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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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ACCIDENT ANALYSIS AND THERMAL-HYDRAULIC SUBCOMMITTEE

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MONDAY

NOVEMBER 2, 2020

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The Subcommittee met via Teleconference, at 9:30 a.m. EST, Jose March-Leuba, Chairman, presiding.

COMMITTEE MEMBERS:

JOSE MARCH-LEUBA, Chairman

RONALD G. BALLINGER, Member

DENNIS BLEY, Member

CHARLES H. BROWN, JR. Member

VESNA B. DIMITRIJEVIC, Member

WALTER L. KIRCHNER, Member

DAVID A. PETTI, Member

JOY L. REMPE, Member

PETER RICCARDELLA, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANTS:

MICHAEL L. CORRADINI

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

ZENA ABDULLAHI

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

9:30 a.m.

CHAIRMAN MARCH-LEUBA: The meeting will now come to order. This is a meeting of the ACRS Accident Analysis and Thermal-Hydraulics Committee.

I am Jose March-Leuba, the ACRS Chairman. Because of COVID-19 concerns, this meeting is being conducted remotely.

I see the following ACRS in attendance. Ron Ballinger, Dennis Bley, Charles Brown, Vesna Dimitrijevic, David Petti, Joy Rempe, Pete Riccardella, Matt Sunseri. I also know that our consultants, Mike Corradini and Steve Schultz are also present.

Today's topic is Topical Report NEDC-33912P, BWRX-300 Reactivity Control. This topical report defines the criteria that we'll be using a future submittal to ensure that BWRX-300 reactivity controls satisfy all applicable regulations.

Portions of our meeting will be closed to the public to protect proprietary information. We will have an opportunity for public comments before we start the closed session of the meeting.

The ACRS was established by a statute and governed by the Federal Advisory Committee Act, FACA.

As such, the Committee can only speak through its published reports.

The ACRS section of the U.S. NRC public website provides our chapter, bylaws, agendas, letter, reports and full transcripts for the opened portions of all full and subcommittee meetings. Including the slides presented there.

The Designated Federal Official today is Zena Abdullahi. A transcript of the meeting is being kept, therefore speak into the microphones clearly and state your name for the benefit of the court reporter.

Please keep the microphone on mute when not being used. And don't use video feed to minimize bandwidth problems.

We are expected to have a full committee meeting on this topic in December. At this point, I would like to give the floor to GEH and start your presentation. George, you're on.

MR. WADKINS: Good morning. My name is George Wadkins and I am the Vice-president, New Power Plants and Products Licensing for GE Hitachi.

Today, GE Hitachi will be presenting an overview of the BWRX-300 small modular reactor design with the description that the content for licensing Topical Report NEDC-33912P BWRX-300 reactivity

control.

We will be describing design requirements, acceptance criteria and regulatory basis for the BWRX-300 reactor protection system, or RPS, and other associated means of reactivity control.

As noted in our previous discussions with the ACRS Members, the BWRX-300 builds upon our extensive experience in boiling water reactor technology. Including our most recent experiences in development and certification of the economically simple boiling water reactor or ESBWR.

The BWRX-300 design leverages the use of proven technology to the greatest extent possible while incorporating advances and design requirements and features to further enhance nuclear safety and to provide for the protection of the public in the unlikely event of an accident.

I first want to thank the NRC Staff for their in-depth professional review of this licensing topical report. The interactions with the NRC Staff were extremely useful in ensuring that the content of the licensing topical report was complete, understandable, accurate and met the applicable regulatory requirements and guidance.

I look forward to continuing these

interactions with the NRC Staff during this ACRS Subcommittee review and the future ACRS Full Committee review plan for December of this year.

As previously requested by the ACRS, we are providing for an extensive open session discussion of the content of this licensing topical report, but also have a planned presentation for a closed session later in this meeting.

During our presentation we will pause at the end of each slide to allow for questions from the ACRS Member, but please feel free to raise questions at any time. If the discussions involve proprietary information, then we will request saving the question until the latter closed session.

CHAIRMAN MARCH-LEUBA: So, let me take advantage of the break and thank you for making such an extensive open session presentation. Obviously, it was very good.

And also, know that Member Walter Kirchner has also joined us. Go ahead.

MEMBER REMPE: Jose, this is Joy.

CHAIRMAN MARCH-LEUBA: Yes, Joy.

MEMBER REMPE: Can I ask a question about schedule? When I was reviewing this material I became aware of the fact that the information in section 4.1

of the LTR we were given is going to change a lot based on the response to an RAI.

When will we see, will we see that updated version of the LTR before the December meeting?

CHAIRMAN MARCH-LEUBA: I'm going to let the Staff probably handle that, but the process is, notifications that are proved on the RAI, are committed to an RAI, is getting incorporated in the dash A approved version.

So, the Staff, can somebody from the Staff handle this question?

MS. FRANOVICH: This is Rani Franovich, the project manager for GEH. I just want to make sure I understand the question.

Is the question, will the ACRS Members have an opportunity to review the RAIs and the RAI responses?

MEMBER REMPE: No, we did see that. And in this case, yes, if it's a small change, yes, we don't usually see it unless, like Jose said, it's just assumed it's going to happen.

But it's a substantial difference and I just was wondering, is that going to be the Staff's approach this time, will GE provide an updated version that incorporates this change?

It's in Section 4.1. And I don't want to get into a lot of the details of the change, but it's basically a description of this second independent reactivity control system.

And to me that's a, it's quite a bit of a difference and I just am wondering, are we going to see this update at all or is the plan just wait and they're going to send an updated version based on this response and that's it.

MS. FRANOVICH: Okay. Thank you for that clarification.

If I could suggest that we cover that when the Staff has its turn to present to the ACRS, we'll address it at that time.

MEMBER REMPE: Okay, that sounds fine. Thank you.

MS. FRANOVICH: Thank you. George, back to you.

MR. WADKINS: Okay, thank you, Rani. So, proceeding on to Slide 2.

Slide 2 shows the agenda for today's open session presentation. This includes the purpose and scope of the licensing topical report, a discussion of the defense-in-depth strategy forming the basis of the safety assessment framework for the BWRX-300 and those

related defense-in-depth design features applicable to the reactivity control fundamental safety function.

We will also discuss a summary of the design features related to the BWRX-300 reactivity control fundamental safety functions for events requiring use of reactivity control measures for ensuring safety. And we will discuss the regulatory evaluations in demonstrating compliance with the NRC regulatory requirements and conform to NRC regulatory guidance.

So, proceeding to Slide 4. Slide 4 and 5 will describe the purpose and scope of the licensing topical report, which includes the design requirements, acceptance criteria and regulatory basis for the BWRX-300 reactivity control design functions.

The BWRX-300 has various means of reactivity control. These design functions will be addressed in the LTR by specifying design requirements for the reactor protection system, or RPS, to ensure regulatory requirements are met, specific design requirements for other means of reactor shutdown necessary to ensure that defense-in-depth diversity requirements are met, specified design requirements for other functions, such as alternate rod insertion to ensure the hydraulics scram meets reliability

requirements.

We will discuss the BWRX-300 acceptance criteria and associated mitigating strategy in response to an anticipated transient without scram, or ATWS, as evaluated against the requirements of 10 CFR 50.62. And we will describe compliance with the requirements of 10 CFR 50 Appendix in the GDCs 12, 20, 21, 22, 23, 24, 25, 26, 28 and 29.

We will also describe our regulatory approach for General Design Criteria 27 where we have specified a principle design criteria due to the language of that GDC and how our design approaches these additional means of reactor shutdown.

And additionally, as we look at Slide 5, we will discuss the BWRX-300 mitigating systems associated with an ATWS event, anticipated transient without scram. We will specify design requirements for systems to control reactor pressure during an ATWS event.

We will specify design requirements for additional means of reactor shutdown. In the case of failure of all means of hydraulic insertion of the control rods.

And we will specify the BWRX-300 acceptance criteria and associated mitigating strategy

in response to an ATWS as evaluated against the requirements of 10 CFR 50.62. Are there any questions on the LTR purpose and scope?

CHAIRMAN MARCH-LEUBA: No.

MR. WADKINS: Okay. I will now turn over the presentation to David Hinds, principle design engineer for the BWRX-300. He will continue describing the non-proprietary contents and conclusions of the licensing topical report.

Assisting David, when necessary to answer questions, maybe Lou Lanese, the GEH senior licensing engineer for this licensing topical report, and Charlie Heck, GEH senior consulting engineering, responsible for safety and transient analysis. So, I'll turn it over to David.

MR. HINDS: Okay, thank you. Good morning. So this is David Hinds.

As was stated a minute ago, I'll just reinforce that we have two slide materials. One for the open session, one for closed session. So, dependent upon the way the questions and discussion go, we may need to defer some topics over to the second session.

In this material we covered, I think, most every area but it sometimes is not quite as detailed

as maybe required. And so, if there is detailed questions we'll likely ask to defer them.

Okay. So, the first area, just to give a feel for their GEH design approach we've taken for BWRX-300, not only in this area but across the board, but the slides are focused upon the results obtained in this area.

In the area of our defense-in-depth type of design approach. And it's especially pertinent to this topical area to ensure that the means for reactor control and reactivity shut, or reactor shutdown, are maintained and in a defensive type posture of defense-in-depth.

So, the next slides we'll be walking through will show some of the ways we've laid that out. And we use terminology that comes from the principles developed through the IAEA. So these next few slides use some of that language.

We applied defense-in-depth approach. It is aligned with the IAEA principles. We have done some customizing within GEH to develop our process specific to align to that type of approach.

We find it very useful to rigorously work our design and our design team through a defensive layer to ensure that the fundamental safety functions

are maintained with more than one layer. In fact, at least two layers for each postulated initiating event. In some cases we've even had more than two layers in place.

So, we evaluate each one of the postulated initiating events. We used the fundamental safety functions. And we assign functions within the design that mitigate in multiple layers.

And we ensure those functions when the design is implemented or have the appropriate independence within the design process. So, again, this LTR is focused on that fundamental safety function of reactivity control.

Go to the next slide please. Okay. All right, so, the first defense line, within the IAEA terminology is, we've got Defense Line 1, which it really amounts to design approaches and fundamentals within the design to reduce challenges to the reactor protection system, reduce challenges to overall reactivity control.

Some of them result in fewer trips per year, so we add reliability features to the plant to minimize the number of trips and the number of challenges to the plant. So, fundamentals begin from those basic approaches.

We strengthen the, all the defense lines through high-quality, reliability conservatisms. So, the Defense Line 1 is a way that we do our design and the fundamentals that apply across the board as opposed to actual physical systems.

If you could go to the next slide. Okay, so some of the examples of some of these fundamentals that result in added safety to the plant are, and of course they're common to other reactor designs as well and our past designs.

Of course, technical specifications control the operational controls. We've made many design choices, and I list some of them here.

And we have N-Lattice core makes the gap between the control rod, the fuel bundles, where the control rods ride to have less probability of rod binding taken into account. Considerations such as channel bow and potential for degradation or movement in the shape of the fuel channels over the life of the core.

And we ensure that we have margins to ensure that we did not create a binding situation. Those are types of approaches that apply to reactivity control.

Normal power changes are with control rods

in this plant. This is a natural circulating power plant so therefore we do not use recirculating pumps to change core flow, and therefore change reactor power. Like some of the, rest of the BWR fleet.

So therefore we are constantly, on a daily basis, ensuring the control rods are moving appropriately and controlling the reactor appropriate so therefore no surprises in that, a hidden malfunction in the control ride drive system. And that that's the normal means for power change.

We incorporate many reliability features within all of the systems design, with a heavy focus on these associated reactor safety.

I alluded to, and I think you are already aware, that this design uses the fine motion control rod drives, which we have experience with through the ABWR fleet development. And we continue to develop through our ESBWR development. And now are carrying forward to BWRX-300.

We'll continue to speak more about the design features here in some of the subsequent slides. But the fine motion control rod drives do, that design choice does aid in the reliability of the reactor control fundamental safety function.

Okay. Next slide.

CHAIRMAN MARCH-LEUBA: I assume you have some experience with, because this control rod motion, continuous control rod motion to compensate for burn-up, what, control areas where there are recirculation pumps, let's see, what do, plays more strain on the fuel, I'm thinking PCI interactions, better planning?

MR. HINDS: So, a couple of comments on that. This core, and again, in this Defense Line 1 area it's design decisions, and you've alluded to another.

So, we made design decisions to intentionally re-limit the power density of this plant. So, we've made design choices on core design to not push it to achieve all the power that we could potentially achieve out of the core of this size.

So, limiting the power density, making design decisions on the actual fuel load. And the number of fuel bundles, we did optioneering, we called it, of how many fuel bundles would this core contain.

Our final selection was, much of it was based upon ensuring that we limit fuel duty. So, we have looked heavily at fuel duty and mechanisms such as PCI.

So, do not think it's going to be a problem, in brief summary. Some other --

CHAIRMAN MARCH-LEUBA: And you're not --

MR. HINDS: Yes.

CHAIRMAN MARCH-LEUBA: You're not already planning for a power uprate, are you?

MR. HINDS: No, we're not.

CHAIRMAN MARCH-LEUBA: Not yet.

MR. HINDS: Our intention is, that we selected the appropriate power level for this plant. And that was part of our optioneering.

But we did it, again, in a very conservative fashion knowing that control rods are the normal means of maneuvering the plant. And so, we did limit our priorities.

But no, we did not plan for a power uprate.

CHAIRMAN MARCH-LEUBA: Okay, thank you.

MR. HINDS: Okay. So, other design choices we've made that help with the conservatism and safety of the plant, of course, seismic qualification. This is all design with a high seismic margin.

I mentioned the FMCRDs. We did have the operating experience with ABWR, continued to design the experience with ESBWR.

Control rod blades, we have extensive experience through the operating fleets that we

understand all the details of their behavior and the way to manufacturer.

And so we've been through generations of control rod blades. And we carry that forward to the BWRX-300.

And I think we've mentioned it in one of our prior meetings, but we are using the same fuel and control rod blades that we've been advancing through our operating fleet. So the length of the fuel bundle is our standard GNF2 fuel and therefore the standard control rod blade. So therefore it's not a first of a kind development that we bring with it some sort of questions.

And just list that many years of experience with, up to and including, the ABWR, although some might think it's a new plant, it's got years of experience. And there is multiple plants that have operated in Japan. Okay.

DR. SCHULTZ: David, this is Steve Schultz.

MR. HINDS: Yes.

DR. SCHULTZ: Question. You mentioned on the previous slide that there are reliability improvements associated with a fine motion control rod drive. And here you talk about the experience that

you've gained from the other unit designs.

Anything in particular that has improved the reliability of that system, over and above, what you've seen before in your operational experience?

MR. HINDS: We have some plans where, depending upon the level of detail I might need to revert to the second segment of this. But we have made some changes to our motor selection.

We have gone through a series of coupling designs and coupling selections. And related to the motor selection it also determines the capability of how fine of a movement.

If it's okay with you, I'll come back to this and maybe highlight a few other features when I'm showing some visuals in the second segment. And please, if I didn't adequately address your question at that time please readdress it. But I wrote a note for myself, I'll bring up again.

But again, primarily in the motor coupling, we've also gone through into the bearings and looked for material reliability. But I'm not stating that we have a reliability problem with the current fleet of FMCRDs, we just continually look to advance and learn.

DR. SCHULTZ: I understand. Thank you

very much. I look forward to your further remarks.

MR. HINDS: Okay, thank you.

CHAIRMAN MARCH-LEUBA: I have lost the slides. Oh, there they are.

MR. HINDS: Yes, they dropped off for a second, sorry. Okay, continuing through our defense line type of defensive measures.

Now, once we get beyond Defense Line 1 and we get into mitigating systems and features, more into what we typically look into systems.

So, in Defense Line 2 includes functions which would normally control the plant. We do have added levels of quality for those systems, although they're not using the U.S. terminology, safety related, but using international terminology, they are Safety Class 3.

So we do apply a higher degree of controls upon design and procurement. And so we do get some credit for safety, but it's only one layer. Defensive layer.

They play a large role in limiting and/or preventing a postulating and initiating event. And they minimize postulated initiating events, I'm sorry if I did this on the acronym PIE, that reach Defense Line 3 set points.

Defense Line 3 is that layer right in the heart of safety, which is what, in U.S. terms, would be safety related or in international terms, safety class 1. So Defense Line 2 is a front-line defensive layer to prevent challenges to the core of the safety of the plant.

But we have a high focus and an elevated focus on that layer in this plant, which is one of the things that we've done to add a more defense-in-depth type approach to this plant.

If we can go to the next. And so I'll show you --

CHAIRMAN MARCH-LEUBA: So would you say that this is the control system that is non-safety grade that prevents the accident, the initiated events from getting worse, is that correct?

MR. HINDS: That's a correct statement. And they additionally will minimize the number of initiating events because, historically, many of the postulated initiating events originated in what we're now calling our Defense Line 2, or Safety Class 3 systems.

Things like the feedwater control system. So, feedwater level control system is a Defense Line 2 system. And it is a potential initiator. And it

also helps to limit other related initiators.

CHAIRMAN MARCH-LEUBA: So, what really is the alliance is, because you plan to use digital controls, computer controls, you can do more than an analog controller?

MR. HINDS: Right.

CHAIRMAN MARCH-LEUBA: Okay. If the feedwater is fast running away, you can create some safety functions inside a controller that would bring it back.

MR. HINDS: Yes.

CHAIRMAN MARCH-LEUBA: Which you couldn't do with an analog controller.

MR. HINDS: Yes. We would --

CHAIRMAN MARCH-LEUBA: Good.

MR. HINDS: Your statements are correct. We're using digital controls. And our defensive layers are separated digital controls.

So the Defense Line 2 is separate from our Defense Line 3 and so therefore if you go down the path, common cause failure, it's not, it will add a defensive layer, as well as the capabilities of technology advance, as you had just mentioned, help as well.

CHAIRMAN MARCH-LEUBA: Yes. Definitely

like a rod connector. It makes sense.

MR. HINDS: Okay. And we have, the really nice thing about our Defense Line 2 and those systems, we, again, picture high quality systems, we call Safety Class 3, and we apply high reliability features such as a selection of a triplicated controller versus just a simple singular controller. And those features add significant reliability to the plant.

I'll go more into the details of what's in Defense Line 2. These are kind of high-level terms. And some of those details will be in the next segment, so if you don't mind, I'll do some higher level introduction here and then revisit it again later.

MEMBER BLEY: Just to interrupt a second.

MR. HINDS: Yes. Please do, yes.

MEMBER BLEY: This is Dennis Bley. I don't really want to dig into it here but I'm guessing that when we get the reviewing I&C we'll dig into this Defense Lines 1, 2 and 3 business. If that's true, that's fine.

If it's not, maybe you can give us more detail in what you mean by, they are separate from each other. That can mean lots of different things.

And how separate are they on the different counts, just electrically or by communication? So,

I'm happy to put this off to I&C, but if it's not going to be there, maybe you can talk more about it.

MR. HINDS: Okay. We'll do both. I'll touch it again in our next segment, in the second portion of our presentation in closed session, and then you'll also see it again whenever you see I&C submitted for that portion of licensing. So we'll hit them both.

But in simple summary, they're quite separate. But I will get back to it in the second segment of this. I understand your question.

MEMBER BLEY: Okay, thanks.

MR. HINDS: So, control power generation systems, they, again, limit and mitigate events. I'll touch more on this in the later segment.

In Defense Line 2 we also mitigate incorrect rod potential, postulated incorrect rod movements, with rod blocks.

George, if you can go to the next slide please. Okay, Defense Line 3 is the heart of safety, as I mentioned. It's what, in U.S. we've used the term safety related, internationally we call Safety Class 1.

We include functions that mitigate the postulated initiating event. We ensure the plant is

placed in a safe state, such as a reactor scram. We assign the highest safety class and the highest procurement controls and design controls.

And a little bit to your question a minute ago, they are independent of Defense Line 2. I'll keep building on that.

Okay, George, next. Okay, so, we, within the BWRX-300 it is a passive safety natural circulating power plant. Hopefully our introduction from a prior ACRS meeting will carry forward to now.

I didn't include an overall summary of the BWRX-300 but I'd be glad to revisit anything if there is questions.

However, in Defense Line 3, functions associated with reactivity control of interests are the reactor protected system and the associated scram features that implement, that are implemented, or actuated by the reactor protection system, the isolation condenser system for heat removal.

Those are key, Defense Line 3, Safety Class 1 or safety related systems and functions that we contain within Defense Line 3.

George. Okay. Then the backup, or Defense Line 4 --

MEMBER BROWN: Excuse me for a minute.

This is Charlie Brown.

MR. HINDS: Sure.

MEMBER BROWN: Looking through your Defense Lines 1, 2 and 3, I'm the I&C person, representative. Along with Dennis, and anybody else that wants to participate in that area.

I was trying to get a handle on the 1, 2 and 3. It appears to me that Defense Line 3 is where your classic reactor protection system is called on. And it's the last, I view that as the last line of defense.

So the Defense Line 1 and 2, I presume are based on what you've been saying, sound like refinements of your operations and control functions that minimize the likelihood of having to have an automatic reactor protection system response. Am I reading what you're talking about correctly?

MR. HINDS: I think most, if not all of your statements, are correct. I'd like to amply on them some in our second segment if --

MEMBER BROWN: That's fine.

MR. HINDS: -- that's okay?

MEMBER BROWN: Yes, that's fine. Thank you.

MR. HINDS: Yes. Defense Line 3, in brief

summary, Defense Line 3 is the hardest safety and that is the traditional and fundamental reactor protection. But we looked on both sides of that in the front end.

In order to minimize challenges to it, we've added features. And then on the back end, in case we reach low probability failures, set of complex sequence with common cause failure, for example, we've got some backup features. So that's where we are now with this, up to Defense Line 4.

MEMBER BROWN: Okay.

MR. HINDS: So, Defense Line 4 we've segregated into 4A, 4B. And the 4A includes functions to mitigate postulating initiating events that occur, that postulate occur, and a subsequent postulate failure of the safety related systems to mitigate them.

So, a very complex, low frequency occurrence. We plan for them as well to mitigate the common cause failures that, CCF acronym, in Defense Line 3 and ensure plant is in a safe state.

Next. So, related to reactivity control, examples of Defense Line 4A, so this would, we'd never go here unless we have a common cause failure, so they arise. An example, alternate rod insertion. It provides the hydraulic scram in event that the HCUS

fail to actuate.

We also have another means, because of our design selection way back in Defense Line 1 of our design selection of fine motion control at drive, we have motors in addition to the hydraulics. So it allows another means for the control rods to be inserted.

Again, I'll keep revisiting these features. So I'm trying to buzz through a little now and then I'll come back and I'll catch all the questions, I hope.

MEMBER BALLINGER: This is Ron Ballinger. I'm assuming, I guess the way I read it, this ARI is a substitute for SLIC?

MR. HINDS: Well, ARI provides another means to ensure that the reactor is shutdown. So, in a way I guess you would be correct.

So, sure, it's another means for reactor, to ensure the reactor is shutdown. We have, and I'll keep building upon this because some of these we protected are the materials so I won't open so detailed right now but I'll keep revisiting and reinforce that. I wrote a note on that one as well.

DR. CORRADINI: So, this is Corradini. I'm with Member Ballinger. I'm a little confused

here.

So, if we go to closed session to explain this, I guess I'd like some clarification as to what the ARI is in difference to what has been common in BWRs and the ESBWR, the SLIC.

MR. HINDS: Okay. I'll start answering it and then I'll finish answering in the closed session, if that's okay.

But you're correct in, I think, your statement that ARI was used on past BWRs. So that statement is correct.

But there are some added features on the BWRX-300. And I'll build upon them as we go.

MEMBER BALLINGER: So this is Ron Ballinger again. So I'm assuming that we'll get, at some point, to the PRA later on in time, I guess, and that the alternate rod insertion scheme will have a significant effect on the PRA?

MR. HINDS: Yes. It is impactful on the PRA, that is correct. All of these layers have an impact on the PRA.

We've done initial, and to your point on PRA, we've done the initial PRA. We did not have the final PRA so we're not as prepared to submit a PRA at this stage. But we do have our initial PRA. And we

continue to use the PRA in parallel with design progression.

And you're correct that these features do impact the PRA. I mean, there's a whole layer in the layered failure.

MEMBER BALLINGER: Yes. In addition to that, I keep hearing the word, increased reliability, inserted more reliable this, more reliable that.

I'm assuming that when we get to the PRA you'll have some kind of data which supports, that puts a number on that.

MR. HINDS: Yes, that's our intention. Now, yes, within the PRA approved methodologies. That's correct.

MEMBER BALLINGER: Thank you.

MEMBER REMPE: So that was actually the question I had, was related to the data. Do you have the data or is it envisioned you're going to have to obtain additional data when you come in with additional documents related to this plant?

By the time you do a DCA or a Part 50 application, will have to obtain additional data?

MR. HINDS: And I assumed you were talking about failure. Failure rate type data that's used within the PRA, I assume, based upon your question.

MEMBER REMPE: Yes, that. And then I thought there was some also thermal hydraulic features with this plant that were a bit different that I was wondering if there was going to be some sort of testing program to demonstrate them. These features.

MR. HINDS: Yes. But we have a detailed thermal hydraulic analysis within our TRACG model.

And as we get into the second segment, if you want to go deeper into that, Charlie Heck is on the line who's our expert on that. But yes, we have been doing detailed thermal hydraulic analysis using our TRACG computer code.

And we additionally are doing PRA analysis for our frequency of N sequences and the frequency of occurrences.

MEMBER REMPE: So, in those, the reliability in the thermal hydraulics, I'm hearing you saying you're doing analysis. But did you have to obtain any additional data or do you need to obtain additional data, is what I was curious about?

MR. HINDS: So, for the thermal hydraulics we have been benchmarking for years with the operating fleet. And that data is pertinent to the BWRX-300.

We also have some additional previous task data for test facilities that we've also used for

benchmarking. But we did not envision the necessity for further testing. It doesn't mean we won't do testing, but we do not see the necessity for further thermal hydraulic testing.

MEMBER REMPE: Okay. Of reliability testing, so you think the data you have is adequate to support these changes in this design? Is that what you're telling me?

MR. HINDS: Yes. It doesn't mean we won't do further confirmatory, but that's what I'm telling you.

MEMBER REMPE: Okay, thank you.

MEMBER BALLINGER: But the alternate rod insertion system is new?

MR. HINDS: The alternate rod insertion is used in the existing fleet. Now, it's not a system that's called upon because it's a deep defensive layer, even on the existing fleet.

But the alternate rod insertion is used in the current BWR fleet. It's an alternate means of depressurizing the scram air header in the case of some sort of failure within the HCUS.

MEMBER BALLINGER: Oh, but this, look, okay, now I guess I'm demonstrating my ignorance.

This ARI system, sorry for the phone, I

can't shut the darn thing off, the alternate rod insertion system, in this case, would be called upon to operate in a different way?

MR. HINDS: It is quite similar to the, that one feature is quite similar to the existing fleet. And that feature, again, is to, in the case we postulate many different failure modes for the reactor scram.

And one of the potential failure modes, not probably, but potential, is the failure of the hydraulic control units to reposition and allow the high pressure water to insert, hydraulically, to control rods.

If that were to occur, we'd have the means to depressurize the scram air header, which causes the HCUS to reposition in an alternate way.

CHAIRMAN MARCH-LEUBA: Right. I believe you have a diagram on the closed slides, which would be --

MR. HINDS: That is correct.

MEMBER BALLINGER: Yes.

CHAIRMAN MARCH-LEUBA: -- a better time to address it, because we're running late guys.

MR. HINDS: Okay.

CHAIRMAN MARCH-LEUBA: You have only 15

minutes.

MR. HINDS: Okay.

CHAIRMAN MARCH-LEUBA: And we are running proprietary information. So keep going.

MR. HINDS: Oh, sorry. Thanks so much. Okay, we'll I'll keep moving, and we'll get back to your questions. I've got many notes here.

So, Defense Line 4B is our deep defensive layer. We call it things such as FLEX, just to get you a realm of, when we, if we were, we even do postulate transition into extreme events or severe accidents, and that's where we enter that 4B.

We really do not features to highlight today in this topical report related to 4B. I'm just letting you know the big picture.

So if we could keep going please. Okay. All right, could you advance, George. Okay. Okay, keep going.

Okay, so we did show some visuals in this non-proprietary segment. These are visuals that we've previously shown, but we have some others in our proprietary version that we did not include in this segment.

But just to give a little quick intro, and to more of the designs we're talking about. This is

just a visual showing the control rod blades.

And the control rods are positioned in-between the fuel bundles, four fuel bundles in a cell. And that's where I was talking about we have ample space for these control rods to move within these fuel bundles. Just a quick introduction. Next.

CHAIRMAN MARCH-LEUBA: Is this drawing on the right to scale that shows that much clearance between the rod, between the blade and the bow?

MR. HINDS: I'm now sure, I'd have to double check. It's not bad but it's, this is a PowerPoint presentation so I cannot claim that it's to scale.

CHAIRMAN MARCH-LEUBA: Okay. It's not to scale but close. Keep going.

MR. HINDS: Yes, I think it's a reasonable representation, but I can't claim it's to scale.

Okay. This is just showing, this is the top view of the core. So it's just showing, just giving you a big picture here.

We have many control rods. So, basically you have 57 control rods in this core. And so, even if one, or even more were to fail, we'd still have ample means to control reactivity of this core.

Okay. GNF2 fuel I mentioned before. So,

our proven fuel.

I've already mentioned several of these topics here, but again, we have much experience with the fine motion control rod drives, it's not just a brand new invention.

It does, they do operate by hydraulic force for scram. And normal movement, day in, day out, is with the fine motion motors.

So, there is hydraulics that insert rapidly in the case of the need for a scram, and there is motors that move in day in and day out. The motors provide a fine means of control, but they also provide diverse needs of insertion.

The ARI that we mentioned previously is a diverse means to actuate the hydraulics. Again, we'll show you the figure in a little while, as was mentioned.

Some might be familiar of the history of the BWRs where we've been using hydraulics for a long time for control rod movement. But the hydraulics on the older plants that did not have motors attached to the control rod drives, they have a scram discharge volume as well.

So they have a hydraulic side on both sides where the, on this, the hydraulics to insert is

all that's applied, there are no hydraulics for withdrawal.

And so, in the previous locking piston control drives, which are still successfully in service in the fleet, there is a scram discharge volume which allows for an exhaust on the top side of the piston. That is not present in the BWRX-300, or in any of our FMCRDs.

There are some failure modes that we've combated over the years with our scram discharge volume. Elimination of that scram discharge volume eliminates a potential failure mode of the hydraulics.

So I'm just mentioning that from the standpoint of another of, I've been saying these words, increased reliability. That's one way of increasing reliability of the hydraulics. And then we additionally have diversity and redundancy.

Okay, George.

MEMBER BLEY: So, David, that implies there is an open release pass for where the scram discharge volume needs to be, is that right?

MR. HINDS: Yes. It basically just goes into the reactor vessel.

MEMBER BLEY: Okay.

MR. HINDS: So it's a one-way path. You

push it in and the water has enough flow by internals in the FMCRD to go into the reactor vessel.

Okay. So, just a related, but a little different, this is just the cut away of the reactor pressure vessel. It is, because it's the natural circulating plant, we alluded to this in our, or we covered this in our first LTR, which we previous presented.

But the large volume, or relatively large volume, for the purpose of natural circulation had advantages of, that steam volume allows for a lower pressurization rate in events. And, again, we covered, I've listed the reference of the previous LTR. I won't go into details here since we've already covered.

Okay, George. And we've also covered this in our prior LTR but I'm mentioning it again because it is pertinent to mitigating failures within reactivity control.

Because, one, important for removing the energy of the reactor, of course is to shut it down, but then, this is the key system to, and this is a very, very simplified visual. So there are, this is not the, as designed, this is just to show your visual representation of the isolation condenser system which

is our Safety Class 1 safety related heat removal system.

So, in the event of an isolation event, the energy is removed by the isolation condenser system by taking steam condensing in pools. Similar to the design that was implemented on the ESBWR, and then returned the condensate back to the reactor vessel, limits reactor pressure and provides for a passive means of cooling.

Once actuated, no further means for any, there's a valve that has to open to open the flow path. And once actuated, it needs no further support system other than just that pool that heat exchangers are immersed in.

Okay.

MEMBER REMPE: So this --

(Simultaneous speaking.)

DR. CORRADINI: This is Corradini.

CHAIRMAN MARCH-LEUBA: Okay, Mike.

DR. CORRADINI: I guess maybe we should wait till the closed session, just so you can confirm it, but I have a number of questions about this cartoon, so, since it's a cartoon should we wait till closed to ask detailed questions?

MR. HINDS: If it's okay, that would be

great. Because we're running a little behind.

DR. CORRADINI: Okay, I'll wait then. I'll wait.

MR. HINDS: Great. Thank you.

MEMBER REMPE: So I have one quick question though. Is the water level, this water level differs from what we were shown in the open sessions or closed sessions in prior discussions of this plant.

Is the water levels substantially above where the piping is?

MR. HINDS: Yes. The water level, meaning the piping, meaning the condensate return? Yes.

MEMBER REMPE: Right. Because that's, thank you.

MR. HINDS: I'll get back to that in the closed session. In case I didn't answer your question, please ask again in the closed session.

CHAIRMAN MARCH-LEUBA: Yes. One thing you didn't mention is the size of the ICS. We mentioned in the previous, this is grossly over designed?

MR. HINDS: It's a large system, yes. It's got a large capacity. So yes, it's capable for controlling reactor pressure.

CHAIRMAN MARCH-LEUBA: Okay, thank you.

MR. HINDS: Okay. Okay, so just a brief

mention, and I think the NRC will cover in more detail, possibly, on the regulatory side of the review. And, George or Lou, if you have anything to interject please do.

So, some of the associated regulations and regulatory guidance that we covered in this licensed topical report, of course, there is 10 CFR 50.62 for the ATWS event.

And we just highlight a point here that the, the ATWS rule was written at a time when these multiple defense-in-depth features, that I was describing and just giving a brief intro here, were not all present.

And so we feel that the, and I also alluded to reliability, you asked me about, that the added defenses, defense line features that we have implemented with BWRX-300 will result in a lower frequency of occurrence of that postulated event sequence, complex sequence of an ATWS. So, things have changed significantly.

And even with the older designs we were, the statement here from the NUREG 1780, which we read to study the history, found that even with the previous designs don't include some of the features that I described. We even met the reliability goals,

as stated in the intent of the ATWS rule. So just a little background, okay.

George. All right. And here is some review guidance that we also referenced. I know its review guidance, but we referenced it to help align with the expectations.

In the SRP 15.8 there is statements about evolutionary plants, which this plant is. Then we will tell you some more in the closed session about diverse features, so I'm just highlighting that point that in the SRP there is some mention of, and that a mitigating strategy could be to add diverse features.

Again, we protected some of the details of our diverse features. I just briefly introduced them. We'll come back to them, but we do have diverse features in this plant is really the point I'm trying to get at.

Okay. We do have alternate means for shutdown. We do have alternate rod insertion, which is explicitly called out in the rule.

We do have electric motors to insert the control rods that are independent of the hydraulic insertion method. We do have multiple means of shutting down the plant.

And we have evaluated even failures of

those in each of our defense line type of approach. If a failure occurs in one defense line or a failure occurs in multiple defense lines.

Okay. So we, 50.62 mandates reduction of risk from an ATWS. We think we have done that. And we will continue to supply information to further prove that, such as what was asked a little while ago, is about the PRA.

During a license submittal for a plant, we would submit the PRA as expected. And if it proves out that we have reduced the risk of an ATWS as called out by this rule.

They require ARI. I mentioned before we have it. Require SLC, we'll cover further in a little while. And requires automatic recirc pump trip.

Okay, George. Okay, so, I've already mentioned most of this. Each control rod contains certified hydraulics. And the hydraulics can also be actuated by its normal means, but also actuated mechanically by the ARI.

Also, the motors, I've mentioned several times, provide a diverse means for insertion. We think those are key features for evaluating the ATWS rule.

We also have diversity and separation

between the control systems associated with the normal means of scram and the alternate means of scram.

Eliminates common mode failures by having these diverse means. Or eliminates at least having the effects of the common mode failure of inability to shut the plant down.

And I already mentioned the scram discharge volume was removed, so that failure mode is an example of one that was just completely removed.

SLC, we eliminated the failure of control rod insertion from a single common cause failure so we used a defense-in-depth approach. We'll talk a little more about, more details associated with SLC because we had that in the second session. Okay.

CHAIRMAN MARCH-LEUBA: Dave. No, go back to the Slide 30.

That statement, I don't see you have eliminated the failure. What you can say is that we have looked very hard and haven't found, found one yet.

MR. HINDS: Okay.

CHAIRMAN MARCH-LEUBA: Do you agree on that?

And in light of that it is a little unclear to me when I read everything, whether we plan

to claim that the probability of ATWS is so small that we don't have to worry about it. Are we going to analyze it and demonstrate that nothing breaks? Within the relaxed ATWS criteria, which are very relaxed, basically comparability.

Because one concern I have is ATWS over pressure. There are some special features that the pressures in ATWS might, it still needs to be calculated.

MR. HINDS: Yes.

CHAIRMAN MARCH-LEUBA: So what is your path, A or B?

MR. HINDS: So, let's see if this at least partially addresses your question. And again, part of our details of thermal hydraulics we had planned for the segment, as needed.

But we did analyze failure of the normal scram system and the associated reactor and pressure transient that occur as a result of failure of the normal scram system.

We did, in that analysis, credit some of the diverse means as mitigation. But we did analyze the pressure response and have acceptable results to the pressure response on the failure of the normal scram system.

DR. CORRADINI: I'm, this is Corradini, can you repeat that, I don't think I appreciate what you just said?

CHAIRMAN MARCH-LEUBA: Yes, I was going to suggest, and it was me, let's delay this till the closed session because we have to talk about this, especially mitigation features and all that.

MR. HINDS: Okay. Yes, I think that's, I would appreciate that.

CHAIRMAN MARCH-LEUBA: Yes.

MR. HINDS: Okay. Thank you. I understand your question.

Okay, so I mentioned this but I this is, hopefully, an easy one. But this plant has no recirculating pumps. No recirc pumps.

It's a natural circulating power plant so the prescriptive rule for tripping the recirc pumps is not technically relevant to the BWRX-300. However, we do consider what was the fundamental purpose of doing that in reducing the overall reactivity.

And we have other features for ensuring that we reduce the reactivity. But we do not have recirc pumps to trip.

CHAIRMAN MARCH-LEUBA: And this is probably for the staff. In something as obvious as

this that clearly is not applicable, do we need an exemption because the recirculation pump trip is easily called up in the rule.

So does this have a mechanic, a proceed here that I think is obvious what the answer is. But maybe I'll ask the Staff whether we need an exemption from 50.62.

MR. HINDS: Okay. Would you like for me to keep proceeding and wait for the --

CHAIRMAN MARCH-LEUBA: Yes, please.

MR. HINDS: -- Staff's presentation or --

CHAIRMAN MARCH-LEUBA: Yes. Yes, go ahead.

MR. HINDS: Okay, thank you. Okay, so, again, we'll talk some more, as you just mentioned, about the analyses results in our next segment. But we did use the regulatory acceptance criteria from the rule and from the regulations. And we just listed some of them here.

Nothing we've changed anything here, it's just restating some. So, if you have questions or would like me to elaborate, please let me know. Otherwise we're just recognizing that we understand and will maintain the regulatory acceptance criteria.

Okay, George. So into the general design

criteria level. So, within GDC27 we did, because of the wording of the GDC, we did have some proposed PEC. And that's included in the LTR. It's related to our means of reactivity control during a failure to scram.

But we do maintain core coolability. And there is just this portion related to pose an addition by ECCS. It's not relevant to this plant and that's what resulted in the PEC. I think we have more slides on this but --

MR. WADKINS: Yes, later.

MR. HINDS: Okay. Then we'll come back to that a little bit later. And I think the Staff will cover some as well.

MEMBER REMPE: So, at this point, Jose, I'd like to come back to my very first question.

I've heard that there is a September 2020 version of this LTR that's been with the, had the revisions from the RAIs incorporated.

MS. FRANOVICH: That's correct.

MEMBER REMPE: We only have the March 2020 version of it. And that's a shame but since we've been given the March 2020 version, can we be provided the September 2020 version, not only the clean copy but also some way that shows track changes so we don't have to go through and re-review everything?

But I just think that the changes were sufficiently substantial. That it would be good for us to see how it is cast at this time.

MS. FRANOVICH: This is Rani Franovich, the project manager. In the SE the Staff wrote an introduction that explained that there was a supplement to the original SE that was provided on September 4th, 2020.

The accession number is provided in the introduction. We do not have a track changes version, but there is, in the document that was submitted by GEH, a table, as I recall, that described the changes that were made.

George, can you confirm that?

MR. WADKINS: Yes, that is true. The Supplement 1 does have a revision record which explains the changes. They were, I believe in this supplement, they were entirely from that one set of RAIs.

MEMBER REMPE: So, please get that to Zena and have her, she'll distribute it to us soon because we, I missed it that this Supplement 1 existed. And, again, I just checked our share point site, we only have the March 2020 version out there.

MS. FRANOVICH: Understand.

MEMBER REMPE: Do you have the September version, Jose?

CHAIRMAN MARCH-LEUBA: No, I don't. I know you asked this last week, or two weeks ago, and I was not aware.

MEMBER REMPE: No. Okay, so please get that to us. Thank you.

MR. WADKINS: Okay, thanks, David. If there are no further questions then I wish to thank the NRC Staff once again and the ACRS Members for their time.

We will discuss some of these items that we tabled in the closed session. But again, if there are no additional questions we will turn this over to the NRC Staff to present their SER.

MS. FRANOVICH: Okay. Thank you, George. I'm going to share my screen. And if I could get some feedback that you guys, everyone can see it, that would be great.

CHAIRMAN MARCH-LEUBA: We can see the screen, but the slide is all garbled. You need to put the slides on top.

MS. FRANOVICH: I'm trying to, I'm trying to do that as we speak. Bear with me. Huh. Can everyone see that?

CHAIRMAN MARCH-LEUBA: Yes. Now it's perfect.

MS. FRANOVICH: Thank you. All right, Ryan, I will turn this over to you to start the Staff's presentation.

MR. NOLAN: Thank you, Rani. This is Ryan Nolan. I am in NRR in the Nuclear Methods Systems and New Reactor Branch and I will be presenting a brief overview of our safety evaluation in the open session.

A lot of the underlying material in which we made our findings is based on proprietary information, so a good portion of our discussion will have to be in the closed session.

Rani, you can go to the next slide. So, in this presentation I'm going to briefly go over who the review team was, a brief background on the BWRX-300, as well as our review of NEDC-33912 and then I'll wrap up with our conclusion.

So, in addition to myself, my colleagues Andrew Proffitt and Alex Siwy will be co-presenting in the closed session with me.

And we also had some support from additional tech staff and other disciplines who are available to answer any questions that come up in their area. However, there is no specific slides.

And I'll address that when we get there.

Rani, you can go to the next slide. So, a very brief background. The BWRX-300, it's a 300 megawatt electric SMR, uses natural circulation. Passive cooling is provided by the isolation condenser system and it's based on the SBWR design.

As GEH has already presented, they use typical BWR bottom entry control rods. The design does include defense-in-depth and diverse features for shutting down the reactor and controlling reactivity.

And this topical report that we are describing provides design requirements, as well as assessments regulatory requirements, related to reactivity control.

Next slide, Rani. The topical report specifies design requirements for the control system, RPS as well as alternate rod insertion system.

There's a couple others there. We will be going into much more detail on these systems in the closed session.

Go to the next slide, Rani. Here's the list of the regulations we evaluated as part of the topical report.

The focus is on 50.62. The ATWS rule. However, the topical report and our safety evaluation

does address a long list of GDCs.

The GDCs that are underlined in this slide will be presented in the closed session in much more detail. The GDCs which are not underlined, we do not have any specific slides on so now would be probably the right time to ask any questions on these particular GDCs.

But in the interest of time, GEH's approach that they described for meeting these GDCs, which are not underlined, seemed fairly typical and traditional. And our overall conclusion, specific to these GDCs, is that the approach is consistent with how they have it implemented historically. So there are no specific slides on the GDCs which are not underlined.

And if there is no questions, I'll think we'll just wrap up the conclusion on the next slide, Rani.

We did write a few limitations and conditions in our safety evaluation for this topical report. These were mainly in areas where the topical report, it didn't really specify what form of analysis will be performed in the future to demonstrate compliance with the regulation.

And so, we wrote a few limitations and

conditions sort of establishing the analysis the Staff expects that would be included in a future licensing submittal. So it's really more of just a clarification of our expectations.

In conclusion, we did find that the topical report provided an acceptable description of design requirements, the acceptance criteria and the regulatory basis for the BWRX-300 reactivity control functions and features.

And as a disclaimer, the detailed design of the BWRX-300 SMR is not complete. And the Staff does expect that an applicant demonstrate compliance with the regulations. And if they cannot demonstrate compliance, we do expect an adequate justification for an exemption.

And with that, the Staff will evaluate any regulatory compliance, with the final design, when we receive an application in the future. And that's all I had for the open presentation.

CHAIRMAN MARCH-LEUBA: Ryan, this is Jose again. GE went into some detail under the GDC 27 issue, but can you say in open session whether there is an issue with return to power when the control was, not in ATWS, but when control rods go in and two rods remain stuck.

MR. NOLAN: Yes. My understanding of the design is that it is capable of maintaining the reactor shutdown, assuming a single failure of the worst rod pair. So they, my understanding is, with two rods out the reactor will remain shut down.

CHAIRMAN MARCH-LEUBA: Of co-conditions and --

MR. NOLAN: Yes.

CHAIRMAN MARCH-LEUBA: -- CW3?

MR. NOLAN: That is --

CHAIRMAN MARCH-LEUBA: Okay. So there is no issue with return to power?

MR. NOLAN: No. Oh, and then with respect to your question on 50.62(c)(5), which is the requirement for an automatic recirc pump trip, and the question was whether an exemption is needed or not, our position is that it is not applicable and an exemption is not needed.

It's a natural circulation plant, they don't have recirc pumps. And so that particular regulation is not applicable, no exemption is needed.

However, we do expect, we will review any compensating measures that are taken to address that. Maybe the intent behind that role. And this is consistent with what was done for the ESBWR.

CHAIRMAN MARCH-LEUBA: So that's good. That's a good answer. I wouldn't even call it transformational.

Yes, we don't need to do work when no work is needed. If we can say, duh, it's obvious, we can save a month of work.

MR. NOLAN: Yes, that's correct.

CHAIRMAN MARCH-LEUBA: Thank you. So, are you done with, the Staff is done with the presentation?

MR. NOLAN: Yes. That concludes my presentation.

CHAIRMAN MARCH-LEUBA: So this concludes the complete open session presentation. Can we open the phone line please?

At this point, anybody in the public, on the phone line, that wants to make a comment, please state your name and make your comment. Is the phone line open? Public phone line?

MEMBER BROWN: Hello?

CHAIRMAN MARCH-LEUBA: Yes.

MEMBER BROWN: Jose? Jose?

CHAIRMAN MARCH-LEUBA: Yes.

MEMBER BROWN: This is Charlie. I've lost all power in my house. None of my phones are working,

other than my cell phone, which has no coverage. Almost. I'm probably going to trip off. Hind winds and something is going down, so I won't be back in until I can get some power.

CHAIRMAN MARCH-LEUBA: All right, it's okay. Thank you for letting us know.

MEMBER BROWN: Okay. Yes, thank you. Take care.

CHAIRMAN MARCH-LEUBA: Any other comments? All right, we'll assume the public doesn't have any more comments.

Any Members of the Committee want to make a comment on the record, at this moment?

MEMBER KIRCHNER: Jose, this is Walt Kirchner. Just an observation, maybe for David from GE to answer.

He explicitly, I know that this topical report is about the activity control and design requirements, but under Defense Line 3 he has the reactor protection system scram and the isolation condensing system. I would assume then the RPV is also in that category, is that correct?

That's more of a question or a clarification for GEH.

CHAIRMAN MARCH-LEUBA: But I do think that

we need to ask that question in closed session. Because we'll get into details of their proprietary design. If you don't mind --

MEMBER KIRCHNER: Oh, sure. No, that's fine. It's just more an observation.

CHAIRMAN MARCH-LEUBA: Yes. Yes, thank you. Any other comments or questions? Hearing none, we are going off the record.

(Whereupon, the above-entitled matter went off the record at 10:46 a.m.)

HITACHI

ACRS Subcommittee Presentation

GE-Hitachi (GEH)
Licensing Topical Report (LTR) NEDC-33912P
BWRX-300 Reactivity Control

(Open Session)

November 2, 2020

Agenda (Open Session)

Licensing Topical Report Purpose and Scope

Defense in Depth Design Features for BWRX-300 Reactivity Control

Summary of Design Features to Meet Regulatory Requirements and Provide Defense in Depth for Reactivity Events

Regulatory Evaluation

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Licensing Topical Report Purpose and Scope

Licensing Topical Report Purpose and Scope

Provide the design requirements, acceptance criteria, and regulatory basis for the BWRX-300 RPS and other associated means of reactivity control:

- BWRX-300 means of reactivity control design functions
  - Specify design requirements for the RPS to ensure regulatory requirements are met
  - Specify design requirements for other means of reactor shutdown to ensure that defense in depth diversity requirements are met
  - Specify design requirements for other functions such as Alternate Rod Insertion to ensure the hydraulic scram meets reliability requirements
  - Specify BWRX-300 acceptance criteria and associated mitigating strategy in response to an ATWS as evaluated against 10CFR50.62
  - Describe compliance with the requirements of 10 CFR 50 Appendix A, General Design Criteria (GDC) 12, GDC 20, GDC 21, GDC 22, GDC 23, GDC 24, GDC 25, GDC 26, GDC 28, and GDC 29
  - Describe regulatory approach for GDC 27

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Licensing Topical Report Purpose and Scope

Provide the design requirements, acceptance criteria, and regulatory basis for the BWRX-300 mitigating systems associated with an ATWS:

- BWRX-300 mitigating systems associated with an ATWS
  - Specify design requirements for systems to control reactor pressure during an ATWS
  - Specify design requirements for additional means of reactor shutdown in the case of failure of all means of hydraulic insertion of control rods
  - Specify BWRX-300 acceptance criteria and associated mitigating strategy in response to an ATWS as evaluated against 10CFR50.62

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Defense in Depth Design Features for BWRX-300 Reactivity Control

Defense in Depth Design for BWRX-300

BWRX-300 applies a defense in depth approach aligned with the IAEA guidance

- Address fundamental safety functions to ensure overall plant safety
- Assigns BWRX-300 functions to defense lines associated with fundamental safety functions
- This LTR is focused on the fundamental safety function of reactivity control
  - Ensure adequate defense in depth of shutdown capability and reactivity control

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Defense in Depth – Defense Line 1

IAEA Level 1

Defense Line 1 (DL1)

Defense Line 1:

- **Reduce challenges to the Reactor Protection System from all occurrences**
  - Fewer trips per year
  - Reduces number of AOOs
    - Some transients become Infrequent Events defined as $\leq$ 1 per 100 Reactor-years
- **Strengthen subsequent lines of Defense**
  - Quality
  - Reliability
  - Conservatism

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Defense in Depth – Defense Line 1

IAEA
Level 1

Defense Line 1 (DL1)

Defense Line 1 Examples:

- Technical Specification operational controls
- N-Lattice core less likely to experience control rod binding
- Advances in channel materials and core design/operation minimize probability of channel bow
- Normal power changes are with control rods – continuous observation of normal function
- Reliability measures included in design minimize probability of Postulated Initiating Events (PIEs) and failure of mitigation
- Fine Motion Control Rod Drives (FMCRD) with improved reliability

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Defense in Depth – Defense Line 1

IAEA
Level 1

Defense Line 1 (DL1)

Defense Line 1 Examples:

- Seismic qualification ensures core geometry maintained
- FMCRDs similar to ABWR and ESBWR
- Control Rod Blades
  - Same as ABWR
  - Almost identical to latest design for BWR fleet
- ABWR fleet has 22+ years of operating experience with control rod blades and FMCRDs

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Defense in Depth – Defense Line 2

IAEA Level 2

Defense Line 2 (DL2)

Defense Line 2:

- Includes functions which normally control the plant
- Plant functions designed to control or stop a PIE
- Minimizes PIEs that reach DL3 setpoints
- Independent from DL3

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Defense in Depth – Defense Line 2

IAEA Level 2

Defense Line 2 (DL2)

Defense Line 2 Mitigation:

- Diverse means to shutdown
- Other diverse system actuations
- Control of power generation systems can assist with mitigation of failures within shutdown systems
- Rod Block mitigates incorrect rod withdrawal

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Defense in Depth – Defense Line 3

IAEA
Level 3

Defense Line 3 (DL3)

Defense Line 3:

- Includes functions which act to mitigate a PIE
- Ensure plant is placed in a safe state
- Assigned to highest safety class
- Independent of DL2

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Defense in Depth – Defense Line 3

IAEA
Level 3

Defense Line 3 (DL3)

Defense Line 3 Mitigation:

- Reactor Protection System (RPS) Scram
- Isolation Condenser System

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Defense in Depth – Defense Line 4a

IAEA
Level 4

Defense Line 4a (DL4a)

Defense Line 4a:

- Includes functions to mitigate a PIE along with failure of DL3
- Mitigates CCFs in DL3
- Ensure plant is placed in a safe state

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Defense in Depth – Defense Line 4a

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Level 4

Defense Line 4a (DL4a)

Defense Line 4a Mitigation:

- Alternate Rod Insertion (ARI) – provides hydraulic scram in event of Hydraulic Control Unit (HCU) actuation failure
- FMCRD insertion with motors

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Defense in Depth – Defense Line 4b

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Level 4

Defense Line 4b (DL4b)

Defense Line 4b:

- Functions to prevent or mitigate severe accident
- Protects from events that exceed DL1 assumptions such as extreme events, multiple events, or multiple failures

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Defense in Depth – Defense Line 4b

IAEA
Level 4

Defense Line 4b (DL4b)

Defense Line 4b Mitigation:

- The need for features in DL4b will continue to be evaluated through the Probabilistic Risk Analysis (PRA) event sequences analyses

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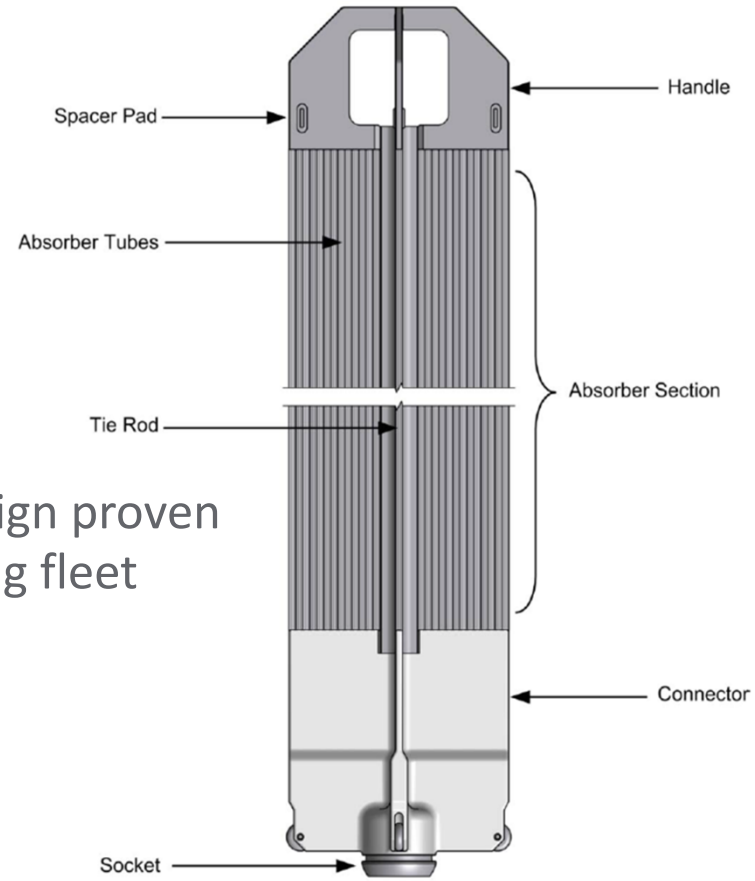
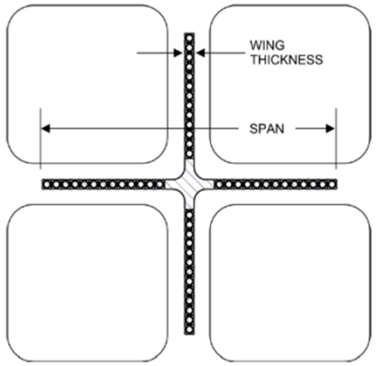
Design Features to Meet Regulatory Requirements and Provide Defense in Depth for Reactivity Events

BWRX-300 Control Rod with Fuel Assemblies





- Control Rod design proven in BWR operating fleet

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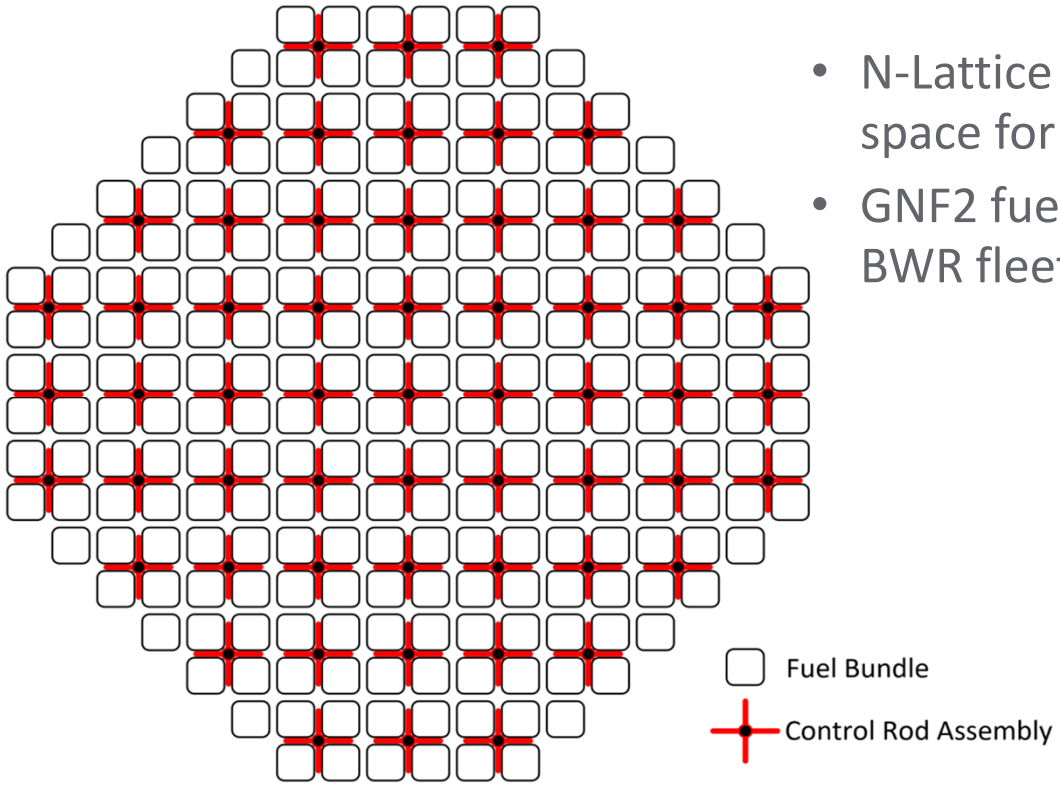
BWRX-300 Core with Control Rods



- N-Lattice core provides ample space for control rod travel
- GNF2 fuel currently operating in BWR fleet

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FMCRD

- FMCRDs are evolution from BWR fleet hydraulic control rod drives
- Motor provides normal means of control rod movement
- Hydraulic scram diverse from motor driven movement
- FMCRDs proven in operating ABWRs
- Driven by fail-safe Hydraulic Control Units (HCUs)
- ARI valves provide diverse means to release stored energy
- Scram outlet valve and scram discharge volume eliminated – no hydraulic lock potential

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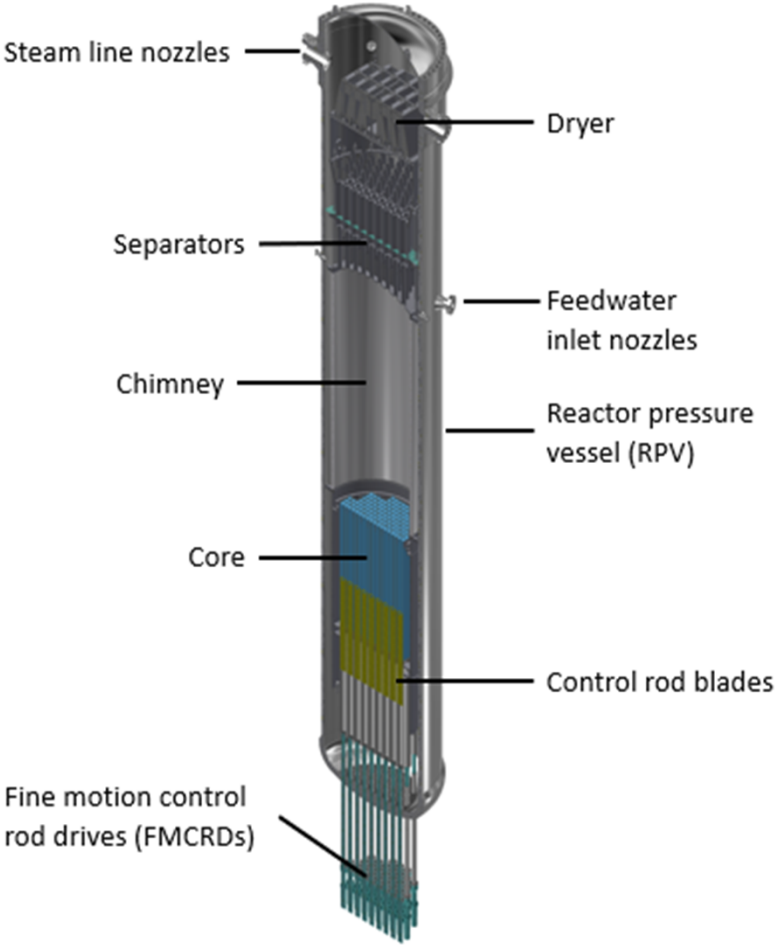
BWRX-300 Reactor Pressure Vessel (RPV)

- Large RPV steam volume results in lower pressurization rate for isolation events (compared to ABWR and existing BWRs) hence resulting in less reactivity effect
- Refer to NEDC-33910P, *BWRX-300 Reactor Pressure Vessel Isolation and Overpressure Protection*



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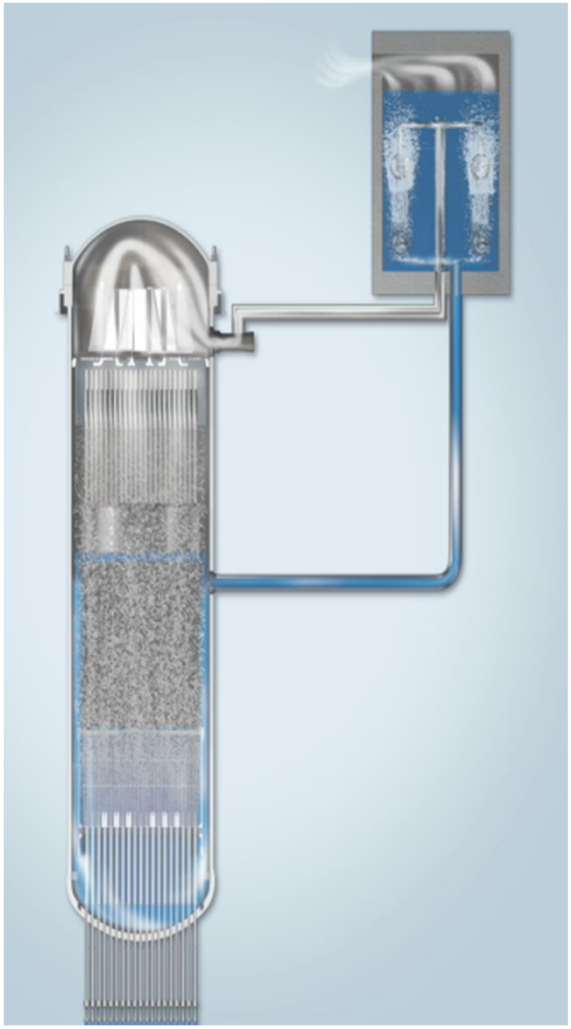
BWRX-300 Design Features - ICS

- Heat exchanger design and capacity of each ICS train is the same as ESBWR
- Fail-safe, simple system
- Limits reactor pressure and temperature and maintains reactor water inventory
- Condensate return valves (not shown) fail open on loss of power to the valves



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Compliance to Regulatory Requirements

Applicability of 10CFR50.62 to Evolutionary Plants

During the ATWS rulemaking the NRC staff set a goal that frequency of an ATWS should be no more than 1.0E-05/reactor-year

NUREG-1780

"Using operating data since the ATWS rule was implemented, found that on a generic basis, all four reactor types achieved the ATWS rule risk goal."

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Design Features Described in Standard Review Plan (SRP)

NUREG-0800, SRP 15.8, states the following:

A. For evolutionary plants where the ATWS rule does not explicitly require a diverse scram system, the applicant may provide either of the following:

i. A diverse scram system satisfying the design and quality assurance criteria specified in SRP Section 7.2

ii. Demonstrate that the consequences of an ATWS event are within acceptable values

BWRX-300 meets both requirements

- Alternate means for shutdown
- ARI and electric motor run-in included in DL4a
- Successful scram ensured by DL2, DL3, DL4a
- Consequences of failure to scram from all three layers of defense acceptable by use of DL4a

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Design Features Required by ATWS Rule

10 CFR 50.62 mandates reduction of risk from an ATWS

10 CFR 50.62(c)(3), (4) and(5) require the following design features for BWRs:

- Alternate Rod Insertion (ARI) System
- Automatic SLCS
- Automatic Recirculation Pump Trip

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10 CFR 50.62(c)(3) – Alternate Rod Insertion (ARI) System

Each control rod can be inserted hydraulically using either of two methods:

- RPS actuated HCUs to release stored high-pressure water from accumulators
- Diverse ARI pilot valves on control air header for scram valves to release stored energy for scram

Additionally FMCRDs have electric-motor-driven positioning used for both insertion and withdrawal of the control rods

Electric motor diverse from the hydraulic scram feature

- Allows rod movement, even with failure of ARI system
- Utilize sensors and logic that are diverse and independent of the RPS

Eliminated common mode failure of hydraulic scram by eliminating the scram discharge volume

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10 CFR 50.62(c)(4) – Automatic SLCS

BWRX-300 Design has eliminated failure of control rod insertion from a single common cause

- Uses the Defense in Depth approach delineated in IAEA SSR-2/1 to provide multiple layers of defense to ensure reactor is shutdown

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10 CFR 50.62(c)(5) – Automatic Recirculation Pump Trip

Forced circulation BWRs trip recirculation pumps to reduce core flow and power:

- BWRX-300 utilizes natural circulation and has no recirculation pumps

BWRX-300 design also utilizes:

- Control of power generation systems to assist in mitigation
- Reduces water level, core flow and reactor power similar to RPT in a forced circulation plant

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Regulatory Acceptance Criteria

Primary System - Maximum primary stress within (RCPB) does not exceed the emergency limits as defined in the ASME B&PV Code, Section III

Fuel Integrity - Cladding temperature and oxidation criteria of 10 CFR 50.46 met

Containment Integrity - Maximum containment pressure does not exceed the design pressure

Radiological Releases - Maintained within 10 CFR 100 allowable limit

Shutdown and Cooling - Reactor is brought to long-term shutdown with continued effective core cooling

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10 CFR Part 50, Appendix A, GDC 27

10 CFR Part 50, Appendix A, GDC 27, *Combined Reactivity Control Systems Capability* - The reactivity control systems shall be designed to have a combined capability, in conjunction with poison addition by the emergency core cooling system, of reliably controlling reactivity changes to assure that under postulated accident conditions and with appropriate margin for stuck rods, the capability to cool the core is maintained

- Exception - Core coolability is maintained for loss-of-coolant accidents because loss of water inventory in the RPV is minimized by the assured function of RPV isolation valves to mitigate large line breaks
- Refer to NEDC-33910P, *BWRX-300 Reactor Pressure Vessel Isolation and Overpressure Protection*

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U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

NRC Staff Presentation- Open Session GEH Topical Report NEDC-33912P, Revision 0, Supplement 1, “BWRX-300 Reactivity Control”

BWRX-300 Small Modular Reactor
ACRS Subcommittee Meeting
November 2, 2020

Presentation Outline

- NRC Staff Review Team
- BWRX-300 Background
- NRC Staff Review of NEDC-33912P
- Conclusion

NRC Staff Review Team

- NRR Nuclear Methods, Systems, and New Reactors Branch (SNRB)
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  - Andrew Proffitt
  - Alex Siwy
- NRR PRA Licensing Branch C (APLC)
  - Anne-Marie Grady
  - Alissa Neuhausen
- NRR Instrumentation and Controls Branch A (EICA)
  - Dinesh Taneja
- NRR New Reactor Licensing Branch (NRLB)
  - Rani Franovich

BWRX-300 Background

- 300 megawatt electric small modular reactor
- Uses natural circulation and passive cooling isolation condenser system
  - Based on ESBWR design
- Uses typical boiling-water reactor bottom-entry, cruciform-shaped control rods
- Includes defense-in-depth and diverse features to ensure the capability to shut down and control the reactor
- NEDC-33912P specifies design requirements and assesses regulatory requirements related to reactivity control

BWRX-300 Reactivity Control Systems and Functions

NEDC-33912P specifies design requirements for:

- Rod control system
- Reactor protection system
- [[ ]]
- Alternate rod insertion
- [[ ]]

Evaluation of Applicable Regulations

- 10 CFR 50.62, Requirements for reduction of risk from ATWS events
- 10 CFR 50, Appendix A, General Design Criteria
  - GDC 12, *Suppression of reactor power oscillations*
  - GDC 20, *Protection system functions*
  - GDC 21, *Protection system reliability and testability*
  - GDC 22, *Protection system independence*
  - GDC 23, *Protection system failure modes*
  - GDC 24, *Separation of protection and control systems*
  - GDC 25, *Protection system requirements for reactivity control malfunctions*
  - GDC 26, *Reactivity control system redundancy and capability*
  - GDC 27, *Combined reactivity control systems capability*
  - GDC 28, *Reactivity limits*
  - GDC 29, *Protection against anticipated operational occurrences*

Conclusion

- With specified Limitations and Conditions, NEDC-33912P provides an acceptable description of design requirements, acceptance criteria, and regulatory bases for design features of the BWRX-300 reactivity control functions.

- Detailed design of BWRX-300 SMR is not complete.
  - If applicant is not able to demonstrate compliance with NRC regulations, the applicant will be expected to justify an exemption from the applicable requirement.
  - NRC staff will evaluate regulatory compliance of the final BWRX-300 design with regards to reactivity control during future licensing activities for BWRX-300 applications.

Questions?

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Invite someone or dial a number

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- Brown, Charles
- Compton, Makeeka
- Dennis Bley (Guest) — Guest
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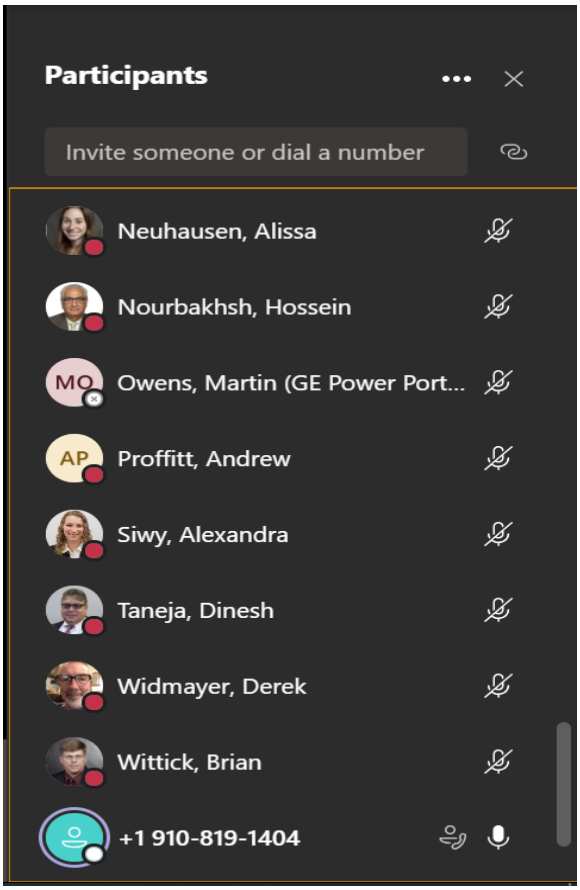
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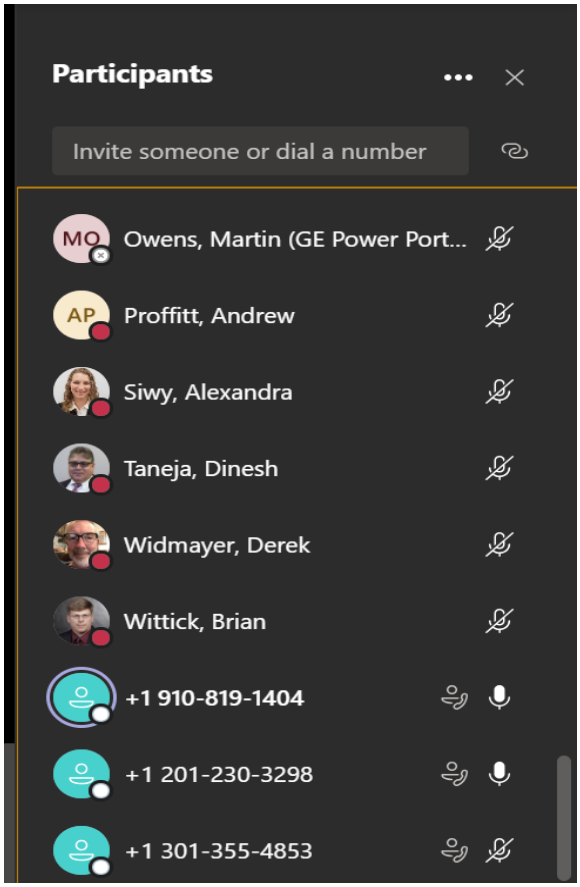
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