as the system cools down.

CHAIR MARTIN: So, the PDC, I wasn't and maybe I'm being too generous, but the PDC as they have written, has mentioned movable poisons.

I guess they don't, doesn't necessarily apply what you say here, just control rods. I guess I felt like the PDC was a still, maybe still open to some interpretation about the means.

They had pointed specifically to PDC 11 related to the inherent reactivity feedback. I guess my impression coming out of the earlier meeting, was

that there was at least an opportunity for X-Energy to address that in a more specific manner.

PARTICIPANT: Well, don't you want to say something?

MR. VAUGHN: Yes, definitely.

PARTICIPANT: Please introduce yourself.

MR. VAUGHN: Yes, yes, Steve Vaughn, Licensee X-Energy. Yes, great question, Member Kirchner.

And we can discuss more details in the closed portion if you want, but you're right, the inherent reactivity will take heat down to a certain temperature, right, then it will start to add positive reactivity.

And so PDC RTC 26 this let's say shutdown rods, will cover all modes, all temperatures. If you want to get into the details in the closed, we can talk to you in a little more detail about that. But we're getting into specific design criteria right now.

CHAIR MARTIN: Does the way you've written that the PDC 26, Bill, support what Walt's saying here about a diverse and even cold shutdown? Something a specific concern.

MR. VAUGHN: The comment that safety analysis will show that combination of inherent

reactivity feedback in RFDC 11, plus PDC RFC 26, the safe shutdown rods, will get you to safe shutdown margin for all modes.

CHAIR MARTIN: Yes, I guess I agree. I feel like we're getting close to proprietary content. So I don't know if we can pursue this.

What do you feel, Walt? I mean.

MEMBER KIRCHNER: No, I'm just making the observation that you don't get to the shutdown based on the inherent feedback conditions.

That they will provide a means for holding the reactor shutdown so that they can go to refueling, et cetera, et cetera.

So, I'm just making a point that we shouldn't mix up, yes, this is true. You've got a desirable design characteristic for this system to prevent reactivity insertion accidents, and overheating. And that's inherent.

You still need two control rod control systems to achieve and meet the goal of PDC 26.

CHAIR MARTIN: All right, so like I said, I still don't think we can go much further into this without getting into some very specific stuff.

MEMBER KIRCHNER: Okay.

CHAIR MARTIN: But it's a good point.

MEMBER KIRCHNER: No, I just, the first bullet there just is a little misleading.

CHAIR MARTIN: I would agree.

MEMBER KIRCHNER: To meet the intent of PDC 26, you're going to need in the case of an MHTGR design, two active control rod, control-like reactivity control systems. That's my point.

With the inherent reactivity feedback is a desirable characteristic that will prevent the power oscillations, and other aspects that are mentioned in PDC 11 and 12.

PARTICIPANT: Yes, we can take it up on the closed session, thank you.

MR. JUNG: Yes, we'll wait until that closed session.

CHAIR MARTIN: All right, well we're like, I'm not sure our schedule supports a closed session. Is that fair to say?

DR. BLEY: This is Dennis. I wanted to sneak a question in kind of for Walt. When I read that first bullet, it doesn't say that means 1 and means 2 either one works. It says and.

So, I'm wondering if we're, the arguments about interpreting at that bullet saying that you can wait till the later session for that.

MEMBER KIRCHNER: Yes, it can, Dennis. You're correct. I was just reacting to that, the way it is presented in the view graph, which is different than the actual PDC.

CHAIR MARTIN: It is different than what it appears in any.

MR. SNODDERLY: So Bob, this is Mike Snodderly with the ACRS staff. We have the ability to go to a closed session. There is a MS Teams meeting available.

I suggest we finish the open session, get public comment, and then we can, and then see what time, what the time is like and figure out next steps.

MR. MOORE: This is Scott Martin. We do need to start the afternoon session at 1:00 o'clock.

CHAIR MARTIN: Exactly, so we do have a constraint. I'd like to provide a little time for lunch but we're used to pinching that a little bit.

Anyway, let's proceed and we'll see if we can't provide a little more clarity in a closed session on this question.

MR. MUÑIZ: Yes, I'm a substitute player so expectations should be a little bit lower.

So, this is time for procedural heat removal passage system for, within that particular

function is done through the fuel, and that radionuclide limits are met for the DVEs and DVAs and a 50-34 limit.

There's a active system that provides the decay heat removal function, such that the SARRDLs have not exited for AOOs.

But it's a CDC, normal operation size for CDC, the helium, the circulating system plays a role there.

The HP, helium pressure boundary maintaining core geometries as discussed earlier in PDC 7, related to integrity of the helium pressure boundary system.

We felt that overall, the intent of direct access on that.

Okay, next one.

I think this was the last item before the limitation condition. PDC 70, reactor vessel and reactor systems short design basis, and there's some changes are made to be a little bit more specific regarding the helium pressure boundary, and core internal support reactor integrity.

And also, achieving low and also achieving low probability of radically profligating failure during DVEs and DVAs.

And also, that also supports PDC 14 that was discussed by the X-Energy earlier this morning, ensuring core geometry for passive heat removal of residual heat.

Also, it's part of this PDC, it supports PDC 34, permitting, permits insertion of the neutron observers and maintain core reactor inherent protection.

As we discussed earlier, it is tied to PDC 11 and 26. So, we feel that intent of the MHTGR DC 70 is met.

CHAIR MARTIN: One just comment/question possibly.

The language of course, focuses on the core internals. You mentioned ensure geometry for passive heat removal.

There's also a permit insertions of neutrons. But in addition, guarding reactivity control, the integrity of those neutron absorbers has to be assured like a light water reactor, because we worry about control rod elements. Same sort of thing here.

And, those familiar with high temperature gas reactors might be aware that Japan's HGTR facility, they were very sensitive about that. And

they have a very interesting reactivity control system.

These delay neutron, or excuse me, control rod insertions, in the hottest part of the core to make sure that they don't have this concern.

And, I can read the PDC and come to an interpretation that obviously addresses some thermal safety limit on control rod temperatures.

Do you feel like the language is strong enough? Did you think through that particular aspect of PDC 70 when you were going through this?

MR. MUÑIZ: I think about I can help. Dan's chiming in but I think overall, that the language there in terms of the scope of reactor vessel and the internals inside of it, talk about how do you captures overall, all the elements of safety, safety significant assets.

Dan, can you chime in?

CHAIR MARTIN: It's certainly a temptation to look at any one of these. I mean, for instance we were looking at 26 and that's very much a reactivity control safety function.

But I think here with 70, it actually crosses the safety functions. It's not just a heat removal, but there's also, and it touches reactivity

control and its integrity.

MR. MUÑIZ: Yes, eventually it gets to the issue of performing requires safety functions, and the structural integrity as well as the reactivity insertion.

All those things play together.

CHAIR MARTIN: Thank you.

MR. MUÑIZ: Next slide.

So keeping an eye on that, I'm not going to labor too much. The first one is the really the kind of more overarching limitation condition given the preliminary nature of the design, as well as implementation of LMP.

We are imposing a, this overarching limitation of condition that says basically the applicants for licenses referencing this topic report, would confirm these PDCs are sufficient.

Because the further implementation of the design and LMP, may identify changes were dealt up from the what we proposed.

DR. BLEY: Excuse me, this is Dennis Bley.

I want to make a comment on these, and I wanted to do it before you go through them all so you could maybe address my comment and question as you go through.

Number 1 and 3 here really bothered me. Number 2 bothered me a little bit. And, my concern is my understanding of topical reports once they're approved, is that when you actually use them in the license application, you have to essentially do the things that are listed here.

And if we're taking out a few things, it might give people the impression unless limitations and conditions are proposed, they don't need to go back over everything in the topical report and make sure it's applicable to their design.

Now, number 2 is, fits that as well, but number 2 has at least the sense of something that might be forgotten.

But it seems to me these are basically unnecessary, and could give a wrong impression that you need something like this to relook at any issues in the topical report, when the license comes up.

So, if you can talk about that as you go through these, I'd appreciate it.

MR. MUÑIZ: Yes, our intention is not to give that impression that the rest of the topical report that we approve are not evaluated for applicability.

We felt that number 1 and 3 are in the

same realm in terms of kind of more of a, I think it was a sufficient number 1.

We felt it was sufficient to --

(Simultaneous speaking.)

DR. BLEY: I feel like a checklist for you guys on what to look for when the actual application comes in. But I stand with what I said before about why it bothers me.

MR. MUÑIZ: Purely speaking, number 1 and 3 may not have been imposed, but we felt that still is a unique approach.

And LMP implementation being that's fully exercised, we wanted to emphasize this area very strongly so that we actually give the clear indication that what we are proving is based on somewhat limited implementation of the design, as well as the LMP.

DR. BLEY: Yes, that's --

(Simultaneous speaking.)

DR. BLEY: -- that's true, but it always is required for using a topical report that you make sure all the assumptions in that report apply to your design.

So, my worry is what I said, that somebody might be reading this and thinking, unless things are spelled out in limitations and conditions, they don't

need to do much more when they use it in the license application.

I'm sure that doesn't apply to this applicant, but it might to others.

MR. MUÑIZ: Understood. I think it's something that X-Energy is, for at least for X-Energy, are intending to be part of the future licensing applications and so on, I think it's there.

But we understand your point, and but fundamentally though, all the fundamentals of use of topical reports as approved by the NRC staff, tends to be consistently emphasized to the other applicants.

CHAIR MARTIN: We might have to look at these as IOUs, right? Because we're on conformation, future license application reference.

PDCs, and I'm voicing an opinion, should ultimately be without L&Cs. At some point when you have all the information, there are no L&Cs associated with the GDC, right? Those are design criteria for light water reactors.

Unlike other topic reports, I can see this being revised much later in the license application process where it's clear, meaning you cleared the L&Cs because you have all the necessary information.

I know the PDC process is relatively new.

Surprisingly, it's only the third one we've seen. But how do you feel about the idea that to a point, you need to clear the L&Cs?

That's for really both the applicant that you come to an agreement that these are the ones that apply to Xe-100, and we are satisfied with this set that it covers kind of after you've gone through these L&Cs, and that I've confirmed and I've seen the PRAs, I've seen the accident analyses.

There's convincing evidence that they have really done everything they said in this PDC document.

Now, I will note that of course, I think both in your SE and in their topical, it kind of says yes, we may revisiting this.

But the ultimate goal I think, should be to get rid of these L&Cs. Is that how everyone feels?

MR. MUÑIZ: From a staff's perspective, that's a ideal case where there's no limitation addition. Plus as these GDCs are applied, there might be some lessons learned on how exactly this criteria led.

So there could be a future improvements.

CHAIR MARTIN: Yes, Steven?

MR. VAUGHN: Before X-Energy had agreed during the upgrading license application, you expect

this top report to be a rev 4 and or 5, and we wouldn't expect any license conditions on it.

CHAIR MARTIN: You can't have an IOU and approve a plant, right?

MR. MUÑIZ: Next slide.

Just quick conclusion. So, based on our review, we found that X-Energy has provided a reasonable set of PDCs that are appropriate for establishing the requirements of the Xe-100 design, consistent with the intent of the Reg Guide and LMP guidance that I discussed.

These are subject to the limitation condition we discussed. We found that this PDC established the necessary design fabrication, construction, testing and improvements design criteria for safety significant SSEs to provide reasonable assurance that the design could be operated with undue risk to health and safety of the public.

Therefore, revision 3 of the topical report is suitable for referencing and future licensing applications under 10 CFR Part 50, Parts 50 and 52, for the Xe-100 design.

That's all we have.

CHAIR MARTIN: Great, open up for any member or consultant questions? Anybody online?

Once, going twice?

I think at this point, I could open up for public comment. So anyone, any member of the public like to?

Ed Lyman, I see your hand raised.

DR. LYMAN: Yes, hi, it's Edwin Lyman, from Union of Concerned Scientists. Can you hear me?

CHAIR MARTIN: Yes.

DR. LYMAN: Yes.

Yes, I'd just like to say I'm disappointed that there was not further attempt to resolve Member Kirchner's comments about the diverse reactivity control system, GDC.

Just from what was presented here, it does not look like what has been proposed as consistent, or the same level of safety as a light water reactor, because light water reactors also under most conditions, have inherent negative reactivity feedback. Yet, they have two diverse shutdown systems in addition to that.

So, at least from what's presented here, it looks like this would not have the same or equivalent level of safety to light water reactors.

So, I'm hoping that more information about that can be provided publicly, because I don't have

confidence in what I've seen.

The second point with regard to functional containment. Again, I would, I think Member Kirchner's observations are very relevant.

This is something that of course, is cross-cutting. It's also applied to the Natrium design. Every other plant with a functional containment. I'm deeply concerned.

And I have very little confidence in the process, especially in a Part 50 context where these are being used, this approach is being used for fundamental, making fundamental design choices based on an inadequate dataset.

And, as is the case with the Natrium, there are key issues related to fuel performance that have not, that there is not the experimental data available to validate those. Yet this key decision about whether to have a containment or not depends critically on the fuel performance, and questions that may not be resolved until the plant is actually operating. And, fuel performance data has been accumulated.

So, I'm deeply concerned that for these paper designs to rely too heavily on expectations about fuel performance to make these critical design

choices like functional containment or not, put great risk on the applicant.

Okay, so that's the applicant's problem. But I'm worried that the NRC ultimately is not going to make a decision to deny an operating license, even if there is a significant design choice that turns out to be wrong, based on the accumulation of operating data. So, I think a holistic, you have to take a step back and look at what is being proposed here, and whether there should be more conservative design criteria, especially for a first of a kind plant.

Thank you.

CHAIR MARTIN: Thank you.

Are there any other further questions from members of the public?

(No audible response.)

CHAIR MARTIN: All right, I need help transitioning to a closed session so we can kind of answer the, that one question that came up.

MR. SNODDERLY: Yes, Dr. Martin. So, I ask that you close this open session and then we would be the closed session invite. If there's anyone that does not have the invitation to the closed session, could you please raise your hand and we'll make sure we forward it to you.

CHAIR MARTIN: Okay, I don't think I got it.

MR. SNODDERLY: Okay, so Derek, if you could please forward the invitation to Bob. Everybody else has it? Okay.

And then, so once Chairman Martin closes this session.

CHAIR MARTIN: Yes, so all of a sudden we have thee hands raised. Are these members of the public?

MR. SNODDERLY: James is our court reporter. So Derek, please send the invite to James Cordes.

MR. WIDMAYER: Okay.

MR. SNODDERLY: Or to Shannon, then Shan, we need to get it to James. And I'm sorry, Mr. Stuhdreher.

MR. STUHDREHER: Stuhdreher, yes.

MR. SNODDERLY: Stuhdreher, can you please identify yourself or your question?

MR. STUHDREHER: Yes, I was asking for the meeting for the closed portion of this. I'm with the Department of Energy.

MR. SNODDERLY: That's up to, can someone from X-Energy please send an invite, or?

MS. MADDOCKS: Hey, this is Jessica with X-Energy, Project Manager. Check your email. I sent it out to you, but it's in an email. It's not a meeting notice.

MR. STUHDREHER: Oh, okay, all right, thank you.

MR. SNODDERLY: Thank you, Jessica.

Is there anyone on the line, anyone else on the line that feels that they have a need to know? Please identify yourself and make a request so that we can determine whether.

(Pause.)

CHAIR MARTIN: Okay, if we can, I don't want to leave this right, until James, until we, James, can you please, let's stay on the line until James confirms that he has the invite.

PARTICIPANT: No dogs allowed at the meeting.

CHAIR MARTIN: Yes, no dogs.

Okay, James, let's --

MEMBER DIMITRIJEVIC: I don't also see invite in my email. So this is Vesna, hi. So Derek, can you also make sure that you send it to my Gmail? Since I'm not in Boston.

MR. SNODDERLY: Okay, I will do that right

now.

MEMBER DIMITRIJEVIC: Okay, thanks.

MR. SNODDERLY: And I'm going to do it to James, too.

CHAIR MARTIN: Yes, thanks, Mike. I couldn't get a, I've been forwarding it but I've lost the ability to do such all of a sudden.

MR. SNODDERLY: Okay.

MR. WIDMAYER: So, I think it was just James and --

MR. SNODDERLY: Right, and James.

MEMBER DIMITRIJEVIC: And, Vesna.

MR. WIDMAYER: And, Vesna, yes.

MR. SNODDERLY: Yes, I've got Vesna.

Shan, are you on the line?

(No audible response.)

MR. SNODDERLY: I don't, all right, James, please put your email address in the chat. For this meeting.

MR. WIDMAYER: Yes, he just did.

MR. SNODDERLY: Okay.

MR. WIDMAYER: Walt, you've got your hand up again?

MEMBER KIRCHNER: Yes, could you forward that closed invitation?

MR. WIDMAYER: Oh, yes, I missed, you, yes. Hey, Mike, can you forward it to Walt?

MR. SNODDERLY: Yes.

(Pause.)

MR. SNODDERLY: Walt, I just sent it to your NRC email address. Is that acceptable?

(No audible response.)

DR. BLEY: Hey Mike, Dennis Bley.

MR. SNODDERLY: Yes, Dennis?

DR. BLEY: I was sure I had it but I've got the one for tomorrow. I don't have this one.

MR. SNODDERLY: No worries, no worries, no worries. I think the main, we just need to get, I'm doing that now.

MR. WIDMAYER: Yes, you should have it Dennis.

(Pause.)

MR. SNODDERLY: All right, I've asked Chairman Martin to please close this meeting and everyone please go to the closed session.

CHAIR MARTIN: Great, I'm going to use the gavel here. We're closing this open session on the Xe-100 principal design criteria.

(Whereupon, the above-entitled matter went off the record at 12:04 p.m.)

# NRC Staff Review of the X-energy Principal Design Criteria Topical Report for the Xe-100 Reactor Design

**Adrian Muñiz, Senior Project Manager**

**Ian Jung, Senior Reliability and Risk Analyst**

**Dan Beacon, Nuclear Engineer**

Office of Nuclear Reactor Regulation

Division of Advanced Reactors and
Non-Power Production and Utilization Facilities

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

# Topical Report Purpose

- Purpose of the topical report:
  - Describes X-energy's process for developing principal design criteria (PDC)
  - Requests the U.S. Nuclear Regulatory Commission (NRC) staff review and approval of proposed PDCs
    - To comply with applicable regulatory requirements under Title 10 of the *Code of Federal Regulations (*10 CFR) Parts 50 and 52
    - To support the design and licensing process

# Review Chronology

- Revision 1 of the topical report (ADAMS Access No. ML22195A260) on July 13, 2022
- Staff's preliminary questions and X-energy responses in a letter dated December 30, 2022 (ML22364A293)
- Regulatory audit to support its review based on an audit plan (ML23009B755) and documented its observations in an audit report dated January 19, 2023 (ML23093A215).
- Revision 2 (ML23181A172) on June 30, 2023
- Staff's additional questions (ML23277A274) on Revision 2 and discussion with X-energy in a public meeting (ML23346A120)
- Revision 3 (ML24047A308) addressing staff questions during the review and X-energy's self-identified items
- Draft safety evaluation issued (ML24190A060) on July 17, 2024 (based on Revision 3)

# Regulations

- In accordance with the provisions of 10 CFR Parts 50 and 52, licensing applicants must submit PDCs for the proposed facility.
  - For example, 10 CFR 50.34(a)(3)(i), which requires, in part, that applications for a construction permit (CP) include PDCs for the facility.
- 10 CFR Part 50, Appendix A discusses the scope and content of PDCs:

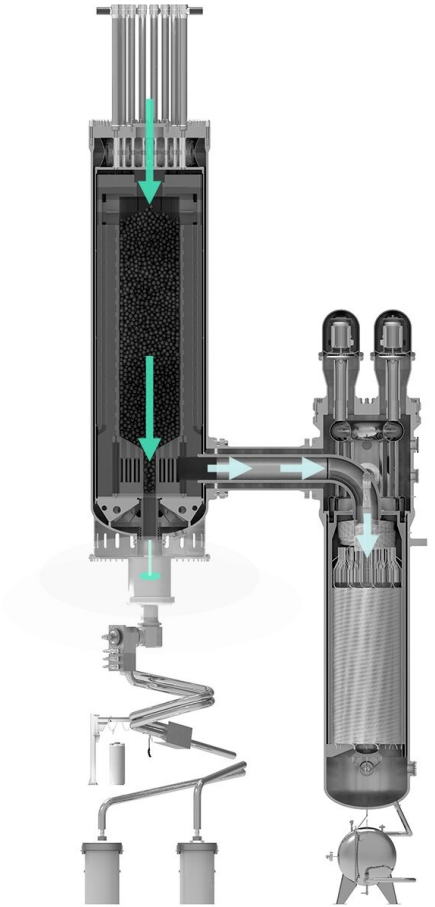
  "[PDCs] establish the necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components important to safety; that is, structures, systems, and components [SSCs] that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public."

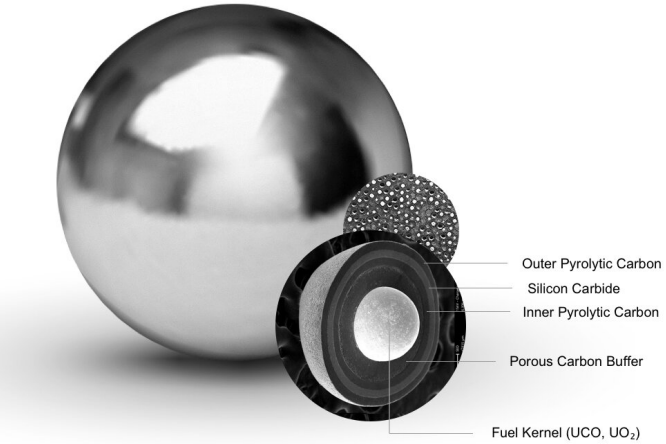
# Guidance

- Regulatory Guide (RG) 1.232, “Guidance for Developing Principal Design Criteria for Non-Light Water Reactors” (ML17325A611)
  - Appendix C provides Modular High-Temperature Gas Reactor Design Criteria (MHTGR-DCs)
- RG 1.233, “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors” (ML20091L698)
  - Endorses Nuclear Energy Institute (NEI) 18-04, “Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development,” Revision 1 (ML19241A472)
- RG 1.253, “Guidance for a Technology-Inclusive Content of Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors,” (ML23269A222)
  - Endorses NEI 21-07, “Technology Inclusive Guidance for Non-Light Water Reactors – Safety Analysis Report: For Applications Utilizing the NEI 18-04 Methodology,” Revision 1 (ML22060A190).

# Xe-100 Design

- Key features
  - Pebble bed, high-temperature gas-cooled reactor (HTGR)
  - Tri-structural isotropic (TRISO) fuel
  - Graphite moderator
  - Helium-cooled
  - Passive heat removal
  - No active electrical power to perform required safety functions





# Xe-100 PDC Approach and Overview

- Xe-100 PDCs are based on MHTGR-DCs (Appendix C of RG 1.232)
  - Xe-100 and MHTGR substantially similar
  - Some PDCs modify MHTGR-DCs to reflect Xe-100
- Xe-100 PDCs are also based on the LMP implementation
  - Risk-informed and performance-based approach
  - Required safety functions (RSFs), required functional design criteria (RFDC), probabilistic risk assessment (PRA) safety functions (PSFs), and complementary design criteria (CDC)
  - Terminologies based on the LMP
- The NRC staff's review used applicable regulatory guidance, mainly RGs 1.232 and 1.233 as applied to PDCs.
  - Evaluate deviations from RG 1.232 in consideration of the key Xe-100 design features and the LMP implementation

# General Changes to PDCs

- Staff review focus: Key differences between the Xe-100 PDCs and the MHTGR-DCs including:
  - Use of the term “safety-significant”
  - Scope of licensing basis events (LBEs) in PDCs
  - Single PDC for monitoring, testing, inspection, and surveillance of safety-significant SSCs
  - PDC 26, “Reactivity control systems”
  - PDC 34, “Residual heat removal”

# Use of the term “safety-significant”

- Replace “important to safety” from RG 1.232 with “safety-significant” to align with language from NEI 18-04
- RG 1.233: “Applicants referencing this RG are expected to use the terminology in NEI 18-04”
- Advanced Reactor Content of Application Project (ARCAP) DANU-ISG-2022-01, “Review of Risk-Informed, Technology-Inclusive Advanced Reactor Applications—Roadmap” (ML23277A139) identified that some SSCs may be “important to safety” but not “safety-significant” per NEI 18-04 process
  - No gap because of use of RG 1.232

# Scope of LBEs for the Proposed PDCs

- X-energy replaces the terms such as ‘postulated accident’ or ‘accident conditions’ used in MHTGR-DCs in RG 1.232 with those describing LBEs* used in NEI 18-04.
- BDBEs are not included in the scope of the Xe-100 PDCs based on the current design and analysis.
- RG 1.253 provides guidance on scope of PDCs for LMP-based applications. Proposed PDCs need to address the functions provided by both safety-related (SR) and NSRST SSCs.
- Xe-100 design is preliminary and implementation of the LMP process is in progress. Proposed PDCs may not represent a full set of PDCs for all SSCs that are safety-significant. The NRC staff proposes a Limitation/Condition (item (1)).

*Anticipated Operational Occurrences(AOOs), Design Basis events (DBEs), Beyond Design Basis Events (BDBEs), and Design Basis Accidents (DBAs)

# PDCs for normal operations and use of Owner Controlled Design Criteria (OCDCs)

- X-energy's proposed PDCs (i.e., 2, 4, 10, 13, 15, 19, 22, 26, 34, 44, 60, 61, and 64) include criteria associated with normal operations or conditions.
- X-energy uses OCDCs to designate design criteria for NST SSCs that are not required to be met during AOOs, DBEs, or DBAs.
  - NST SSCs are not classified as safety-significant SSCs according to the LMP process.
  - OCDCs are not part of the Xe-100 design bases scope
- Use of OCDCs for design criteria that correspond to NST SSCs distinguishes OCDCs from PDCs (RFDCs and CDCs) that correspond to SR and NSRST SSCs.

# Replacement of single-failure criterion with reliability criterion

- PDCs 17, 34, and 44 do not use the single-failure criterion language in RG 1.232.
- X-energy is using the approach described in NEI 18-04 as endorsed by RG 1.233.
  - Commission approval in SRM-SECY-03-0047
- The NEI 18-04 methodology subjects the design to a reliability criterion (e.g., a reliability target) and to an evaluation of defense-in-depth (DID) adequacy based on assessments of event sequences.

# PDC 16: Use of functional containment concept

- PDC 16 uses the language of MHTGR-DC 16 with changes.
  - PDC-RFDC 16 for barriers in fuel particles and pebbles for DBEs and DBAs.
  - PDC-CDC 16 for a barrier of the helium pressure boundary for AOOs.
- Additionally, replaces “design conditions important to safety” with “design limit” to clearly articulate that a design limit related to the functional containment exists and cannot be exceeded.
- Meets the intent of MHTGR-DC 16 in RG 1.232.
  - The Commission approved the use of functional containment concept in Staff Requirements Memorandum (SRM) to SECY-18-0096.

# PDC 6, “Monitoring, Inspection, Testing, Surveillance”

- X-energy proposes PDC 6 as a single criterion for monitoring, testing, inspection, and surveillance of safety-significant SSCs.
  - Subsumes MHTGR-DCs 18, 31, 36, 37, 45, and 46
- Meets the underlying intent of the related MHTGR-DCs in RG 1.232.
  - Scope of activities consistent with those that would be required by the subsumed MHTGR-DCs
  - Broadly applicable to all safety-significant SSCs (i.e., SR and NSRST SSCs)

# PDC 11, “Reactor inherent protection”

- Meets the intent of MHTGR-DCs 11 and 12
- Also provides for one of the two means to meet the intent of MHTGR-DC 26 (“adequately control heat generation”)
- Sufficient negative reactivity feedback ensures fuel performance and radionuclide release limits are not exceeded for DBEs and DBAs, and that specified acceptable system radionuclide release design limits (SARRDLs) are not exceeded for AOOs
- Condition/Limitation 2: The “in the power operating range” phrase is expanded to ensure that safety analyses include the full scope of the power operating range, DBE, and DBA conditions

# PDC 14, “Reactor helium pressure boundary”

- Integrity and testing considerations are removed from corresponding MHTGR-DC 14.
  - Covered by PDC 70 and PDC 6, respectively.
- “Ingress of moisture, air, secondary coolant, or other fluids” is replaced with “moisture ingress.”
  - No risk-significant AOOs, DBEs, or DBAs with unacceptable ingress of air or other fluids. (Limitation/Condition item 3 applies)
  - “Moisture” encompasses the secondary coolant (water).

# PDC 26, “Reactivity control systems”

- The independent and diverse means are control rods (means 1) and inherent reactivity feedback (means 2)
- Control rods insert and maintain safe shutdown for DBEs and DBAs (RFDC)
- Independent and diverse means ensure SARRDLs and HPB limits are not exceeded, and safe shutdown is achieved and maintained for AOOs (CDC) and normal operations (OCDC)
- Means to support shutdown interventions: Included verbatim from MHTGR-DC 26 paragraph 4 (PDC)
- Further supported by PDC-RFDC 11 (core cooling/heat generation)
- All underlying intents of MHTGR-DC 26 are covered
- Specific design features are not being approved in this SE.

# PDC 34, “Residual heat removal”

- Passive system for decay heat removal (DHR) to ensure fuel and radionuclide release limits are met for DBEs and DBAs (RFDC)
- Active means to ensure DHR and residual heat are removed such that SARRDLs are not exceeded for AOOs (CDC) and normal operations (OCDC)
  - The function of the HPB to maintain core geometry is covered in PDC 70
- All aspects of MHTGR-DC 34 are covered

# PDC 70, “Reactor vessel and reactor system structural design basis”

- HPB and core internals support reactor integrity and low probability of rapidly propagating failure during DBEs and DBAs.
  - Supports PDC 14.
- Ensure geometry for passive heat removal of residual heat.
  - Supports PDC 34.
- Permit insertion of neutron absorbers and maintain reactor inherent protection.
  - Further bolsters PDCs 11 and 26.
- All aspects of MHTGR-DC 70 covered.

# Proposed Limitations and Conditions

(1) X-energy is requesting approval for the proposed PDCs based on a preliminary design and the LMP implementation at the time of the topical report submittal. Xe-100 design changes and associated LMP implementation could necessitate a revision to the proposed PDCs described in the TR. Therefore, future licensing applicants referencing the topical report must confirm that the PDCs in this topical report remain appropriate for its design. In addition, if additional or revised PDCs are identified that are not within the scope of what is approved in this topical report, those PDCs will be subject to further NRC staff review.

(2) For PDC-RFDC 11, X-energy used the words “in the power operating range”. This phrase has the potential to complicate the applicability of PDC-RFDC 11 to the scope of MHTGR-DC 12. Power oscillations or reactivity upsets that may occur outside the power operating range should be assessed. Accordingly, the NRC staff conditions the acceptance of PDC-RFDC 11 on confirmation by future licensing applicants referencing this topical report that applicable safety analyses cover the full scope of the operating range, DBE, and DBA conditions for the final design.

(3) For PDC 14, X-energy is proposing to delete the words “ingress of air, secondary coolant, or other fluids” from MHTGR-DC 14 and replace it with the words “moisture ingress”. For justification, X-energy states that “no risk significant AOOs, DBEs, or DBAs were identified with unacceptable ingress of air or other fluids”. This cannot be verified at the present state of the Xe-100 design. Accordingly, the NRC staff conditions the acceptance of this PDC on the NRC staff’s review of AOOs, DBEs, and DBAs as part of a future license application referencing this topical report.

# Conclusion

- X-energy has provided a reasonable set of PDCs that are appropriate for establishing requirements for the Xe-100 design consistent with the intent of RG 1.232 and the LMP guidance.
- Subject to these limitations and conditions, these PDCs establish the necessary design, fabrication, construction, testing, and performance design criteria for safety-significant SSCs to provide reasonable assurance that the Xe-100 design could be operated without undue risk to the health and safety of the public.
- Revision 3 is therefore suitable for referencing in future licensing applications under 10 CFR Parts 50 and 52 for the Xe-100 design.

# Abbreviations

ARDC – advanced reactor design criteria

BDBE – beyond design basis event

CFR – *Code of Federal Regulations*

CP – construction permit

DANU - Division of Advanced Reactors and Non-Power Production and Utilization Facilities

DC – design criterion

DBA – design basis accident

DBE – design basis event

GDC – general design criterion

HPB – helium pressure boundary

L&C – limitation and/or condition

LWR – light-water reactor

MHTGR – modular high temperature gas reactor

NEI – Nuclear Energy Institute

NRR - Office of Nuclear Reactor Regulation

NSRST – non-safety related with special treatment

NST – non-safety related with no special treatment

OCDC – Owner Controlled Design Criterion

PDC – principal design criterion

PSAR – preliminary safety analysis report

QA – quality assurance

RG – Regulatory Guide

SAFDL – Specified acceptable fuel design limit

SARRDL – Specified acceptable system radionuclide release design limit

SSC – structure, system, or component

SE – safety evaluation

SR – safety-related

# References

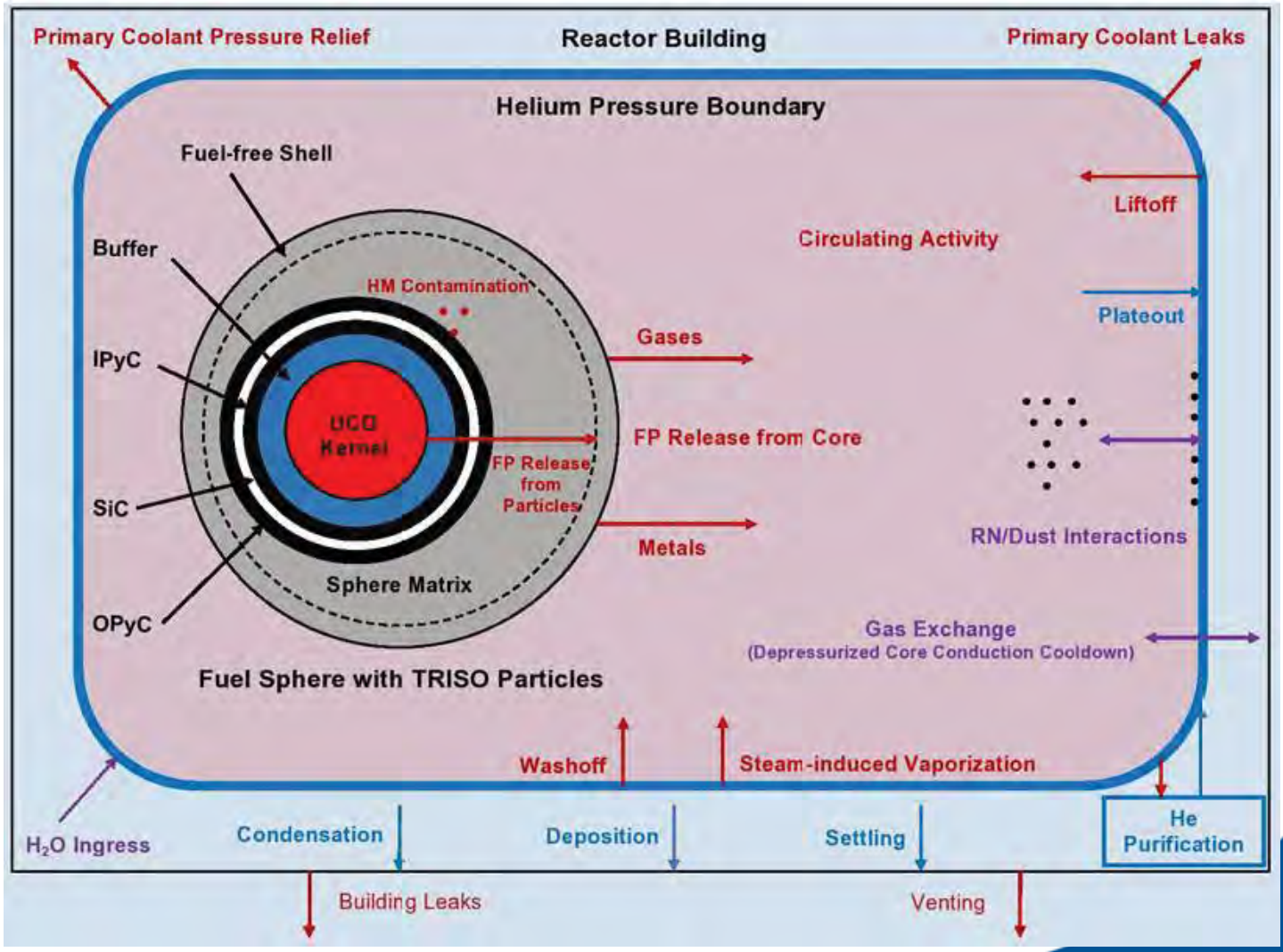

- RG 1.232, “Guidance for Developing Principal Design Criteria for Non-Light Water Reactors” (ML17325A611)
- RG 1.233, “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors” (ML20091L698)
- RG 1.253, “Guidance for a Technology-Inclusive Content of Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors,” (ML23269A222)
- NEI 21-07, “Technology Inclusive Guidance for Non-Light Water Reactors – Safety Analysis Report: For Applications Utilizing the NEI 18-04 Methodology,” Revision 1 (ML22060A190).
- NEI 18-04, Revision 1, “Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development” (ML22060A190)
- SECY-18-0096, “Functional Containment Performance Criteria For Non-Light-Water-Reactors” (ML18115A157)
- SECY-03-0047, “Policy Issues Related to Licensing Non-Light-Water Reactor Designs” (ML030160002)
- DANU-ISG-2022-01, “Review of Risk-Informed, Technology-Inclusive Advanced Reactor Applications—Roadmap” (ML23277A139)

# MHTGR

- The standard MHTGR consists of four identical reactor modules, each with a thermal output of 350 MWt, coupled with two steam turbine-generator sets to produce a total plant electrical output of 540 MWe. The reactors are helium cooled and graphite moderated and utilize ceramically coated particle type nuclear fuel. The design includes passive reactor-shutdown and decay-heat removal features.
- The MHTGR reference configuration was established by DOE after tradeoff evaluations that indicated the selection of (1) "prismatic" fuel blocks over “pebble-bed” spheres; (2) steel primary-system vessels over PCRVs; (3) modular-sized reactors over a larger, single reactor; and (4) separation of the reactor from the remainder of the primary-system components in a side-by-side design rather than the containment of all components "in-line" within a single vessel.

# Xe-100 Functional Containment

- (SECY-18-0096) Functional containment: “a barrier, or a set of barriers taken together, that effectively limits the physical transport of radioactive material to the environment.”
- Relevant phenomena are modeled mechanistically
- Multiple barriers between the UCO kernel and receptors of Interest
- X-energy’s XSTERM code is a suite of modules that model these phenomena in an integration manner
- Informed by RG 1.233 / NEI 18-04 implementation



# Xe-100 Principal Design Criteria (PDC) Licensing Topical Report (LTR)

Steve Vaughn, Director, Licensing

Kyle Metzroth, Deputy Director, Xe-100 Systems Development

X Energy, LLC

August 21, 2024

# Department of Energy Acknowledgement and Disclaimer

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# Agenda & Objectives

**Agenda:**

- Introductions/Opening Remarks
- Xe-100 PDC Development Process
- Xe-100 PDC:
  - General differences from RG 1.232
  - Example PDC Implementing the NEI 18-04 Methodology
- Questions/Closing Remarks

**Objectives:**

- Accurately communicate:
  - The Xe-100 PDC development process
  - General differences from RG 1.232 guidance
  - Example Xe-100 PDC that implement the NEI 18-04 methodology
- Respond to questions and comments from the ACRS Sub-committee

# Xe-100 PDC Development Process

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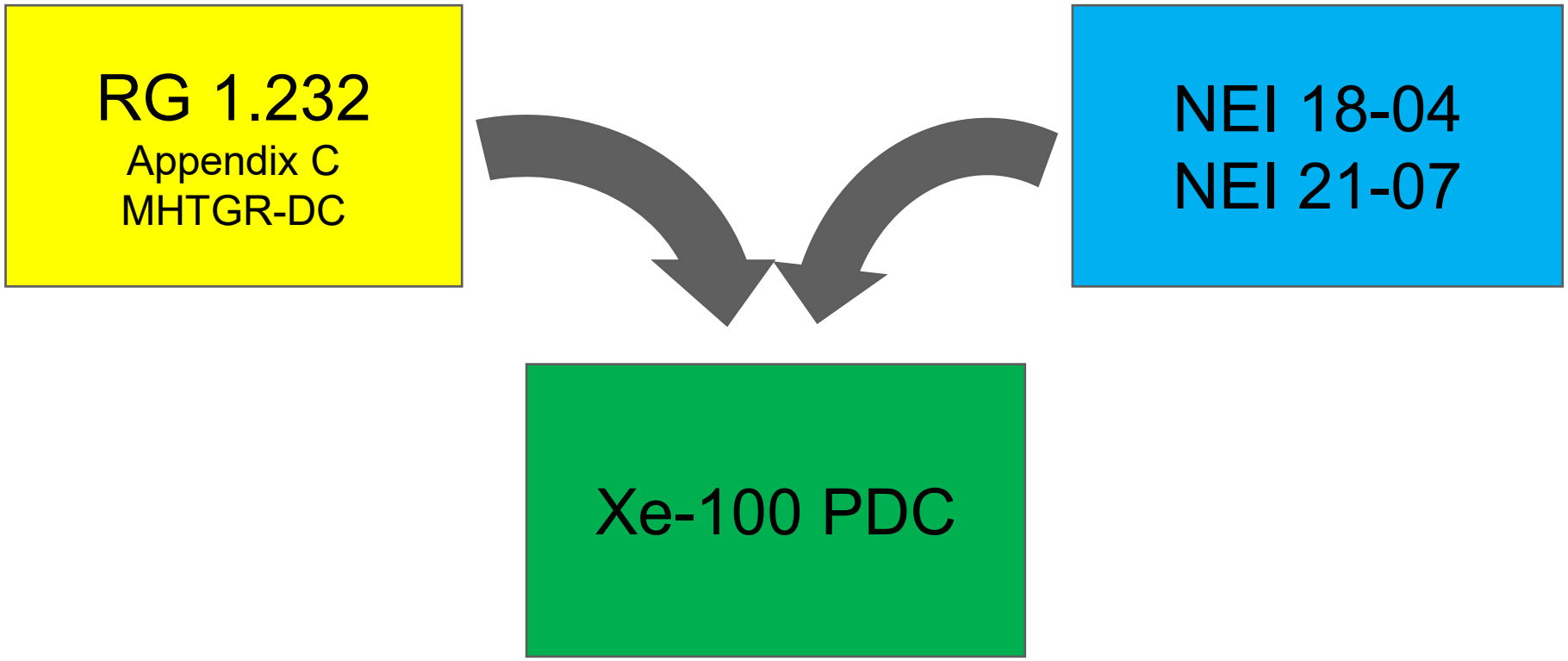
# Xe-100 PDC Development Process

- The Xe-100 PDC LTR is developed based on the following:
  - RG 1.232 “Guidance for Developing Principal Design Criteria for Non-LWRs”
  - NEI 21-07 and RG 1.253 “Guidance for a Technology-Inclusive Content of Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors”
  - DANU-ISG-2022-01 “Review of Risk-Informed, Technology-Inclusive Advanced Reactor Applications—Roadmap”
  - Xe-100 implementation of the NEI 18-04 Methodology
    - *Xe-100 Required Safety Functions and PRA Safety Functions, Revision 5 (001279)*

# Xe-100 PDC Development Process



# Xe-100 PDC Development Process

- Added some definitions to expand on the NEI 18-04 terminology:

| Function | Design Criteria |
|---|---|
| Required Safety Function (RSF) | Required Functional Design Criteria (RFDC)<br>Safety-Related Design Criteria (SRDC) |
| Non-Safety-Related with Special Treatment (NSRST) PRA Safety Function (PSF) | Complementary Design Criteria (CDC) |
| Non-Safety-Related with No Special Treatment (NST) PSF | Owner-Controlled Design Criteria (OCDC) |

# Xe-100 PDC:
# General Differences from RG 1.232

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# Xe-100 PDC | General Differences from RG 1.232

- Replaced “important to safety” with the NEI 18-04 definition of “safety-significant”
- Removed “single failure criterion” given NEI 18-04 leverages the defense-in-depth (DID) evaluation approach
- Replaced “postulated accident” and “accident conditions” with NEI 18-04 defined licensing basis event (LBE) terms (e.g., AOO, DBE, and DBA)
- Combined the language from MHTGR-DC 18, 32, 36, 37, 45, 46, and 72 into a single Xe-100 PDC 6 “*Monitoring, inspection, testing, surveillance*”

# Xe-100 PDC: Example PDC Implementing the NEI 18-04 Methodology

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# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- Combined PDC 11 "*Reactor inherent protection*" and PDC 12 "*Suppression of reactor power oscillations*" and decomposed a PDC-RFDC 11 and PDC-CDC 11
- PDC-RFDC 11 is one of the two means for supporting PDC-RFDC 26 "*Reactivity control systems*"
- Aligns with RSF 1.1.1 "Control Reactivity with Inherent Reactivity Feedback"

| Title: | *11. Reactor inherent protection* |
|---|---|
| Xe-100 PDC RFDC | The reactor core and associated systems shall be designed with sufficient negative reactivity feedback characteristics such that, in the power operating range, the net effect compensates for a rapid increase in reactivity, adequately controls heat generation, and ensures fuel performance and radionuclide release limits are not exceeded during design basis events or design basis accidents. |
| Xe-100 PDC CDC | The reactor core and associated systems shall be designed with sufficient negative reactivity feedback characteristics such that, in the power operating range, the net effect compensates for a rapid increase in reactivity, adequately controls heat generation, and ensures that specified acceptable radionuclide release design limits are not exceeded during anticipated operational occurrences. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC 13 "*Instrumentation and control*" contains RFDC, CDC, and OCDC
- PDC-RFDC 13 aligns with RSF 1.1.2 "Control Reactivity with Moveable Poisons" and RSF 1.3.1 "Isolate Water/Steam Ingress"
- PDC-CDC 13 aligns with NSRST PSF 1.1.2 "Control Reactivity with Moveable Poisons", NSRST PSF 1.2.2 "Control Heat Removal with Active Means", and NSRST PSF 2.5 "Maintain HPB Pressure Integrity During Transients"

| Title: | *13. Instrumentation and control* |
|---|---|
| Xe-100 PDC<br>RFDC<br>CDC<br>OCDC | Instrumentation shall be designed to monitor variables and systems over their anticipated ranges for normal operation and during anticipated operational occurrences, design basis events, and design basis accidents, as appropriate, to support and provide indication of the functions performed by safety-significant structures, systems, and components, including those variables and systems that can affect the fission process and the integrity of the reactor core, reactor helium pressure boundary, and functional containment. Appropriate controls shall be designed to maintain these variables and systems within prescribed operating ranges. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC-CDC 15 clarifies that the HPB design does not provide an RSF and therefore aligns with CDC not RFDC
- Aligns with NSRST PSF 2.7 “Prevent Loss of HPB Integrity”

| Title: | *15. Reactor helium pressure boundary design* |
|---|---|
| Xe-100 PDC CDC | Safety-significant structures, systems, and components that are part of the reactor helium pressure boundary shall be designed with sufficient margin to ensure that the design conditions of the reactor helium pressure boundary are not exceeded during normal operations and anticipated operational occurrences. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC-RFDC 16 describes the functional containment provided by the fuel particles and pebbles and PDC-CDC 16 describes the functional containment provided by the HPB
- Aligns with RSF 1 “Retain Radionuclides in Fuel Particles and Pebbles” and NSRST PSF 2 “Retain Radionuclides in the HPB”

| Title: | *16. Functional containment design* |
|---|---|
| Xe-100 PDC RFDC | The design of the reactor fuel particles and pebbles shall provide barriers as part of the reactor functional containment to control the release of radioactivity to the environment to ensure that the functional containment design limit is not exceeded during design basis events and design basis accidents. |
| Xe-100 PDC CDC | The design of the helium pressure boundary shall provide a barrier as part of the reactor functional containment to control the release of radioactivity to the environment to ensure that the functional containment design limit is not exceeded during anticipated operational occurrences. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC 26 "*Reactivity control systems*" contains RFDC, CDC, OCDC, and PDC
- PDC-RFDC and PDC-CDC aligns with the "Control Reactivity with Moveable Poisons" RSF and NSRST PSF respectively

| Title: | *26. Reactivity control systems* |
|---|---|
| Xe-100 PDC RFDC | The reactor shall be designed to provide movable poisons that can insert and maintain safe shutdown during design basis events and design basis accidents. |
| Xe-100 PDC CDC | The reactor shall be designed with a means, which is independent and diverse from the reactivity control systems required functional design criteria, to insert negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the specified acceptable system radionuclide release design limits and the helium pressure boundary design limits are not exceeded, and safe shutdown is achieved and maintained during anticipated operational occurrences. |
| Xe-100 PDC OCDC | The reactor shall be designed with a means, which is independent and diverse from the reactivity control systems required functional design criteria, to insert negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the specified acceptable system radionuclide release design limits and the helium pressure boundary design limits are not exceeded during normal operations. |
| Xe-100 PDC | A means for holding the reactor shutdown under conditions that allow for interventions such as fuel loading, inspection, and repair shall be provided. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC-RFDC 30 is focused on mitigating a steam generator tube rupture DBE and DBA and PDC-CDC 30 is focused on preventing helium leakage during AOOs
- PDC-RFDC 30 aligns with RSF1.3.1, “Isolate Water/Steam Source” and PDC-CDC 30 aligns with NSRST PSF 2.5, “Maintain HPB Pressure Integrity During Transients”

| Title: | *30. Integrity of reactor helium pressure boundary* |
|---|---|
| Xe-100 PDC RFDC | The reactor shall be designed to detect moisture ingress within the helium pressure boundary and automatically isolate the source of moisture ingress during design basis events and design basis accidents. |
| Xe-100 PDC CDC | The reactor shall be designed to detect and, to the extent practical, identify and isolate the source of reactor helium leakage during anticipated operational occurrences. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC-RFDC 34 "*Residual heat removal*" provides a passive heat removal function while the PDC-CDC and PDC-OCDC provide an active heat removal function
- PDC-RFDC 34 aligns with RSF 1.2.1, "Control Heat Removal Through Passive Means" and PDC-CDC 34 aligns with NSRST PSF 1.2.2, "Control Heat Removal with Active Means"

| Title: | *34. Residual heat removal* |
|---|---|
| Xe-100 PDC RFDC | A passive means to remove residual heat shall be designed to provide effective heat removal to ensure that fuel and radionuclide release limits are not exceeded during design basis events and design basis accidents. |
| Xe-100 PDC CDC | An active means shall be designed to transfer fission product decay heat and other residual heat from the reactor core to an ultimate heat sink at a rate such that specified acceptable system radionuclide release design limits are not exceeded during anticipated operational occurrences. |
| Xe-100 PDC OCDC | An active means shall be designed to transfer fission product decay heat and other residual heat from the reactor core such that specified acceptable system radionuclide release design limits are not exceeded during normal operations. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC-RFDC 70 "*Reactor vessel and reactor system structural design basis*" supports maintaining core geometry for passive heat removal and controlling reactivity
- PDC-RFDC 70 aligns with RSF 1.4.1, "Maintain HPB and Core Geometry"

| Title: | *70. Reactor vessel and reactor system structural design basis* |
|---|---|
| Xe-100 PDC RFDC | The helium pressure boundary and core internal structures shall be designed such that the reactor vessel and reactor system integrity is maintained and that there is a low probability of rapidly propagating failure during design basis events and design basis accidents to (1) ensure the geometry for passive removal of residual heat from the reactor core to the ultimate heat sink and (2) permit sufficient insertion of the neutron absorbers and maintain reactor inherent protection to provide for reactor shutdown. |

# Example Xe-100 PDC Implementing the NEI 18-04 Methodology

- PDC-RFDC 71 "*Reactor building design basis*" structurally protects the reactor vessel and reactor system in support of maintaining core geometry for passive heat removal and controlling reactivity
- PDC-RFDC 71 aligns with RSF 1.4.2, "Maintain Reactor Building Geometry"

| Title: | *71. Reactor building design basis* |
|---|---|
| Xe-100 PDC RFDC | The reactor building shall be designed such that it structurally protects the reactor vessel and reactor system geometry during design basis events and design basis accidents to ensure passive removal of residual heat from the reactor core to the ultimate heat sink and permit sufficient insertion of the neutron absorbers and maintain reactor inherent protection to provide for reactor shutdown. |

# End of Presentation

## Questions and Closing Remarks