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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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681ST MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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TUESDAY

DECEMBER 1, 2020

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The Advisory Committee met via Video-Teleconference, at 2:00 p.m. EST, Matthew W. Sunseri, Chairman, presiding.

COMMITTEE MEMBERS:

MATTHEW W. SUNSERI, Chairman
JOY L. REMPE, Vice Chairman
WALTER L. KIRCHNER, Member-at-large
RONALD G. BALLINGER, Member
DENNIS BLEY, Member
CHARLES H. BROWN, JR. Member
VESNA B. DIMITRIJEVIC, Member
JOSE MARCH-LEUBA, Member

DAVID A. PETTI, Member
PETER RICCARDELLA, Member

ACRS CONSULTANT:
MICHAEL CORRADINI
STEVE SCHULTZ

DESIGNATED FEDERAL OFFICIAL:
ZENA ABDULLAHI

ALSO PRESENT:
MICHAEL DUDEK, NRR
DAVID H. HINDS, GE-Hitachi
MARIELIZ JOHNSON, NRR
SCOTT MOORE, Executive Director, ACRS
NOLAN RYAN, NRR
GEORGE WADKINS, GE-Hitachi

AGENDA

P R O C E E D I N G S

2:01 p.m.

CHAIR SUNSERI: Meeting will now come to order. This is the first day of the 681st meeting of the Advisory Committee on Reactor Safeguards.

I'm Matthew Sunseri, Chair of the ACRS. And I now call the roll to confirm communications and that a quorum exists. I'll start with Ron Ballinger. Dennis Bley.

MEMBER BLEY: Here.

CHAIR SUNSERI: Charles Brown.

MEMBER BROWN: Here.

CHAIR SUNSERI: Vesna Dimitrijevic.

MEMBER DIMITRIJEVIC: Here.

CHAIR SUNSERI: Walt Kirchner.

MEMBER KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba.

MEMBER MARCH-LEUBA: Present.

CHAIR SUNSERI: Dave Petti.

MEMBER PETTI: Here.

CHAIR SUNSERI: Joy Rempe.

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella.

MEMBER RICCARDELLA: I'm here.

CHAIR SUNSERI: And myself. We'll go

back. Ron Ballinger, have you joined us yet? Okay. He was just on another line with us. I guess he'll join shortly. But we do have a quorum. So we will proceed on.

The ACRS was established by the Atomic Energy Act and is governed by the Federal Advisory Committee Act. The ACRS section of the U.S. NRC public website provides information about the history of the ACRS and provides documents such as our charter, bylaws, Federal Register notices for meetings, letter reports, and transcripts of all full and subcommittee meetings, including slides presented at the meetings.

The Committee provides its advice on safety matters to the Commission through its publicly available letter reports.

The Federal Register notice announcing this meeting was published on November 20, 2020 and provides an agenda and instructions for interested parties to provide written documents or request opportunities to address the Committee.

The Designated Federal Officer for this meeting is Ms. Zena Abdullahi.

During today's meeting, the Committee will consider the following, a BWRX-300 topical report on reactivity control, and we will proceed into report preparation if time permits.

A phone bridge line has been opened to allow members of the public to listen in on the presentation and Committee discussions. We have received no written comments or requests to make oral statements from members of the public regarding today's session.

There will be an opportunity for public comment. And we have set aside time in the agenda for comments from members of the public attending or listening to our meetings. Written comments may be forwarded to Ms. Zena Abdullahi, the Designated Federal Officer.

A transcript of the open portion of the meeting is being kept. And it is requested that speakers identify themselves and speak with sufficient clarity and volume so that they may readily be heard. Additionally, participants should mute themselves when not speaking. And that's all.

So, as far as opening remarks, I really don't have anything else to add. Our agenda is fairly abbreviated for this session. Over the course of the entire meeting, we will be looking at two letter reports in preparation for our Commission briefing, along with a planning and procedure session.

So that's all I have for my opening remarks. Any members care to make any statements before we get into the agenda? All right. I'm not hearing anything.

So our first topic is BWRX-300 topical report. This session is characterized as open and closed. And Dr. March-Leuba is our lead member on this. And so I will turn it over to Jose at this point.

MEMBER MARCH-LEUBA: Thanks, Mr. Chairman. We are going to be listening about the reactivity control design requirements in the topical report for the BWRX-300 from GEH.

And before we start, I'd like to remind the members that GEH has chosen to protect our intellectual property. And there are many proprietary issues on this topical report.

So, if the questions -- we have a closed phone line that we can jump to if there are questions that get into the proprietary nature. So, if I feel that we are going that direction, I will use the magic words of let's table this for the proprietary session, the closed session, and please don't -- at that moment, let's move to the closed session.

That said, I want to thank both the staff and GEH for making the extra work to make all the presentations open so the public can learn about this novel design.

And we, the Commission, or not the Commission, the Committee heard about all the proprietary and detailed information in the subcommittee meeting just last month.

So, with that said, I believe the staff is going to make the introductory remarks. So, Mike, are you ready?

MR. DUDEK: I am. Thank you, Lead Person March-Leuba and Chairman Sunseri and the rest of the full Committee. Thank you for your time today.

On behalf of the staff, I'm just going to give brief opening remarks on this third topical report from GEH on reactivity control that requested us to review their design requirements, analytical methodology, acceptance criteria, and regulatory basis associated with these reactivity control functions for their small modular reactor design. As you stated, a lot of this is proprietary and information that we should protect.

This meeting comes off the heels of a very successful subcommittee meeting. And I think that we are prepared to discuss anything that you have or answer any questions that you have.

So, without any further ado, I turn it back over to you. And thank you guys, thank you, Committee, for your time today.

MEMBER MARCH-LEUBA: Thanks, Mike. So it's time for GEH to start their presentation.

MR. WADKINS: Thank you. This is George Wadkins. I am the Vice President, New Power Plants and Products Licensing for GE-Hitachi.

Today we will be presenting an overview of the BWRX-300 small modular reactor design features for reactivity control, including a brief description of the content for licensing topical report NEDC-33912P, BWRX-300 Reactivity Control.

As noted in our previous discussions with the ACRS members, the BWRX-300 built upon our extensive experience in boiling water reactor technology, including our most recent experiences in development and certification of the Economic Simplified Boiling Water Reactor or ESBWR.

The BWRX-300 is the tenth generation of GE boiling water reactors. And the BWRX-300 design leverages the use of proven technology to the greatest extent possible while incorporating advances in 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. Many of these advances will be discussed today.

I first want to thank the NRC staff for their in-depth review of this licensing topical report. It is obvious to GE-Hitachi that the safety review completed by the NRC staff was thorough and focused on ensuring that the content of the licensing topical report was complete, understandable, accurate, and met the applicable regulatory requirements and guidance.

As previously requested by the ACRS, we are providing for an extensive open discussion of the content of this licensing topical report. During our presentation, we will pause at the end of each slide to allow for questions from the ACRS members. But please feel free to raise questions at any time.

If the discussions involve proprietary information, then we will request tabling the question until the latter closed session.

So, proceeding on to slide 2, the purpose of today's presentation includes an overview of the BWRX-300 design features involved in the mitigation of licensing basis reactivity events.

This includes how the BWRX-300 design complies with the applicable regulatory requirements and guidance and how the BWRX-300 design provides for defense-in-depth shutdown capability and reactivity control.

The licensing topical report addresses design requirements, acceptance criteria, and regulatory basis for the BWRX-300 reactor protection system, or RPS for short, and other design features for reactivity control and mitigation of anticipated transients without scram, or ATWS for short.

I will now turn over the presentation to David Hinds, principal design engineer for the BWRX-300, to discuss defense-in-depth design features for BWRX-300.

MR. HINDS: Hello. This is David Hinds. I will first check to ensure you can hear me.

MEMBER MARCH-LEUBA: We can hear you.

MR. HINDS: Okay. Thank you. All right. So this is a very brief summary of our licensing topical report. I'm trying to touch on technical and the associated licensing input information.

And again, if there's detailed questions, we'd be glad to take them. Some of them we may take for the next session.

So, in BWRX-300, we apply a very detailed defense-in-depth approach to the design across the board. And we base that upon the fundamentals of the IAEA approach for defense-in-depth. We think it's quite rigorous and easy for our engineering team to follow and align to.

So we have applied that approach, which uses a defense line approach such that it's very clear as to where the layers of defense-in-depth are.

And for this discussion today and this licensing topical report, we are focused on the defense-in-depth approach associated with the fundamental safety function of reactivity control.

Of course, we have defense-in-depth for the other fundamental safety functions. But, again, this is focused only on reactivity control today, which is to ensure defense-in-depth for shutdown capability and reactivity control. If you could, move to the next slide, please.

So, in keeping with what I just stated about our defense-in-depth approach, I'll walk briefly through our defense lines.

We begin with defense line 1. And defense line 1 is the fundamental design approach where we do, we apply a high level of quality and reliability and conservatism into the design.

And some of those design approaches that we use for defense line 1 help to reduce challenges to the plant from a trip perspective, reduces the trips per year, reduces the numbers of AOOs. We use a very rigorous operating experience review approach.

And as George stated, since this is the tenth generation of our boiling water reactors, we have a long lineage of operating experience to draw from to build upon and continuous improvement. Next slide, please.

Just to highlight a few of the associated design features in the plant associated with reactivity control, we'll start right at the basics of control rods.

So our control rods -- and, of course, this is not to scale. Our control rods that we're using have a long period of operating experience. We're using control rods that are already receiving operating experience in the current fleet of boiling water reactors.

And this is just showing a visual for anyone that's not used to looking at the figures, and on the right, just shows a visual of how the control rod fits in a control cell or fuel cell with four fuel bundles surrounding the control rod blade.

So it is a proven design, a high level of reliability. And we have even, in addition to the high reliability that we're currently achieving with our control rods, we have done some additional things (audio interference) for the blades, the control rod blades.

We've applied a, what we call an in-lattice core such that we have a slightly larger water gap there for the control rod blades to travel between fuel assemblies, helping to minimize any potential for binding or prevention of movement of the rods upon demand. So we've slightly increased the pitch from fuel bundle to fuel bundle, gives plenty of margin for control rod movement.

We're also using advancements in the fuel channels that helps to minimize any chance of deformation of fuel channels. We are collecting operating experience on those channels today. We have no evidence of shadow corrosion on those NSF type channels that we're using.

And these, this type of design, it also helps ensure we have a very high degree of shutdown margin as well. Can you move to the next slide, please?

So, just touching on some of the associated regulations, and then I'll continue through the defense lines as well. So 50.62, 10 CFR 50.62 was one of the regulations that was addressed in the licensing topical report.

In that regulation, one of the explicit requirements is for alternate rod insertion system. And we do have the ARI system, which we have experience with on our current operating fleet.

And in the slide here, I have the brief summary of the hydraulic scram function or hydraulic ability to insert the control rods.

So our control rods are driven on the BWRX-300 by fine motion control rod drives. Our older plants have hydraulic only or locking piston control rod drives.

The BWRX-300, just like the ABWR and ESBWR, apply a newer design, which also has operating experience of fine motion control rod drives. They have motors to, electric motors to provide the normal control rod movement in both directions, insert and withdraw, for very small and fine motion. That's for normal power control and also serves as a backup to hydraulics for quick shutdown.

The hydraulics are there on this design, unlike the current operating fleet of only hydraulic, the hydraulics on this design, as water hydraulics, are only there for the purpose of fast shutdown, i.e., scram.

So we use pressurized water in accumulators, stored energy. Many of you, if not all of you, are probably quite familiar with the operating fleet of the HCUs.

So we have redundancy by providing hydraulic control units. Two control rods are aligned to each HCU. We have, the HCUs are actuated by a reactor protection system. And in the BWRX-300, we also have a diverse means.

Then, we additionally have a ARI function that will depressurize the scram air header if necessary to provide further backup for insertion or reactor scram if needed.

So this is somewhat of a busy slide. But it's somewhat busy because we have many ways to get to the control rods. And so I'll run back through again, because I maybe jumped around a little.

Control rods normally inserted and withdrawn by electric motors through the fine motion control rod drives. They're inserted with hydraulics for fast shutdown in a scram. The hydraulics are actuated by our reactor protection system. And there's also a diverse means to actuate them.

In addition to those two means to actuate the hydraulic control units, if there's a common cause failure of hydraulic control unit actuation, there's a diverse ARI, depressurization to cause the scram as well.

So that's basically three ways to get the hydraulics and the electric motors, also in addition to their normal power control, can provide a backup to insertion during the case of a failed scram. So that's a little, brief summary of a little complicated discussion.

But in addition, at the very bottom of this slide, for those who are quite familiar with the operating fleet hydraulics, one of the possible, not likely but possible, failure modes was hydraulic lock of the scram discharge volume.

I'll note that on this design we've additionally incorporated a way to remove the scram discharge volume. And it's just a one-way insertion of hydraulics. Okay. If we could, move to the next slide, please.

MEMBER MARCH-LEUBA: Jose. By that, you mean instead of discharging into, a dedicated volume will discharge into the vessel, correct?

MR. HINDS: That is correct. Okay. I'll keep on moving. And I'll be glad to take questions any time.

So defense line 2 is -- so defense line 1 is more programmatic and fundamental features and design decisions, such as the in-lattice.

Once we get into defense line 2, 3, and 4, we have systems and features that may actuate or control to improve safety of the plant or to respond to an event.

And defense line 2, that includes functions that normally control the plant, such as pressure control, water level control, things, rod control, normal control features of the plant.

And we have a high level of quality applied to defense line 2 than just plain non-safety equipment, but not to the pedigree of the full safety-related or safety class 1 equipment. However, it does have enhanced quality and reliability features applied to the design and the procurement.

The defense line 2 is, includes functions to control or stop postulated initiating events. You know, I mentioned pressure control and level control, key features in control of the plant.

So the quality that we place and the redundancy that we place into these systems minimizes postulated initiating events that could challenge the safety class 1 or safety-related systems that will be in defense line 3 as I get to that.

Defense line 2 is independent from defense line 3 all the way through, provides a high reliability and, again, reduces the challenges to the plant from a trip perspective. If you could, go to the next slide, please.

Here's another design feature just highlighting, of course, the reactor pressure vessel. Just to, there are many things to talk about on the reactor pressure vessel, but I'll only highlight a couple of them.

One is, this is a natural circulating boiling water reactor similar to the ESBWR but smaller in size. So we took ESBWR concept, and we scaled it to a nominal 300-megawatt electric power plant.

However, many of the features that come with natural circulation are quite helpful in mitigating events.

So the part I'll highlight here is large steam volume. It's a higher volume to power ratio as compared to, for example, the ESBWR. So the high volume to power ratio minimizes any pressurization transients.

However, in part of our defense line 1 design decisions, we added conservatism in. Even though we have that larger volume to power ratio, we have chosen to raise the design pressure from our historical values such that we have additional margin in the design pressure of the reactor vessel, and we have a higher volume to power ratio. So, therefore, the pressurization transients are not a challenge for this plant.

And we've already gone through a previous LTR, as listed here, for the reactor pressure vessel isolation and overpressure protection. However, that overpressure or that volume to power ratio and the minimization of pressurization helps also in reactivity abnormal events such as a slow or failed scram. Okay. If you could, go to the next slide, please.

Defense line 3 is the heart of safety. That's our highest safety class right in the middle of our defense-in-depth and posture. So safety class 1 or safety-related systems reside in defense line 3.

And it includes the functions to mitigate a postulated initiating event, assures the plant is placed in a safe condition, assigned the highest safety class. And we ensure that we have independence from defense line 2, and for that matter, independence from defense line 4 as well.

MEMBER MARCH-LEUBA: Dave, this independence from DL 2, is there going to, do you -- obviously, you have the final design. But you won't have any detailed communications between the control system and the protection system, DL 2 and DL 3?

MR. HINDS: They are separate digital control systems. The only potential would be for protected communication, for example, one-way information sharing, but not -- there will be protected communications, if any. They are completely separate systems.

MEMBER MARCH-LEUBA: Most likely, I would imagine, the communication will go from DL 3, if a scram happens, and you pass it to the control system.

MR. HINDS: Yes.

MEMBER MARCH-LEUBA: And those should be unidirectional.

MR. HINDS: Yes.

MEMBER MARCH-LEUBA: And when we review the details, we are going to be very interested on the architecture and make sure that those unidirectional communications are really unidirectional.

MR. HINDS: I understand.

MEMBER MARCH-LEUBA: Okay.

MEMBER BROWN: By that he means not software configured. This is Charlie.

MR. HINDS: Okay. I understand.

MEMBER BROWN: Hardware, data diode type, one way, not configured by software.

MR. HINDS: Okay. I understand. And we'll have, for any license submittal, we would go into, of course, great detail on the I&C architecture and address those features. But I understand your comments. Thank you.

MEMBER BROWN: And I presume that will be covered in the, when we finally get to a reactor protection system topical report or whatever you're going to issue for that, will provide that as well as the information of how you intend to achieve, not the detailed parts, obviously, but the architecture approach --

MR. HINDS: Yes, for future licensing submittals, yes. Now, there's further decisions to be made as to whether they would be under a licensing topical report or under an actual application. But, yes, I agree with your statement.

MEMBER BROWN: Okay. That's fine. I just wondered where it's going to be, because, I mean, when I went through the other, these other documents, so far there's -- you talk about the RPS as an RPS and you say what it's going to do, but there's no other details. That's all.

MR. HINDS: That is correct. Your review is correct. So I agree with your statements.

MEMBER BROWN: Okay. Thank you.

MR. HINDS: Okay. If you could, move to the next slide, please.

Okay. One of the key systems within the highest of safety classes, in addition to the reactor protection system, is the isolation condenser system.

So I mentioned that the RPV itself has certain pressure mitigating features by its volume to power ratio. However, the pressure control is primarily at least in the safety class 1. In an event where we have an isolation, we use an isolation condenser system.

We inherited the design from ESBWR as far as the condensers themselves. We are applying three trains of the same size of condensers that we applied on ESBWR.

So, by doing that, with this smaller power plant, we have a very large margin and significant capacity for minimizing any pressurization transients and controlling any challenge to pressurization by use of the isolation condenser system.

It primarily operates in a passive mode. This is a very simplified figure that doesn't show the valves. There are valves in here.

But all it takes to actuate the system is the opening of one valve in the return line, the condensate return line to the vessel. And there are parallel, diverse means in that condensate return line to actuate. And in the worst case, if we were to lose all power and signal, it fails in the in-service condition.

And again, there's redundancy here as well with a very simple actuating system. Once placed in service, it stays in service and requires no support features once placed in service.

Again, there's three trains. We have them as a staggered operating points for the automatic initiations on pressure such that they don't all come into service at the same time. But in a severe event where, such as a complete failure to scram, we would expect to hit all three and use them to mitigate the event.

Again, failsafe, simple system. And again, we drew upon the program from ESBWR, which included a full-scale test of these isolation condensers. And we also covered this design feature in our previous LTR for overpressure protection as well.

MEMBER MARCH-LEUBA: Dave, this is Jose again. Typically when we do these things, we have competing requirements. From the thermal-hydraulic point of view, it's super exciting to have extra capacity because you can cool down better. You can cool down more and you can cool down with failures.

From the criticality safety point of view, you can bring the core to cold. And I'm going to ask you to remind us that no matter how cold the core gets, even with two blades stuck out, you are not going to return to power. That's your requirement, is that correct?

MR. HINDS: That's correct. We, as I've mentioned before when I was talking about the hydraulic control units, we have one hydraulic control unit aligned to two control rod drives. And we assume a failure of one of those hydraulic control units and still have adequate shutdown margin.

We have ample shutdown margin. In fact,

I think we'll be fine with more than that. However, that's what our analyzed state is, is two stuck-out control rods with ample shutdown margin.

MEMBER MARCH-LEUBA: And you plan to do this with all three ICS running at full blast and making the core as cold as it can possibly get?

MR. HINDS: Yes, within reason, yes. So yes, agree with your statement.

MEMBER MARCH-LEUBA: Thank you.

MR. HINDS: So we do have, you know, temperature extremes on our analysis. I think that's permanently addressing your point. And I'll note that we do include some design enhancements from the ESBWR. To get into details on those, if you're interested in getting that level of detail, we'd prefer to discuss that in the closed session.

But it does help with, I'll just simply state that those design enhancements improve the pressure control while helping with the reactivity control. So this system helps with pressure control while at the same time assisting with reactivity control. Okay, if we could go to the next slide, please.

MEMBER KIRCHNER: David, this is Walt Kirchner. So going back to your statement, you mentioned there's defense line 3 is the highest quality class, I'm -- or safety class. I just assume that the reaction coolant pressure boundary as illustrated in this diagram then would also be of the highest quality.

MR. HINDS: That's correct.

MEMBER KIRCHNER: Safety-related if you're using 10 CFR 50 or 52 definitions.

MR. HINDS: Yes, that is correct. And we've applied --

MEMBER KIRCHNER: Thank you.

MR. HINDS: We've applied the IAEA approach, we've been using terminology of safety class I, II, and III. But I agree with your statement. And so this system is a safety class I or safety-related system highest safety class, that's correct.

MEMBER BLEY: David, this is Dennis Bley. I want to go back to what Jose was talking about. And I don't think it's for this current report, but later when we get to this design cert review, you mentioned that the intent is to have maximum ICS occur.

You know, in the past, at least in some places, people have worried that that was too much and developed thoughts about how to cut it back, which can lead to significant problems. We'll be interested in discussing that when we get into details, that system.

MR. HINDS: Okay, thank you. And the part when I mentioned, alluded to some design enhancements, and I'll be glad to discuss a little further in a closed session, will help with your question as well. So I understand your question. And that staggered set point that I mentioned earlier, that also helps with your question as well. But I understand it.

So we have evaluated inadvertent IC actuation as part of our standard suite of analysis, and so I understand. Okay.

MR. SCHULTZ: Dave, Steve Schultz. In the system that you've described, the return valves fail open, and also they're -- the system is failsafe. With regard to operator action, any operator actions that are proposed or could take place that would close those valves?

MR. HINDS: No, the operator is not -- okay so I think you asked that, I'll address your question in two ways, and hopefully one way will answer you. It is one is that the system completely actuates without operator action. I think the other side of your question is could the operator cause a problem by disabling the safety function.

We have that as a design requirement to

ensure that the proper human factors, of course there will be operators and the operators will be expected to be aware of this situation and monitor. Part of our human factors design will take into account the human reliability analysis and potential that an operator could disable a safety function.

And our intent that we're still working through is that that would not occur. It is an automated system and so I do not think that's difficult to achieve.

MR. SCHULTZ: Good, thank you.

MR. HINDS: Okay, thank you. If we could move to the next slide, please. Okay, so now we're up to the backup defense behind the safety-related systems, which should hopefully never be called upon. So, defense line 4-alpha, and we've take the IAEA defense lines 4 and split to 4-alpha and -bravo. Won't talk much about 4-bravo, it's more like the flex or deep defense-in-depth.

But in the defense line 4-alpha, we have functions to mitigate the postulated initiating event, similar to the goals of defense line 3, but it's in a backup way. And this is there to mitigate times when defense line 3 or the safety-related systems are called upon and experience a common cause failure.

They're ensured -- they also ensure that the plant is placed in a safe state.

If you go to the next slide, please.

MEMBER MARCH-LEUBA: Dave, go back to this slide.

MR. HINDS: Sure.

MEMBER MARCH-LEUBA: And have you ever seen a non-proprietary setting, an example so we can think what you're --

MR. HINDS: Yes.

MEMBER MARCH-LEUBA: We can focus on what you're talking about?

MR. HINDS: Certainly, ARI. So I touched on, because I talked about many features of the control rod movement in an earlier slide, I hit may defense lines. So I hope I didn't confuse things there, I was worried about that slide.

So with the control rod insertion, I hit many defense lines there. If you remember, there's many ways to insert the control rods. So an example of the defense line 4-alpha method to insert the control rods is the ARI. And then there's some others where we would get a little further into proprietary. But, and I'll be glad to discuss further. But that's an example, ARI, alternate rod insertion.

MEMBER MARCH-LEUBA: Okay, I'll make a note to ask you in the closed session, because I'm interested. Is this defense-in-depth actions going to be performed by a non-safety-grade computer?

MR. HINDS: They are a lower safety class than what in the US we'd call safety-related. However, we are applying the IAEA approach, so it's not just taken all the way back to what you would think of non-safety as a graded approach to quality. So we've applied a safety class II, which a not all the way to the level of safety-related, but not all the way down to the level of non-safety-related and augmented quality.

MEMBER MARCH-LEUBA: So in I&C lingo, it will be redundant but not diverse?

MR. HINDS: This platform in defense line 4 is diverse from defense line 3.

MEMBER MARCH-LEUBA: All right, but within itself, it will be more than one channel, hopefully three. But they will all be the same type of computer.

MR. HINDS: Correct, this is appropriate level of redundancy, but it could be all the same, it could be all the same technology within the redundancy.

MEMBER MARCH-LEUBA: Okay, thank you. We'll look at those details with the next --

MR. HINDS: Okay.

MEMBER MARCH-LEUBA: Yes, I'm sure.

MR. HINDS: Okay, thank you. All right, next slide please. Okay, just a little bit into -- further into the ATWS rule, 50.62. These are -- this is really a restatement of ATWS rule, which I'm sure you're well aware of. So, but only pulling out the portions of the ATWS rule 50.62 which apply to boiling water reactors specifically, ARI, SLC, and automatic recirc pump trip. Can you go to the next slide please.

Okay, as far as going through those features. So automatic recirc pump trip. As I stated earlier, this is a natural circulating power plant, so therefore the automatic recirc pump trip is deemed to be not technical relevant in that we do not have recirc pumps to trip, so therefore we do not include a recirc pump trip feature.

However, the purpose of the recirc pump trip is to minimize a reactivity in the case of a failure to scram, and we do have other features to minimize reactivity in a similar fashion.

So basically we can control water level

within the reactor, and the enhancements that I mentioned for the isolation condenser system that I can discuss further in the closed session help in this respect as well. We, the feedwater system is controlled as well to minimize reactivity effects. Okay, if we could go to the next slide, please.

So the SRP, we just stayed a little bit out of the SRP, and I'm sure the NRC will cover this further, so I'll go over it very quickly, is the SRP related to 15.8, related to the ATWS rule. And there is a statement in there, in the SRP, that talking about evolutionary plants, which we think the BWRX-300 is an evolutionary plant.

And it says that you could have a diverse scram system and satisfying design and quality assurance criteria. And/or you could demonstrate the consequences of the ATWS event or within acceptable values.

In keeping with our defense-in-depth approach, we've addressed both of these so we do have a diverse means of shutdown, the details of which I've kind of alluded to at a very high level, but I can talk a little further in the closed session. But we do have a diverse means to shut down. I talked about it a little bit in a very high level in the prior slides. We do have ARI and we do have electric motors to move the control rods that are in addition to the normal hydraulic scram.

I've listed there, a little bit to the question a minute ago, where ARI and electric motor run-in are included in defense line 4-alpha. And there's multiple defense lines that are ensuring the hydraulic insertion occurs as well in defense line 2, 3, and 4-alpha.

MEMBER BROWN: Does the next -- this is Charlie Brown.

MR. HINDS: Yes.

MEMBER BROWN: Does the fine motor control drive, is that able to insert rods at a fast enough speed to handle the reactivity transience? Is that -- it's intended to do that as well?

MR. HINDS: Yes. So it's -- great question. It's, during normal operation, we want the fine movement to minimize the reactivity effects at high power, for example. However, the speed is calibrated such that we have an insertion capability that is fast enough to handle the complete failure of all of the other means to get the control rods in.

So if all of those other means that I discussed on the hydraulic actuation, as well as the

ARI, all of them fail, the control rod insertion by motors is fast enough. And that's coupling that with the pressure control features of the isolation condenser system that I just talked about earlier. So short answer is yes, it is fast enough.

MEMBER BROWN: Is, does that -- based on your comments, does that mean it has more than one speed? In other words, for insertion it can go faster than you would -- than you would necessarily for your fine motion control during normal operations?

MR. HINDS: We're actually still working on whether we're going to adjust the speed any during normal operation, but we do have this setting for the rapid insertion, as we discussed here. We're planning to use servomotors, which have a capability to move at variable speeds. So it's likely that we will have a slower speed during high power operation, but we're still working through making that decision. But it's an excellent question.

MEMBER BROWN: Okay, thank you.

MR. HINDS: Okay, if we can move to the next slide please, I'll try to wrap up.

MEMBER MARCH-LEUBA: While we're on the open session, let me just say that we, ACRS, are going to be terribly interested. I know you, the design team, has spent a lot of time thinking about ATWS and during the review, both the staff and ACRS are going to be very interested in this topic when you have the final design and the final calculations to ensure that nothing can go wrong. Just putting it on the record, and we'll talk more about this in the closed session.

MR. HINDS: Okay, all right, understand. So just a brief summary here, don't -- hopefully don't need to go into much detail. But here's the listing of regulatory acceptance criteria, all pulled from regulations. So I don't think any, should be any surprises here. So we have pressure requirements, fuel integrity, containment integrity, rad release, and ensuring that shutdown and long-term cooling are all evaluated and analyzed.

Okay, if no questions there, I'll keep on moving and trying to keep the time moving. Okay, and so I think this is the last slide in this --

MEMBER BROWN: Sir, can I ask one other question? I kind of forgot.

MR. HINDS: Sure.

MEMBER BROWN: You mentioned this as back on the speed of the time motion motor controls.

MR. HINDS: Yes.

MEMBER BROWN: You mentioned that that was going to be servos.

MR. HINDS: That's our intent, yes.

MEMBER BROWN: Okay. And --

MR. HINDS: We do have some options there where we have some motors that we've used previously that are stepper motors and we have some motors we've used previously that are induction. But our current preference is servos. We've not procured them yet, so there is a chance that that would change, but our current intent is servomotors.

MEMBER BROWN: The reason I ask is that servomotors don't always have the same torque characteristics that an induction motor or even a step motor. I'm familiar with both the step motors, I had rod control systems that were step motors in my old plants in the Navy, in one of the design plants. And the motor control were basically reluctance motors, which you could control and make sure they had enough torque.

But servomotors don't always have a lot of torque since they're pretty fine control type devices. That was my only question is are those really satisfactory for a higher speed type insertion where you might need to generate some additional torque. That's the only thought process I had.

MR. HINDS: Yes, we have applied torque specifications to our motor supplier and not had any problem to date with aligning to get a supplier for that. But I agree with your focus on that topic. We do not think we'll have a problem meeting it.

MEMBER BROWN: Okay.

MR. HINDS: But again, we do have further work to be done and through the procurement cycle, but we do have a supplier that we think can meet our requirements there on torque.

MEMBER BROWN: Okay, thank you.

MR. HINDS: Okay.

MEMBER MARCH-LEUBA: The rules of the game -- this is Jose -- the rules of the game is, we don't design the reactor for you, but in my opinion, I would go for the highest torque, the biggest force you can have on that FMC, I mean, the fine motion control rod drive, the electric motors. So that even if there is some binding, you can push the rod in. And I can control the velocity by stepping it slowly with a step motor.

Just think about it. I mean, the safest thing is to have the high -- the biggest motor you can find that will push the rod in no matter what. And -- okay, that's it. I'm not helping you design your reactor, but just giving you some hints.

MR. HINDS: Okay. Okay, thank you for the comment, I understand the nature of it. Thank you.

So the final slide here in this segment is we did highlight another one of the regulations, the GDC 27, and we just highlight it here because we go through in the LTR and evaluate all the appropriate GDCs and regulatory documents associated with reactivity control. And I'll highlight this one in addition to the ATWS rule, just because we had an alternate means of compliance or actually an exception.

And it's primarily just the wording of the GDC and that the GDC is, so you can see above, the reactivity control system shall be designed to have a combined capability in conjunction with poise and addition by ECCS of reliability, the reliability controlling reactivity changes to assure under postulated access. Anyway, you can read it.

We changed the words but meet the intent, just because the words didn't explicitly align with our design since we are, as stated in our prior submitted LTR and reviewed LTR on the RPV isolation and overpressure protection. We do not rely upon ECCS injection systems and associated borated coolant.

And therefore the wording of this did not explicitly apply, so we've reworded it but still meet the intent such that core coolability is maintained for a locus. Because we have sufficient water inventory, and we're assuring that through the RPV isolation. So we preserve the coolant and we do not have a borated solution and there's no concern with ECCS injection diluting a borated system and causing a reactivity excursion.

So this -- I think, we feel like was written for different type designs, and so we've applied a PDC to substitute for the GDC, and that's an exception stated in the LTR.

MEMBER BROWN: Presume when you do your submittals in whatever form they are, they will somehow address the fact whether the plant will be able to be shut down under all temperature conditions, the sub-critical as opposed to perking along at low power for weeks?

MR. HINDS: Yes, and as I stated before, as we do our shutdown margin calculations with the two highest worth control rods associated with an HCU fully withdrawn and we have ample shutdown margin. And we also have a temperature range which we apply to that, and so I think we will not have a problem meeting the point that you're alluding to.

MEMBER BROWN: Okay, thank you.

MR. HINDS: Okay. That's it for the slide presentation, and I think I've exceeded my time, I'm sorry.

MEMBER MARCH-LEUBA: Well, you did good. Just as a reminder to the members, we are going to have an open presentation by the staff, and then we are going to go to the closed session to see some details of calculations by GEH. And we have plenty of time.

Our plan is to read the letter, the ACRS letter in the open session, so we will have the staff present open session here. We will all, that are allowed to, move to the closed session to see those calculations, and then we'll come back to the open session to read the letter.

And on that line, GE, Zena is going to send you the final copy of the letter, because we've made some modifications based on members' inputs. And if you could give it a quick read to make sure the modifications did not put any proprietary information on it, we would appreciate it. And we have to do it real fast.

So staff, can you start your presentation please.

MR. NOLAN: Okay, thank you. This is Ryan Nolan. I'm in the Nuclear Methods and Systems and New Reactors Branch in NRR, and I'll be presenting the staff's presentation for our review of the BWRX-300 reactivity control topical report. And I will be assisted by Marieliz Johnson, who is helping me with the slides today. Marieliz, you can go to the next slide.

So here's an outline of the presentation today. We'll quickly go through the review team, a little bit of background on the BWRX-300. The bulk of the presentation will focus on the staff's review of specific regulatory requirements, and we'll wrap up with the conclusion.

These slides are very similar to what you saw in the subcommittee meeting. However, I plan on just touching the highlights and not going into the full detail that we did in the subcommittee meeting. However, if there are questions we can certainly go into more details. Next slide, Marieliz.

So this is just to present the review team, many of which are here to support, answer any questions that I cannot. So with that, you can move to the next slide, Marieliz.

So a quick background. BWRX-300, it's a 300-megawatt electric SMR. It's natural circulation, uses a passive cooling isolation condenser. The control rods are typical BWR control rods that we're all familiar with.

This design does include some defense-in-depth and diverse features with respect to reactivity control for ensuring the reactor is properly controlled and shut down. And this topical report goes through specific requirements, design requirements, as well as assesses regulatory requirements specific to reactivity control functions. Next slide, Marieliz.

So here's a short list of the specific design features that are included, or and systems that are included in the BWRX-300 design. I'll just briefly step through each one. The control rod system is made up of control rods, we've already talked about them, GE provided a good overview, as well as control rod drives.

The drives are split up into the safety-related rapid insertion function that's performed hydraulically, as well as a non-safety-related fine motion control function that uses electric motors and is used for normal operation as well as a scram follow-up function as a backup means.

Also, there's an alternate rod insertion system. This provides a diverse means of a hydraulic scram in the event of an HCU failure. And it uses energized to actuate pilot valves. And so it's an alternate means to vent the control air. Next slide, Marieliz.

This is a list of the regulations that we addressed in the safety evaluation. I'm going to go through each. I'll go through the ATWS rule first, and then I will go through each of the GDCs that's underlined. I do not have specific slides on the GDCs which are not underlined. This is mainly due to the means for the requirements or design requirements on certain systems for meeting these requirements are fairly traditional and straightforward.

And so just at a high level, the GDCs which are not underlined, the staff found that the approaches described in the topical report were consistent with the associated GDCs, and we found those to be acceptable. So with that, we'll talk about 50.62 on the next slide. Marieliz.

So the topical report defines the acceptance criteria for evaluating the effectiveness of the reactivity control systems and functions. It's listed here on this slide. These are consistent with the SRP, as well as it's consistent with the acceptance criteria that the operating fleet has used to evaluate the ATWS transients. Next slide, Marieliz.

So first, specific requirement for 50.62 related to BWRs is C3. This requires all BWRs to have an alternate rod insertion system that's diverse from the reactor trip system. This is fairly straightforward because the BWRX-300 uses a fairly traditional ARI system. They commit to having one, and so the staff found that that approach is acceptable and consistent with the requirement. Next slide.

50.62(c)(4) requires BWRs to have a standby liquid control for injection into the vessel. The topical report specifies that the design will meet the risk goals for 50.62, which is a probability of an ATWS is less than one times ten to the minus five per reactor year. This is achieved through diverse scram actuation logic, diverse rod motor force, as well as a couple other things that is proprietary.

The staff found that this risk goal is consistent with the intent of 50.62, and this could be used as -- to support a future exemption if so desired. We did write a limitation and condition on this, next slide. We wrote several limitations and conditions in certain areas where the topical report maybe didn't go into a lot of detail as what type of analysis will be performed in the future.

And so we just wanted to clarify some of the staff's expectations or what we would expect to demonstrate some of the statements that were included in the topical report. So specific to ATWS, we have a limitation and condition to provide a reliability analysis that takes into account operating experience in order to demonstrate that the probability of an ATWS is less that one times ten to the minus five per reactor year, demonstrating the intent of the rule is satisfied.

50.62(c)(5) requires BWRs to automatically trip the recirculation pumps under ATWS conditions. This one as well is fairly straightforward. It's not applicable to the BWRX-300 because it is a natural circulation -- a plant does not have recirc pumps. And so this regulation is not applicable to the BWRX-300. However, the design does have compensating measures, which is proprietary, and we did discuss at the subcommittee meeting. Next slide.

So now we're going to step through some of the general design criteria. The first one is GDC 12, which requires control and protection systems to ensure that oscillations that could exceed the SAFDLs are prevented or they're detected and suppressed.

The topical report specifies that the BWRX-300 will meet GDC 12 through several design features, some of which are included here, which is a small core, sort of a newer of form of orifice design, a coupled power to flow response, as well as the design of the RPB chimney. We wrote a limitation condition on this as well. Next slide.

And this is really just to ensure that the analysis which demonstrates some of the statements made in the topical report is performed using an approved method. And that's really the intent of this limitation condition, is to make sure that there is an appropriate analysis to demonstrate GDC 12 is met.

MEMBER MARCH-LEUBA: Ryan, this is Jose. We talked about some of this in the subcommittee. When we say approved method, do we need to have a topical report that says NRC approves it for use in the BWRX-300? Or an approved method for ESBWR is acceptable? Or does it need to be extended? Can you talk a little bit about approved methods?

MR. NOLAN: Yeah, yeah, we did talk about it a little internally as well, just briefly. And there needs to be demonstration that the topical report is applicable to the BWRX-300. I think there's some flexibility in how that's done. Traditionally that is done through topical reports.

But I think the staff is open and is flexible to how that is documented. So I think at a minimum it needs to be documented somewhere. Traditionally it's the topical report, but it probably doesn't have to be.

MEMBER MARCH-LEUBA: Okay, so we'll revisit this in the future, and it's for GEH and the staff to negotiate what will be acceptable. Clearly, I think we all agree, even GEH, that the recommendation needs to be performed. And the question is how we do it with minimal pain. Okay, thank you.

MR. NOLAN: Certainly. Next slide. So GDC 26, it requires two independent reactivity control systems based on different design principles. The topical report specifies that the BWRX-300 will meet the GDC by providing control rods, which is used for normal operations including AOOs and addresses malfunctions, as well as holding the reactor subcritical under cold conditions.

And then the feedwater level control system is used to satisfy bravo above, which, you know, is used to adjust the reactivity control during planned and normal power outages. And this of course is something that we will review obviously in more detail once we get an application. But as described in the topical report, it is consistent, the approach is consistent with GDC 26.

So GDC 27, the intent of the GDC is to require reactor designs to achieve and maintain subcriticality, and this is using only safety-related equipment following accidents, as well as addressing, taking into account single failures. And as was discussed by GEH in their presentation, they proposed a PDC.

It maintains fundamentally all of the same information that is in the GDC, with a focus of just satisfying the intent of that regulation. And as was discussed already, the BWRX-300 will use the control rods to ensure that the reactor remains subcritical under cold conditions.

We do expect to see an analysis in the future which would demonstrate this. That analysis would look at both, you know, instantaneous shutdown margin, as well as, you know, a long-term shutdown margin, which would account for, you know, any cooldown from the isolation condensers.

MEMBER KIRCHNER: So Ryan, this is Walt Kirchner. Just a process question. So they are proposing a PDC in lieu of the GDC, and then in the actual review of an application, then this would require a formal exemption.

MR. NOLAN: That's correct. I think, you know, as we, you know, we've been reviewing some interesting designs recently and some exemptions are maybe more administrative in nature and less technical, and perhaps this would fall into that category.

So technically from a legal perspective, yes, it would require an exemption. However, I don't think it raises any substantial technical issues or concerns at this point. It's more just a matter of documenting it.

MEMBER KIRCHNER: Yeah, and analysis will demonstrate that they have the rod work necessary to keep it shut down as in subcritical through a range of conditions. And it's been brought up earlier, you know, obviously it's the temperature, it's the cooldown that would be something to look at in the future.

Okay, I'm just checking how you're doing this now. And then this would be consistent with the requirements also of 10 CFR 50 or 52 then in terms of a safe shutdown condition.

MR. NOLAN: That's correct.

MEMBER KIRCHNER: Yeah. I noticed that the GE used the, I think it's the IAEA language, they talked about a safe state. But I suspect for the staff, you would be looking for what's required as for 10 CFR 50 or 52.

MR. NOLAN: That's correct. And we documented in our safety evaluation specifically the interpretation that the staff has on GDC 27. And that was pulled from the recent SECY paper that we wrote where we specifically state the intent is, and it's a first bullet here, you know, the intent is to maintain long-term subcriticality using only safety-related equipment.

MEMBER KIRCHNER: Excellent, thank you.

MR. NOLAN: Yup. Next slide. So GDC 28 requires that reactivity control systems be designed with appropriate limits on the amount and rate of reactivity increase to ensure that reactivity accidents can neither damage the reactor pressure boundary or disrupt the core or the internal structures to a point where it impairs significantly the capability to cool the core.

These types of events are called out specifically in GDC 28. Some of them include, you know, rod ejection, rod dropout, things of that nature. The topical report states that the BWRX-300 will meet GDC 28, and this is through a series of design features of the control rod drive system in its ability to limit the rate and amount of reactivity increase, as well as a safety analysis which demonstrates compliance with the requirement.

And so this analysis would look at control rod drop accidents, and in the topical report GE has committed to using, you know, existing approved methodologies to perform that analysis. It's a similar analysis which was performed for the ESBWR. And so the staff found this approach to be consistent with the GDC.

This is the final limitation and condition specific to a control rod drop accident. Again, this is really to document the staff's expectation that this analysis be performed using design-basis assumptions, as well as using approved methods. And we tried to write some flexibility into this condition as well.

And so we provided also another option if GE wants to go a different route that they could demonstrate perhaps that the control rod accident is a beyond-design-basis event and do a sort of a different type of analysis and include that into Chapter 19. Versus a, you know, more of a traditional transient accident analysis, what we typically would refer to as a Chapter 15 analysis.

And so that was just to establish sort of expectations and provide some flexibility for the future.

MEMBER MARCH-LEUBA: Is there a real need to do that? I mean, we have all the methodology and GEH knows how to do the rod drop calculations on a cycle-specific basis. It doesn't save any money, it doesn't make anything easier to try to change what we're doing. In my opinion, yes, continue to do what you're doing for operating reactors, which is every cycle, just analyze the rod drop and do it.

MEMBER KIRCHNER: Yeah, just to add to what Jose's saying, I would expect they're all -- that the applicant, or GEH in particular here, I mean, they're well experienced and must be totally up to date on DG 1327, I don't remember what it now is as a final reg guide, as Jose suggests. So it would seem to me that the path forward for expediting one's way through the licensing review would be to stick with the current rod drop analyses.

MR. NOLAN: Yes, I think the staff would find that acceptable. The reason this is here is really rooted in the way the original topical report described this analysis, as well as some of the RAI responses. And so we wanted to just be very clear of what our expectation was that it be a design-basis safety analysis, as well as I think GE proposes a one-time analysis to bound cycle-by-cycle variations.

But we wanted to clarify that it doesn't have to do that. And I think we felt that this condition provided that flexibility and clarification that we needed to make the finding from a compliance perspective.

MEMBER MARCH-LEUBA: I agree with you, Ryan, that either way it satisfies regulations. But the path of least resistance is do the calculation and recycle. You know how to do it. It doesn't -- maybe we'll GE in the closed session, but I don't think it adds that much cost to the -- I would keep doing what has worked for 60 years, and that's my personal opinion. Thank you.

MR. NOLAN: Yup, and that's what we're

trying to communicate here. We would certainly find the traditional approach acceptable. Next slide, Marieliz. Yeah.

So to conclude here, taking into account the limitations in conditions, the topical report provides an acceptable description of the requirements, the acceptance criteria, and the regulatory basis for the design feature specific to the reactivity control functions for the BWRX-300.

And just as a disclaimer, we don't have the application in front of us at this time, we don't have the detailed design in front of us. And we will evaluate full regulatory compliance at the time that that application or other future licensing activities are submitted to the staff. If an applicant can't demonstrate compliance, you know, we do expect them to justify an exemption to a regulation.

And with that, that concludes my presentation.

MEMBER MARCH-LEUBA: Great. Do we have any questions for the staff in the open session? And just a reminder, there's going to a GEH closed session presentation, and there will not be a staff closed session presentation, but they will be able to answer questions if necessary.

So any questions?

MEMBER KIRCHNER: Jose, this is Walt again. This is not a question, maybe a statement. I'm just thinking about the fine motion control rod drives and the discussion we had. If indeed they wind up down the road designing that system such that it has one speed for normal rod withdrawal during normal operation and a different speed for insertion, then one -- just I'm thinking aloud a little bit here -- then one worries that there's the potential for the system to not operate, function correctly and run the rods out at the higher motor speed or however they design it.

I'm, just an observation, something to look at down the road when there's an actual design, a detailed design.

MEMBER MARCH-LEUBA: We would be very interested on that. But my suspicion is that the rod ejection would be faster than the speed the motor can move at. But and I will bound it.

MEMBER KIRCHNER: I agree, that would likely bound it, you know, the traditional ejection or drop in this case.

MEMBER MARCH-LEUBA: Yes. Okay, can we open the public line please? For comments? Is the public phone line open for comments? Is anybody on the public phone there, can you please say hello? I don't hear anybody. So if there is anybody in the public line that wants to make a comment, please state your name and do the comment.

We'll leave the public line open for a moment longer, and I'm going to ask the members if anybody wants to make a statement around the table. Remember that we will come back to the open line this session to read the letter. But if you want to make a comment on the record right now, that will be the time.

Seeing no feedback, we are going to temporarily recess this meeting, and we are going to move to the closed team meeting, the closed phone line to get the proprietary information. Everybody knows that? Yes, sir.

CHAIR SUNSERI: No, I'm sorry, when you're done, I had a question. I wanted to ask you about timing and things.

MEMBER MARCH-LEUBA: Comment, go ahead, I'm done.

CHAIR SUNSERI: Okay, so we're going to recess here and go to closed session. I'm going to suggest we take a 20-minute break and reconvene the closed session at 20 minutes before the hour, so that'd be 3:40. How long do you think that closed session is going to last? And I know it's just a slag, but do you have an idea? Because we should give the public an ideal of when we would return to the open session approximately, so.

MEMBER MARCH-LEUBA: I believe, let me make sure, --

CHAIR SUNSERI: Why don't we just say 4:30?

MEMBER MARCH-LEUBA: GE has provided 20 slides, but if we -- and I assume Charlie Hicks is going to be doing it, okay, he likes to talk even more than I do. But we can do -- let me make an executive decision. We'll be back in the open line no earlier than 4:30.

CHAIR SUNSERI: Okay.

MEMBER MARCH-LEUBA: That will give us --

CHAIR SUNSERI: Yeah, that's fine. That's fine. That's good enough. And then we can have staff monitor the 4:30 open line and let people --

(Simultaneous speaking.)

CHAIR SUNSERI: Yeah, okay, thank you.

MEMBER MARCH-LEUBA: So we are on recess, and we will see everybody on the -- everybody that is allowed to be in the closed line at 3:40, that's 20 minutes from now.

CHAIR SUNSERI: Thank you.

MEMBER MARCH-LEUBA: So we are off the open line record. We will still have a transcription of the closed session at 3:40. We are on recess.

(Whereupon, the above-entitled matter went off the record at 3:19 p.m.)

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Subject: Submittal of ACRS Full Committee Presentation Slides for NEDC-33912P, BWRX-300 Reactivity Control Licensing Topical Report

Enclosed are the final presentation slides for use during the upcoming Advisory Committee on Reactor Safeguards (ACRS) GE-Hitachi Nuclear Energy Americas, LLC (GEH) Full Committee Meeting on December 1, 2020. This supports the ACRS review involving NEDC-33912P, BWRX-300 Reactivity Control, Revision 0, Supplement 1, and the corresponding NRC Advanced Safety Evaluation Report (SER) with No Open Items.

Enclosure 1 contains non-proprietary information and may be made available to the public.

If you have any questions, please contact me at 910-200-9836.

Sincerely,

Michelle P. Catts

Michelle P. Catts
Senior Vice President, Nuclear Programs
GE-Hitachi Nuclear Energy Americas, LLC

Enclosure:

1. ACRS Full Committee Presentation Slides for NEDC-33912P, BWRX-300 Reactivity Control Licensing Topical Report – Non-Proprietary Information

cc: R Franovich, US NRC

Document Components:
001 M200153 Cover Letter.pdf
002 M200153 Enclosure 1 Non-Proprietary.pdf

ENCLOSURE 1

M200153

ACRS Full Committee Presentation Slides for NEDC-33912P, BWRX-300 Reactivity Control Licensing Topical Report

Non-Proprietary Information

ACRS Full Committee Presentation

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

December 1, 2020

Purpose of ACRS Full Committee Presentation

- Describe Design Features to Meet Regulatory Requirements and Provide Defense-in-Depth for Licensing Basis Reactivity Events
- Address design requirements, acceptance criteria, and regulatory basis for the BWRX-300 Reactor Protection System (RPS) and other associated means for:
  - Reactivity Control
  - Anticipated Transients Without Scram (ATWS)
- Provide the design requirements, acceptance criteria, and regulatory basis for the BWRX-300 mitigating systems associated with an ATWS

HITACHI

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 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 that ensures defense-in-depth shutdown capability and reactivity control

Defense-in-Depth – Defense Line 1

IAEA Level 1

Defense Line 1 (DL1)

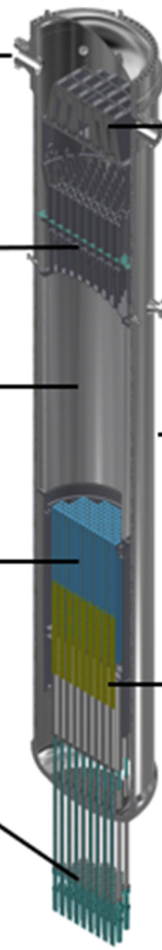
Defense Line 1:

- Reduce challenges to the Reactor Protection System (RPS) from all occurrences
  - Fewer trips per year
  - Reduces number of Anticipated Operational Occurrences (AOOs)
    - Reduced challenges to RPS
    - Some transients become Infrequent Events defined as < 1 per 100 Reactor-years
- Strengthen subsequent Defense Lines
  - Quality
  - Reliability
  - Conservatism

HITACHI

BWRX-300 Reactor Pressure Vessel (RPV)

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



HITACHI

Defense-in-Depth – Defense Line 2

IAEA
Level 2

Defense Line 2 (DL2)

Defense Line 2:

- Includes functions which normally control the plant
  - Rod control and control of power generation systems
- Plant functions designed to control or stop a Postulated Initiating Event (PIE)
- Minimizes PIEs that reach DL3 setpoints thereby reducing challenges to DL3 systems
- Independent from DL3
  - Includes diverse means of shutdown
- Provides high reliability of plant control

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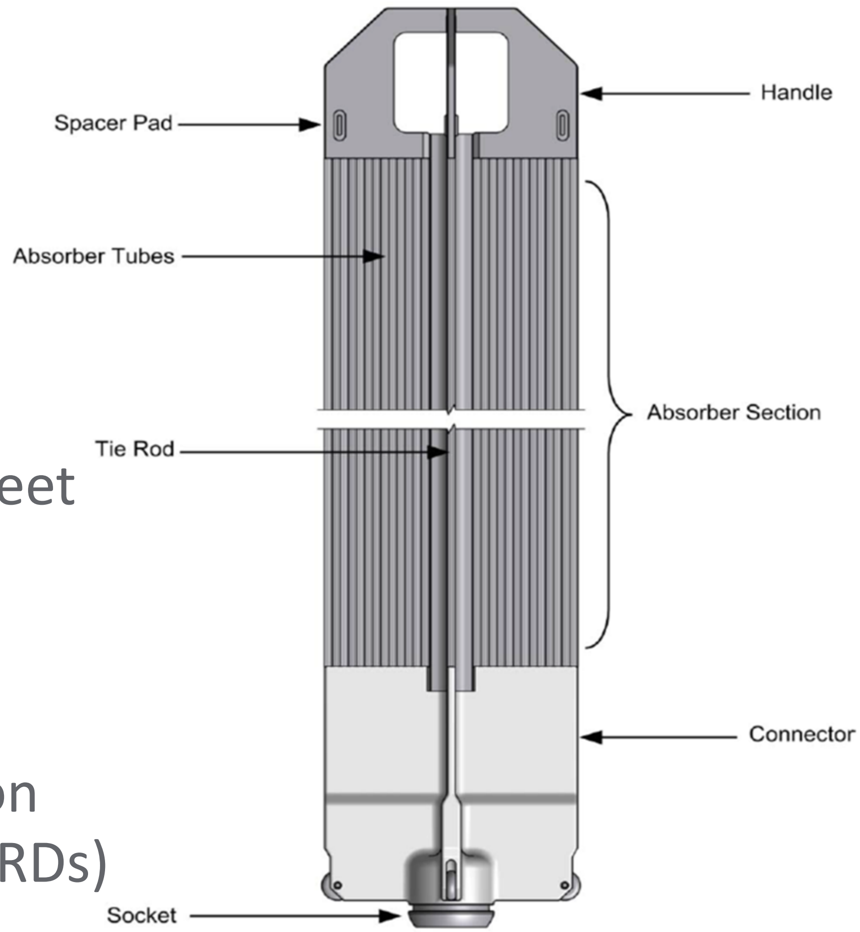
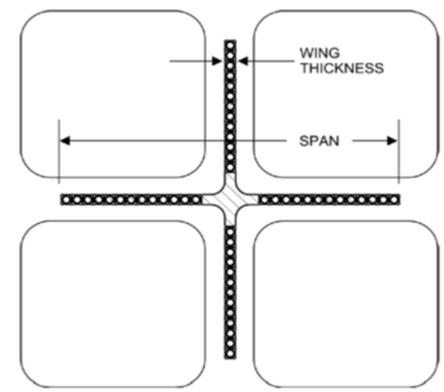
BWRX-300 Control Rod with Fuel Assemblies





Proven BWR operating fleet Control Rod design

Increased clearance for control blades

Positioned by Fine Motion Control Rod Drives (FMCRDs)

Defense-in-Depth – Defense Line 3

IAEA
Level 3

Defense Line 3 (DL3)

Defense Line 3:

- Includes functions which act to mitigate a PIE
  - Isolation Condenser System (ICS)
- Ensure plant is placed in a safe state
  - Reactor Protection System (RPS) Scram
- Assigned to highest safety class
- Independent of DL2

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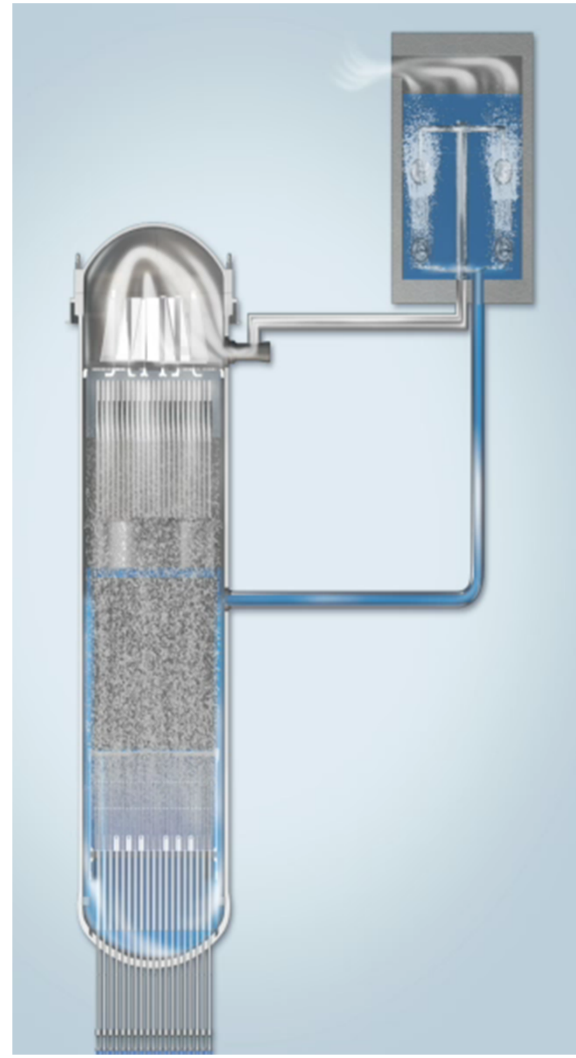
Isolation Condenser System (ICS)

- Heat exchanger design and capacity of each ICS train is the same as ESBWR
- Total % heat removal capacity from ICS larger than 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
- Condensate return well above the core
- ICS design enhancements provides pressure control and assists in power reduction



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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
  - Alternate Rod Insertion (ARI) – provides hydraulic scram in event of Hydraulic Control Unit (HCU) actuation failure
  - FMCRD insertion with motors
- Ensures plant is placed in a safe state

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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:

- ARI System
- Automatic Standby Liquid Control System (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 stored high-pressure water from hydraulic control unit (HCU) accumulators by either:
  - RPS and diverse actuated scram solenoid valves removing control air to each HCU
  - Diverse ARI pilot valves removing control air to scram solenoid valves for all HCUs
- Fine Motion Control Rod Drives (FMCRDs) have electric-motor-driven positioning used for both insertion and withdrawal of control rods
- Electric-motor-driven positioning diverse from hydraulic scram
  - Allows rod movement, even with failure of ARI System
  - Utilize sensors and logic that are diverse and independent of RPS
- Common cause failure (CCF) of hydraulic scram caused by scram discharge volume used in older designs is eliminated
  - Scram discharge fluid goes into Reactor Pressure Vessel

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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 incorporates:

- Control of power generation systems to assist in mitigation
- Reduction of water level, core flow and reactor power in a similar manner as recirculation pump trip in a forced circulation plant

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Design Features Described in Standard Review Plan (SRP)

NUREG-0800, SRP 15.8, states:

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 for an AOO with failure to scram

- Alternate means for shutdown
- ARI and electric motor run-in included in DL4a
- Successful shutdown ensured by DL2, DL3, DL4a
- Consequences of failure to scram from normal and diverse means mitigated by use of DL4a

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Regulatory Acceptance Criteria

- **Primary System** - Maximum primary stress within Reactor Coolant Pressure Boundary (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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United States Nuclear Regulatory Commission

Protecting People and the Environment

NRC Staff Presentation-
GEH Topical Report NEDC-33912P, Revision 0, Supplement 1, "BWRX-300 Reactivity Control"

BWRX-300 Small Modular Reactor
ACRS Full Committee Meeting
December 1, 2020

Presentation Outline

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

NRC Staff Review Team

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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*

Evaluation of Applicable Regulations:
10 CFR 50.62

- NEDC-33912P, Section 3.7.1 defines the ATWS acceptance criteria for evaluating the effectiveness of the reactivity control diverse shutdown means:
  - RCS and main steam pressure below 120% design
  - Peak cladding temp. and oxidation within 10 CFR 50.46 limits
  - Peak containment pressure/temp. below design
  - Coolable geometry
  - Radiological doses are maintained within 10 CFR 100 limits

- Consistent with SRP Section 15.8, “Anticipated Transients Without Scram.”

Evaluation of Applicable Regulations:
10 CFR 50.62(c)(3)

- Requires BWRs to have an ARI system diverse from the reactor trip system.
- The BWRX-300 includes an ARI system for diverse depressurization of the scram air header and will meet the requirement of 50.62(c)(3).

Evaluation of Applicable Regulations:
10 CFR 50.62(c)(4)

- Requires BWRs to have a standby liquid control system (SLCS) for injection into the vessel.
- NEDC-33912P specifies the BWRX-300 will meet the risk goals of 10 CFR 50.62 for P(ATWS) less than $1x10^{-5}$ per reactor year [[ ]].
  - Diverse scram actuation logic
  - Diverse rod motive force
  - [[ ]]
- This risk goal is consistent with the intent of 10 CFR 50.62 [[ ]]
- Limitation and Condition 5.1

Evaluation of Applicable Regulations:
10 CFR 50.62(c)(4)

Limitation and Condition 5.1:

Any applicant referencing NEDC-33912P must perform and document:

- Reliability analysis or testing, considering applicable operating experience and expected load follow conditions, of the BWRX-300 diverse scram features to demonstrate the probability of an ATWS is less than $1x10^{-5}$ per reactor year [[ ]].

Evaluation of Applicable Regulations
10 CFR 50.62(c)(5)

- Requires BWRs to automatically trip the recirculation pumps under ATWS conditions.
- This requirement is not applicable to the natural circulation BWRX-300.

Evaluation of Applicable Regulations:
General Design Criterion 12

- Requires control and protection systems to ensure power oscillations that could exceed the SAFDLs are prevented or detected and suppressed.
- NEDC-33912P states the BWRX-300 will meet GDC 12 and maintains margin to instability through:
  - small core and orifice design
  - coupled power-flow response
  - RPV chimney
- Limitation and Condition 5.3

Evaluation of Applicable Regulations:
General Design Criterion 12

<u>Limitation and Condition 5.3</u>:

Any applicant referencing NEDC-33912P must perform and document:

- A stability analysis in accordance with an approved methodology to demonstrate that the BWRX-300 maintains a coupled power-flow response such that any operational perturbation, maneuver, or AOO that does not cause an immediate scram is naturally damped and decays quickly to steady state for all modes of operation; prevents SAFDLs from being exceeded; is not susceptible to regional or radial modes of oscillation; and includes necessary provisions to address cycle-specific conditions.

Evaluation of Applicable Regulations:
General Design Criterion 26

- Requires two independent reactivity control systems of different design principles
  a) The first must use control rods and is used for normal operation, including AOOs, with margin for malfunctions
  b) The second must reliably control reactivity changes resulting from planned, normal power changes
  c) One system must be capable of holding the reactor subcritical under cold conditions
- NEDC-33912P states that the BWRX-300 will meet GDC 26 by providing:
  - Control rods (satisfy a and c above)
  - Feedwater level control system at power, other means to adjust level in other modes (satisfies b above)
- NRC staff finds this approach consistent with GDC 26

Evaluation of Applicable Regulations:
General Design Criterion 27

- The intent of GDC 27 is to require reactor designs to achieve and maintain long-term subcriticality using only safety-related equipment following a postulated accident with margin for stuck control rods.
- NEDC-33912 proposes the following principal design criterion (PDC) in lieu of GDC 27:

  The BWRX-300 reactivity control system shall be designed to have the capability 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.

- BWRX-300 control blades will be capable of holding the reactor subcritical under cold conditions assuming failure of the highest worth control rod pair.
- Analysis that demonstrates the control rod system is sufficient for achieving and maintaining shutdown margin could justify an exemption to GDC 27 and the use of the design-specific PDC.

Evaluation of Applicable Regulations:
General Design Criterion 28

- Requires reactivity control systems be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that postulated reactivity accidents can neither:
  1) result in damage to reactor pressure boundary greater than limited local yielding
  2) sufficiently disturb the core, its support structures or other reactor pressure vessel internals to impair significantly the capability to cool the core.
- Reactivity accidents that must be considered:
  - Rod ejection (unless prevented by positive means), rod dropout, steam line rupture, changes in coolant temperature/pressure, and cold water addition
- NEDC-33912P states that the BWRX-300 will meet GDC 28 by:
  - Design features of CRD system and rod control system limiting the amount and rate of reactivity increase
  - Safety analyses demonstrating compliance submitted in future licensing activities
    - Including analysis of CRDA event using approved methodology (NEDE-33885P-A)
- NRC staff finds this approach consistent with GDC 28

Evaluation of Applicable Regulations:
General Design Criterion 28

Limitation and Condition 5.2:

Any applicant referencing NEDC-33912P must perform and document:

- A CRDA design-basis safety analysis applied to an equilibrium cycle in accordance with an approved methodology, providing justification for any deviations (e.g., performing a one-time analysis to bound cycle-by-cycle variations), or request an exemption to justify the CRDA as a beyond-design-basis event and document the CRDA analysis results in the probabilistic risk assessment.

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?