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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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654th MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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WEDNESDAY

JUNE 6, 2018

+ + + + +

ROCKVILLE, MARYLAND

+ + + + +

The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 1:00 p.m., Michael Corradini, Chairman, presiding.

COMMITTEE MEMBERS:

MICHAEL CORRADINI, Chairman

RONALD G. BALLINGER, Member

DENNIS C. BLEY, Member

WALTER L. KIRCHNER, Member

JOSE MARCH-LEUBA, Member

HAROLD B. RAY, Member

JOY L. REMPE, Member

PETER C. RICCARDELLA, Member

GORDON R. SKILLMAN, Member

MATTHEW SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

ALSO PRESENT:

TONY AHN, KHNP

TIM DRZEWIECKI, NRO

JAMES GILMER, NRO

JAEHOON JEONG, KNF

REBECCA KARAS, NRO

MOHSEN KHATIB-RAHBAR, ERI

JUNGHO KIM, KHNP

YONGGUN KIM, KHNP

YOUNGKI KIM, KEPCO E&C

YUN HO KIM, KHNP

SANGIK LEE, KHNP

DAEHEON LIM, KEPCO E&C

KWANGIL LIM, KEPCO E&C

MARK LINTZ, NRO

SHANLAI LU, NRO

JILL MONAHAN, Westinghouse

JIYONG (ANDY) OH, KHNP

JUHYUN PARK, KNF

ROB SISK, Westinghouse

JAMES STECKEL, NRO

ROBERT SWEENEY, KHNP/AECOM

WALTER TAUCHE, ERI*

BOYCE TRAVIS, NRO

ANDREA D. VEIL, Executive Director, ACRS

DAVE WAGNER, KHNP

WILLIAM WARD, NRO

*Present via telephone

T-A-B-L-E O-F C-O-N-T-E-N-T-S

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P R O C E E D I N G S

(1:01 p.m.)

CHAIR CORRADINI: Okay. The meeting will come to order. This is the first day of the 654th meeting of the Advisory Committee on Reactor Safeguards. During today's meeting the Committee will consider the following.

The APR1400 long-term core cooling issue. The APR1400 large break loss of coolant accident analysis, and preparation of ACRS Reports.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, or FACA. As such, this meeting is being conducted in accordance with the provisions of FACA. That means that the committee can only speak through its published letter reports. We hold meetings to gather information to support our deliberations.

Interested parties who wish to provide comments can contact our offices requesting time after the Federal Register Notice describing the meeting is published.

That said, we set aside ten minutes for extemporaneous comments from members of the public attending or listening to our meetings. Written comments are also welcome. Mr. Christopher Brown is

the Designated Federal Official for the initial portion of the meeting. The session on APR1400 Long Term Core Cooling may be closed in order to discuss and protect information designated as proprietary and the session on Large Break Loss-of-Coolant Accidents will be closed in order to discuss and protect information designated as proprietary.

The ACRS section of the USNRCs public website provides our charter, bylaws, letter reports, and full transcripts of all full and subcommittee meetings, including all the slides presented at the meeting.

We have received no written comments or requests to make oral statements from members of the public regarding today's sessions.

There will be a phone bridge line to preclude interruption of the meeting. The phone will be placed in a listen-in only mode during the presentation and Committee discussions.

A transcript of portions of the meeting is being kept and it is requested that speakers use the microphones, identify themselves, and speak with sufficient clarity and volume so they may be readily heard.

I'll just recommend to the members, remind

the members to shut down all their appliances to make sure nothing buzzes, clicks, beeps, or rings during our discussion.

So the first topic will be long-term core cooling. I'll turn to Member Ballinger to lead us through. I'll leave it to Ron to decide when you want to check for open versus closed on that, and then I assume the large break LOCA will be closed.

MEMBER BALLINGER: Thank you, Mr. Chairman. None of the slides that we have are designated as proprietary. So if we get, we'll have to be reminded by the presenters if there's something that's closed or if the questioning gets into an area where we have to close the session.

So we're going to hear again as the Chairman indicated, presentations on long-term core cooling as well as large break LOCA accident. We've not had subcommittee meetings on long-term core cooling but that's been sprinkled throughout many of the presentations on the chapters.

We have had subcommittee meeting on the large break LOCA. So and we actually have a, well, okay, we've had subcommittee meetings on the large break LOCA.

So with that. I think, Bill, do you want

to, he has to, Bill has to say four words and then bolt for another meeting.

MR. WARD: Actually, this meeting marks a milestone. It's the last full committee on a specific topic that we have scheduled. We are appreciative of the fact that we are talking about large break LOCA again because there was a slight edit to the SER in the top of the report which requires that we complete the review. So thank you for doing that and we look forward to the discussion on long-term core cooling.

I would like to ask if we could check to see who's online. I know we asked for one --

(Off the record comments)

MR. WARD: One, yes.

CHAIR CORRADINI: You're expecting someone?

MR. WARD: Yes. There's one person that was a support person, yes. A reviewer that supposed to be on the --

CHAIR CORRADINI: Okay, okay. Well, let's make sure he's on before we get started.

MR. WARD: Yes. Is there anybody online?

(Off the record comments)

CHAIR CORRADINI: When we hear the crackle we know it's there.

(Telephone)

MR. TAUCHE: This is Walter Tauche supporting ERI.

MR. WARD: Okay. Thank you.

CHAIR CORRADINI: That's who you needed?

MR. WARD: That's who we needed.

CHAIR CORRADINI: Okay.

MR. SISK: So this is Rob Sisk, Westinghouse. And again, I do appreciate the opportunity to present long-term core cooling and large break LOCA to the ACRS Committee today.

The presentations that are being provided today as mentioned earlier are nonproprietary, but we will be cautious that some of the questions could take us to closed. We're not anticipating it but if it does, we'll let the ACRS know.

And with that and no further delay, I'm going to turn it over to Mr. Sangik Lee to lead us through the long-term core cooling presentation.

MR. LEE: Good afternoon, everyone. My name is Sangik Lee and I'm working in the Safety Analysis Department in KEPCO Nuclear Fuel.

This presentation is for the post-LOCA long-term core cooling analysis of the APR1400. I'll make presentation on the boron dilution parts only and

the remainder of the presentation will be presented by Yonggun Kim from KEPCO E&C.

This is the list of topics to be discussed. List of documents submitted for LTCC are soon in the, at first, boron dilution, containment over pressure credit, gas formation, sump strainer performance, in-vessel downstream effects, will be discussed, one after another. Summary and acronyms will be followed for your convenience.

This is the list of documents submitted for LTCC. Five documents have been submitted in total as you can see.

This slide shows the issue of the post-LOCA boron dilution analysis. RAI 8455 requires that the core should not reach a re-criticality when the boron dilution event occurs.

KHNP showed why a start of natural circulation and restart of one RCP will not cause core re-criticality by a simple mixing calculation.

So simple mixing calculation assumes that the maximum unborated water volume can be accumulated in the system as much as possible.

The unborated water moved to the core will be mixed equally with the borated water initially existed in the core region by the geometry of the

system.

The reactor core is maintained to 4000 ppm of boron concentration coolant initially if the boron concentration in the core region needs to be maintained above critical boron concentration of 970 ppm to avoid the potential for re-criticality.

This slide shows the analysis results for the simple mixing calculation. Assumptions of the calculations are described here.

The initial 4000 ppm of borated water in the lower plenum region of 664.2 cubic feet is assumed to be mixed with the delivered unborated water.

For the natural circulation case, 984 cubic feet of unborated water from four loops is delivered to the core.

For the restart of one RCP case, 246 cubic feet of unborated water from one loop is delivered to the core.

And here is the calculation results. For the natural circulation, calculation results shows 1612 ppm in the core which is greater than the critical boron concentration.

For the RCP, one RCP restart case, calculation results showed 2298 ppm in the core which is greater than the critical boron concentration.

Therefore, the re-criticality occurrence for the boron dilution in post-LOCA is not an issue for APR1400.

From now on Yonggun Kim from KEPCO E&C will take the presentation.

MR. KIM: Good afternoon. My name is Yonggun Kim in KEPCO E&C as a system designer engineer. I'll introduce the rest of our topics which is related to the GSI-191 and it was calculated containment over pressure credit CAP first.

In the APR1400 design, we are crediting the containment accident pressure for IRWST temperature equal to or greater than 212 Fahrenheit with assumption that the containment accident pressure is equal to the IRWST liquid vapor pressure. Then were are calculating the NPSHA for the IS and CS pump.

This assumption is based on the containment accident pressure analysis which is demonstrates the containment accident pressure, maintains the IRWST water vapor pressure during an accident.

The CAP analysis, the GOTHIC containment model was used there with assumption that the higher IRWST water temperature and deliver highest containment pressure.

All the assumptions are used in the CAP analysis, all the assumptions used in the CAP analysis were based on the document, the SECY 11-0014.

According to the CAP analysis result the containment pressure during the accident maintains higher than IRWST vapor pressure. So we can say that NPSHA calculation in APR1400 design has conservatism.

And this topic is the gas formation at the IRWST sump strainer. The strainer has adequate submergence to preclude the vortexing, sump fluid flashing, and the deaeration which can be induced by the differential pressure, different pressure drop at the strainer.

First regarding the strainer vortexing. During the strainer performance test of two feet of submergence, no vortexing were observed. So we can say that no visual observation, there is no vortexing at the strainer.

And the flashing in the debris bed, because the strainer has the submergence height of two feet, the LOCA, the flashing at the strainer. And because the Maximum strainer head loss of 1.06 feet was identified during the test which is less than the strainer submergence of two feet.

And for the deaeration of the sump fluid

at the strainer, we are expecting no deaeration of sump fluid occur at the strainer because the increase in solubility of the air due to the static pressure increase of the water above the strainer is more than the decrease in solubility of air due to the head loss across the strainer.

So we are expecting that there will be no gas formation in the strainer due to the difference of pressure drop at the strainer.

And the next is the sump strainer performance. In IRWST, sump strainer performance evaluation for APR1400 was performed in accordance with NEI 04-07 and the associated safety evaluation by NRC and concluded that there were margins in the NPSHA for the IS and CS pumps.

In the evaluation, no fibrous insulation was assumed. The RMI was assumed there as a 75 percent to small fines and 25 percent to large pieces. That is based on the NEI 04-07.

And all particulates, fibers, and miscellaneous debris was assumed to reach sump strainer.

And in order to deal with the miscellaneous debris such as tape or stickers, penalty over a sacrificial strainer surface area the sump is

applied and there's a margin for future detailed design and installation of the APR1400. Also latent to fiber debris of 15 pound was assumed.

Regarding the ex-vessel downstream effect, the ex-vessel downstream effect evaluation was performed in accordance with the WCAP-16406-P methodology.

The pump evaluation will be performed by the vendor and according to the ASME QME-1 endorsed by the Regulatory Guide 1.100 Revision 3. The qualification of the pump will be performed by test or a combination of test and analysis.

The plugging, performance and wear of the heat exchanger that will be evaluated by the vendor during the procurement process. Also the blockage, settling, and wear of valves, orifices, and pipes.

The wear of the orifices and plugging and performance, I'm sorry, the blockage and settling at the valves and orifices and pipes will not occur and the rear of the orifices and pipes increase the fluid just slightly and the valves will be qualified in accordance with the ASME QME-1.

And there was the chemical effect evaluation and it was performed by using NRC approved methodology, the WCAP-16530-NP.

From now on, I'll introduce the vessel downstream effects performed in the APR1400 design. APR1400 design evaluated the in-vessel downstream effect through the test in accordance with WCAP-16793-NP.

In the test, this is just the flow rates to the core where it remained clustered in the LOCA scenarios. Three were presented to the LOCA scenarios such as hot-leg break, cold-leg break, and cold-leg break after hot-leg switchover were considered.

In the event of hot-leg break, the circulation pump was to pump the water of course to the rear core and the maximum flow is equal to the force that the injection pump flow rate.

In the test, one fuel assembly was the test, one fuel assembly was used so flow rate for fuel assembly was calculated by dividing the total flow rate by total fuel assembly number 241 and available fuel assembly was 20.5 gpm.

In the event of a cold-leg break, the flow rate to the core is equal to the boil-off rate at the moment. The maximum boil-off rate was calculated at --- start time of 700 seconds.

And the flow rate for fuel assembly was 3.65 gpm. At the time of two hour after cold-leg

break operator starts small canister operation over hot leg injection and direct vessel injection. Because of two safety injection pumps are for hot leg injection, the flow rate to the core is a half of the total injected safety injection pump flow rate --

CHAIR CORRADINI: Can you just -- if I might just interrupt you, I'm sorry. What is the third scenario again? It's a cold-leg break after what?

MR. KIM: A hot-leg switch over.

CHAIR CORRADINI: Hot-leg switch over, okay. Thank you. Go ahead. Thank you.

MR. KIM: Next is the input for in-vessel fuel assembly test. The table in this slide summarizes the debris type and amount for fuel assembly used in the in-vessel fuel assembly test.

The in-vessel fuel assembly test is for measuring a pressure drop at the fuel assembly when they assess water with bypass debris flow into the fuel assembly during the long-term core cooling operation.

For fibrous debris, the sump strainer bypass test was performed and the test result shows that 1.67 kilograms of the fiber debris was bypassed through four sump strainers. Then the fibrous debris

mass for fuel assembly was calculated to 6.93 grams but in the actual in-vessel test, 15 gram fibrous debris was applied for conservatism.

All other debris such as coating, latent debris, and chemical compounds was assumed to bypass the sump strainer and pump to the core.

This is the test results. There was five tests to evaluate hot-leg break conditions and seven tests for cold-leg break.

Limiting results on cold-leg case of the particle to fiber ratio of one and 15 over under the condition of a hot-leg break and cold-leg break respectively.

The vessel pressure drop on the hot-leg break condition was 19.24 kilopascal and on the cold-leg break condition it was 3.85 kilopascal.

The test results met the acceptance criteria of 42.7 kilopascal for hot-leg break and 13.2 kilopascal for cold-leg break with a sufficient margin. Therefore, all the in-vessel fuel assembly tests, the results shows that there are sufficient margins to maintain the core flow during post-LOCA conditions.

So in APR1400 this is complete and KHNP continues to monitor LTCC to assure any conforming

changes are addressed.

And APR1400's design provides sufficient margin to maintain long-term core cooling during post-LOCA conditions.

Next is the acronyms I used in this presentation.

MEMBER BLEY: I have a question. I was not at subcommittee meetings when this -- I'm curious, to the folks who were here on that committee, did you talk much about the containment accident pressure?

CHAIR CORRADINI: We, in previous discussions we did earlier.

MEMBER BLEY: Okay. I missed those. I didn't think of it at the PRA meeting the other day. I assume you've purged the containment at intervals during operations and if you do, every time you do that after you close it back up, there's a chance the purge valves don't completely close.

Was that scenario, which would defeat your containment accident pressure assumptions, was that scenario in the PRA? If not, why not?

CHAIR CORRADINI: I'm not sure. Do they have PRA experts in them?

MR. SISK: We do not have a PRA --

MEMBER BLEY: Anybody from the staff that

can answer that?

MR. TRAVIS: This is Boyce Travis, Containment Relation Branch. I can speak to that mechanistically, not from a PRA perspective.

MEMBER BLEY: Okay.

MR. TRAVIS: In the event that a purge valve is open prior to the accident, it's not going to challenge the containment pressure, containment accident pressure assumption that the applicant's made because it's purely based on the saturation pressure for the conditions inside containment.

So if the containment never gets above 14.7 psi they don't have to correct containment accident pressure because it's under two, the saturation pressure's under 212.

So the saturation pressure associated with the vapor temperature of the fluid is under 212.

MEMBER BLEY: Okay.

MR. TRAVIS: I can speak more to it if you'd like later. We don't have slides prepared on it but I --

CHAIR CORRADINI: I think all he's saying is that you're limited, that you're not going to get a pool temperature that's higher than 212?

MR. TRAVIS: Right.

MEMBER BLEY: Okay. That makes a difference. Okay, thanks.

MR. TRAVIS: Yes. Your welcome.

MEMBER REMPE: Just to follow-up on your question, how much, do we have a good feel for how much containment accident pressure is given to this design and like for how long? Like sometimes we do that with the EPUs and I can't remember if we were told the value for that.

CHAIR CORRADINI: Do you understand what he's asking? What she's asking?

MR. KIM: Could you say it again?

MEMBER REMPE: You do have some contain, you do rely on containment accident pressure, right?

MR. KIM: Yes, right.

MEMBER REMPE: How much? Like sometimes it'll say, oh, it's only five psi for a short period of time or some, yeah, an hour. Would you give us a value for that? It's been a long time since the subcommittee meeting.

MR. KIM: Well, the exact value was not defined, you know, just on that one. But we can say that we are clustering the containment with the peak pressure and the back pressure would be the liquid vapor pressure and so and we have really two pumps in

the analysis calculation. So we can assume that if we don't question the containment accident pressure then we will need about 30, more than 30 in the NPSHA calculation.

MEMBER REMPE: Okay.

CHAIR CORRADINI: But I think what Dr. Rempe is asking is if you were to go back to your Slide 6, thank you, how long would you exceed in the assumption H atmosphere is equal to H vapor? If H atmosphere was equal to the initial containment pressure --

MR. KIM: Yes?

CHAIR CORRADINI: I think the question is how long would you exceed the initial containment pressure?

MR. KIM: The over --

CHAIR CORRADINI: The time span? Are we talking a minute, an hour, a day, during the analysis? Isn't that what you're asking?

MEMBER REMPE: Yes. That's --

MR. KIM: How long?

MEMBER REMPE: How long?

MR. KIM: --- that function, should it be considered just on -- well, I don't --

CHAIR CORRADINI: I think the staff --

MR. KIM: I don't, idea about that.

MR. TRAVIS: Yes. This is Boyce Travis again. I don't have the exact numbers in front of me, but I'll say it's a handful of hours on the order of 15 to 20 psi for, I mean, that's the peak. Obviously, it starts very low, peaks at about 15 or 20 psi and then comes back again.

MEMBER REMPE: So just to recap, you said 15 to 20 psi for a handful of hours?

MR. TRAVIS: Yes. So like tens of thousands of seconds is, that's, I think it --

MEMBER REMPE: That's good. Okay. That helps, thank you.

(Off the record comments)

MR. SISK: Any other questions we can ask?

MEMBER REMPE: We're arguing, repeat how long? Again, I thought you said in seconds.

MR. TRAVIS: No, no. Tens of thousands of seconds, excuse me.

MEMBER REMPE: Tens of thousands of seconds.

CHAIR CORRADINI: March 22, 2017.

MEMBER REMPE: Yes, that's fine.

CHAIR CORRADINI: Here are the slides. Let her borrow these.

MR. TRAVIS: I have some of them over there. I can tell you slide numbers if necessary.

CHAIR CORRADINI: I think this is his presentation from a --

MR. TRAVIS: It is, yes.

(Off the record comments)

MEMBER BALLINGER: Can we motor on? Okay. So I think we're all set.

PARTICIPANT: We're ready to go.

MEMBER BALLINGER: I don't see where the staff -- oh, there is a staff person. Who's the staff? Oh, there he is.

MR. SISK: You want to switch over to?

MEMBER BALLINGER: Yes, I think we need to.

MR. SISK: Yes. Okay. We can switch over to the staff.

MR. KIM: Thank you.

(Off the record comments)

MEMBER BALLINGER: Go ahead.

MR. LU: All right. Okay.

MR. STECKEL: Afternoon, this is Jim Steckel and I'm here with Shanlai Lu through our presentation on long-term core cooling.

MEMBER MARCH-LEUBA: Jim, your mic's not

on.

MR. STECKEL: So we're going to take you on our presentation on long-term core cooling. We'll hit main topics on post-LOCA boron dilution and in-vessel downstream effects. Fortunately, Boyce Travis is here with us too if there are any questions on the overpressure of gas formation or something.

MR. LU: It looks like he already answered all the questions.

MR. STECKEL: And I'll turn it over to Shanlai Lu.

MR. LU: Okay. All right. Shanlai Lu from staff, Reactor Systems Branch. So I'll cover two topics presented by KHMP as the post-LOCA boron dilution and in-vessel downstream effects.

Out of five, the main topics they presented, I'll cover two of them because those two are covered by Reactor System Branch.

So about three months ago we talked about the post-LOCA boron dilution so I will then keep the full committee another high-level summary. So let's go to the next page.

So the reason we have the, that we issue this RAI 8455, it was, when we received the diversification application and then we found that,

you know, regarding GSI-185, we had not done any specific APR1400 analysis related to small break LOCA during long-term cooling potential loop seal clearing, what might be the boron dilution results.

So we issued RAI during the Phase II and then we almost, you know, ready to issue the Phase II GSI that we got the RAI response with.

So during Phase III, when we gave the presentation to the subcommittee, we summarized at that time what's staff's view. And I think three months ago we gave the presentation about the closure of this issue and I think we have a sufficient, we have a sufficient margin there.

So we did respond to RAI and also applied the conservative assumptions in terms of the mass and then especially the volume of the fresh water in the loop seal and then the, what's the, how much the fresh water slug, how many slugs discharged based on PKL test.

So the bottom line is the calculated boron concentration in the core and is sufficiently higher than the critical boron concentration required. So the shutdown margin is maintained and so this issue has been closed and now we approve that there is part of the analysis.

And then that's the conclusion and we don't believe that they're doing long-term cooling in for specific small break, you know, small break LOCA and as a part of, as a result of loop seal clearing there is a potential to have a re-criticality due to our dilution.

MEMBER SKILLMAN: Shanlai, let me ask this question.

MR. LU: Yes?

MEMBER SKILLMAN: The single slug coming from the one reactor coolant pump --

MR. LU: Yes?

MEMBER SKILLMAN: -- enters the downcomer and comes up through the bottom of the core. What assumption do you make regarding the mixing since, if you will, one might imagine the core is sliced into quadrants and a particular reactor coolant pump might preferentially find its way down the one quadrant and up through one quadrant --

MR. LU: Okay. Right.

MEMBER SKILLMAN: -- and you get the slug well-poisoned in one quadrant --

MR. LU: Right.

MEMBER SKILLMAN: -- leaving three quadrants not poisoned?

MR. LU: Right, right. Okay. I think if KHNP wants address that, that would be fine and if he does that's their analysis. But when we review that one, the original one, until any particular test results you want to make and, you know, it's very interesting.

When we look into the PKL test and then when the loop seal clearing happens and then the water in the loop seal, the temperature of the water actually is higher than the downcomer because that has the continuous cold water injections through the DVI line.

So when that part is, you know, restarted, like you can find natural circulation or by pump, the water actually started to really inject it at the top of the downcomer actually is because of some stratification there. So really, so it's mixing supposed to happen all of the, through all of the entire downcomer.

We suspect that initially we also had a similar problem as you have. What's going to happen when you have a plume coming down and then going down to the, you know, the downcomer getting to the lower plenum and it's the one quadrant of the core that's getting diluted. It's what's going to happen there.

But the tests show and for a reasonable good test and shows that that part of the, you know, plume, the mixing pattern doesn't really happen there. So the assumption there is quite a lot of mixing both in the downcomer and northbound even you have one slot coming in.

And then another aspect if -- yes?

MEMBER KIRCHNER: What scale of test is that?

MR. LU: PKL --

MEMBER KIRCHNER: PKL is tiny core.

MR. LU: Yes, PKL, it's tiny core. But aside from that --

MEMBER KIRCHNER: So that will really mix well. That will give you the striping that you'll get --

MR. LU: That's right.

MEMBER KIRCHNER: -- on that large vessel.

MR. LU: You're correct. But there is also, we actually looked into this particular calculation. If you recall during the subcommittee presentation, we had a small break LOCA evaluation of their methodology and then we run our code, both TRACE and we also run their RELAPS5 code too and then we checked the temperature distribution.

That's part does not really mean, you know, actual skinny tiny, you know, very full height, full pressure test which is very skinny, you're right on that part.

But in terms of temperature distribution, it's quite large and then when you have that high temperature discharge through the loop seal to the top of the downcomer, it's much, much hotter than the water because you have continuous guideline injection into the downcomer there. So therefore, mixing is its pattern.

MEMBER KIRCHNER: How fast does that slug move through?

MR. LU: Oh, how fast there, okay. From the mixing perspective of, I do not believe that their RAI responses really address the specific timing of that one.

They just want to capture through this bounding back to earlier calculation with this temperature distribution and the mixing for the given volume of the loop seal, how much that will be mixed, and then so they calculate critical boron by the self, the timing becomes very hard to predict because it all depends on the break side when you have the natural circulation, how that part is reaching the core.

So it's not a transient specifically transient amount, it's just provided by as part of our RAI responses but it's a bounding back to in an of conservative calculation to make sure that we have a, in the core, the core concentration is higher than the critical boron concentration.

MEMBER SKILLMAN: Yes, my hunch is that the Reynolds number is so high and the reactor coolant pump or discharge flow rate is so great --

MR. LU: Right.

MEMBER SKILLMAN: That when that interface occurs at the downcomer, the water doesn't necessarily if you will, flow downward.

MR. LU: Yes.

MEMBER SKILLMAN: It flows downward and sideways and there's full mixing around the entire downcomer.

MR. LU: Exactly.

MEMBER SKILLMAN: And so you end up with push of all the downcomer water including the slug --

MR. LU: Right.

MEMBER SKILLMAN: -- that's very well mixed in the downcomer plus --

MR. LU: That's right.

MEMBER SKILLMAN: those lower internals

have extraordinary capability of turning. So I think this is accurate. Okay. Thank you.

MR. LU: Exactly, exactly. And actually when you're having, if you have really the pump injection then you start have the slug water with the quite high speed, then you have splash right out of the part.

MEMBER SKILLMAN: Oh, when you kick that reactor going pump it's a --

MR. LU: Right.

MEMBER SKILLMAN: It's a blizzard of a flow. I mean it's a monster.

MR. LU: Yes, it is. Agree. So I think that's the reason we decided to close this issue and then if this last chance, any questions, then let's narratively, I think we're done with this part of the topic. So we can move onto in-vessel downstream effects.

Okay. I think this was the first time we gave the presentation to subcommittee. At that time it was only a half a year ago.

So we did go through this and it was the entire Chapter 15 slides. It's a lot of overwhelming information so I would ask to give a one more time into the feedback how the staff was able to reach the

conclusion, why it's okay.

And then so I'll just give you a little more details than just the standard high level summary for the full committee presentation.

So for in-vessel downstream effect evaluation and normally for any, you know, test, you know, AP1000, ESPW, we follow four steps.

Debris source analysis and the fiber only bypass testing. That's first step. Available driving head across the debris bed where they are being based on the accident analysis.

And then we review their fuel assembly head loss testing and then see whether the debris bed DP is higher than or lower than the acceptance criteria.

And then the fourth step is the LOCA deposition model. That's a standard procedure and they are, we also perform the, we have the all those analysis and testing and then we use staff to follow those steps too which has been doubled over the during the past 13 years.

All right. The basis, regulatory basis 10CFR50.46 a very high level Generic Letter 2004-02, that's the starting point of PWR sump. And what's really actually something new is Regulatory Guide

1.82, Revision 4. You guys have already presented and reviewed many times.

All right. The SER for WCAP, really it's a major part is related to that chemical advantage, how they're being treated and how they calculate the debris deposition on the fuel assembly. That's part of it, has already been approved by the staff and you guys and which has been used by the applicant too.

All right. I do want to point out one, what we call the clean plant criteria which is not what KHNP used. It is not what staff uses for this particular review but it's a reference.

The reason that there is a reference in there is there is a number there, it's a 15 gram per assembly.

So according to that clean plant criteria approved by ACRS and our staff who are operating fleet, you have a plant, PWR with reflective metallic insulation and then happen to have the latent debris fiber loading solo and if it's only 15 gram per assembly there is no need to perform all those four steps. Done deal. Approved. And that's the clean plant criteria as been developed by the staff for operating fleet.

And this particular criterion, if it was

used by at KHNP, we do not even need to do all those. However, the reason we ask them during the presubmittal meeting which back five years ago and then I guess they are used in their own fuel assembly.

So we are just saying, okay, well, since you have your own fuel assembly it may not have been covered by the PWR Owner's Group testing. So therefore, we do not really want to go that route meaning you have to show all those detailed analysis at testing.

And finally later we found actually we're just using typical Westinghouse fuel and the derivative from there and including the spacer break. So but just wanted to make sure. That's a reference only. Next slide.

Okay. Let's go on to the first step and review the debris source and bypass testing. And I think the containment and the regulation branch, they have already presented during the subcommittee meeting that this plant was given to have a reflective, a metallic insulation RMI. So really the source of the debris, either particulate or the fiber came from, will come from the latent debris.

And we also have a cleaners program including the strainer by itself. It does remove a

certain amount of debris for this given strainer.

So we as part of responsibility of reactor safety branch, we all did their bypass testing which is part of their strainer head loss testing for up in the, add the fiber only into this same strainer assembly they used to measure the DP.

So they measured how much fiber would bypass the strainer to get in the core. And very interesting and then if you look at their slides and also my slide too, only 6.93 grams per fiber assembly is predicted.

And then they used very, I would say it's a conservative testing protocol to measure the bypass fraction and using in my titration system so everything goes through the strainer as not as the solid particles unless greater than 2 micron is captured by the filtration bag.

So therefore, we feel that the bypass testing and debris source as the part of the input to the vessel downstreaming fact for the fuel assembly head loss testing, it's conservative.

And so conservative it's much less than 15 grams. If we stop here, you had to stop here there's no need to have further analysis of testing but we kept going and then they kept going too.

So the staff finding is debris source analysis bypass testing are conservative.

MEMBER SKILLMAN: Did you say greater than one micron?

MR. LU: Yes. I think so.

MEMBER BALLINGER: 0.09 inches or something like that?

MR. LU: Yes, it's very tiny and I think it's filtration bag when we ordered that one, that was another sample sent to audit. The audit report was still also referenced as part of the staff SER and it was one micron. If you have a solid particle that's greater than one micron it will be captured.

And then so what really it has, is we have a large, another tank downstream of the strainer and then the outer water going through, goes through the tank.

But that the reason we cannot run the test facility debris as a particulate, the only downstream fiber. So in that case then, they dry the screen and make it dry and then measure the weight between and before and after and figure out how much the weight of the fiber debris was captured.

MEMBER SKILLMAN: One micron sounds awfully, awfully fine. I'm going to have to think

about that.

MR. LU: Ten micron or one micron --

MEMBER SKILLMAN: I can double check. I don't think it's one micron.

MEMBER BALLINGER: It's got to be larger than one micron.

MR. LU: Maybe my, my memory, I thought it was one micron but I will double check.

MEMBER BALLINGER: Can we check on that? You said one micron.

MR. LU: Yes, I'll check.

MEMBER BALLINGER: Because 0.09 inches --

MR. LU: Yes, we'll do test.

MR. TRAVIS: I know for a fact it's not one micron.

PARTICIPANT: It's not one.

MR. TRAVIS: I've got the tests. I will get back to you guys this afternoon if necessary with the exact number for you but it's a set up with a clean pool with filter bags that are downstream and then the filter bags have a certain filter size as Shanlai said, that captures all of the debris but it's not one micron.

CHAIR CORRADINI: It's not one micron.

MR. TRAVIS: And I will get back with an

exact number this afternoon.

CHAIR CORRADINI: That might be a memory.

MEMBER SKILLMAN: Let's get the accurate number.

MR. TRAVIS: No problem. Thank you.

MR. LU: All right. I'll get you a number.

MEMBER KIRCHNER: Shanlai, thank you. I understand pulling this from memory. I understand.

MR. LU: No, No. It's a, yes. Sorry.

MEMBER KIRCHNER: Shanlai, the 6.93, why don't you just say less than seven grams?

(Laughter)

MEMBER KIRCHNER: Yes, that 6.93 just is a stick in the eye like the one micron.

MR. LU: Yes, okay.

MEMBER KIRCHNER: But it just doesn't, that's dividing whatever number you have. 241.

MR. LU: The three is significant digits.

MEMBER KIRCHNER: Yes.

MR. LU: So that's good, that's good --

MEMBER KIRCHNER: I mean, you've got a lot of margin under your criteria, or criterion so.

MR. LU: I should say it's less than fifteen gram. Thank you.

MEMBER BALLINGER: Think about it. This is a step up from the PRA people.

MR. LU: We have deterministic, whatever they resubmitted are the determined.

MEMBER KIRCHNER: Whatever they determined, yes.

MR. LU: We just want to make sure exactly that, I thought that their slide also stated that 6.93. You might get it correct, right? So if you go into deterministic then we are into the digits.

MEMBER KIRCHNER: That may be what they calculated but it was in there.

MR. LU: That's right.

MEMBER KIRCHNER: But it's probably better presented less than seven grams per assembly or something.

MR. LU: Yes. I agree. That's good policy, yes. But the bottom line is that we have a suction margin in terms of debris loading and then for the in-vessel downstream effects.

MEMBER KIRCHNER: And when you do something like that, what it prompts me to say is how do you know that it all went across the uniform, uniformly across the core?

MR. LU: Well, yes.

PARTICIPANT: More than two.

MR. LU: Okay. Yes.

MEMBER KIRCHNER: I know. I agree.

MR. LU: That's a, we had another discussion back to, this was 13 years ago, I remember. I had this same option. Back to the first time that we're dealing with just want to know when the in-vessel downstream effect comes in.

And I think at this point it's a, the specific answer to that question is if for this case it doesn't really matter because it's all uniform anyway. And because it would be there was no debris bed but if there was debris bed really forming on the bottom of the core inlet, you have what we call the zipper effect.

So that means one part of the core is blocked, then the water tends to flow to other parts then you gradually seal that entire core.

And that's what we observed as part of strainer testing. That's the reason we normally still felt comfortable, that's why we perform one assembly test not the entire core. This should be okay. So that's our assumption. But we can always argue that and then if you really have the -- okay.

(Off the record comments)

MR. LU: Okay. Thank you. Next slide. All right.

MEMBER SUNSERI: Oh, but just one more question and you can leave it right here. We came across an issue recently with another applicant where they were running some electrical cables that encroached in the zone of influence and it was determined to affect this whole scenario.

So my question is what's to prevent that from happening with this plant and do we need to have a COLA item or something to be aware that this analysis could be changed by the as-built configuration of the plant?

MR. TRAVIS: So as it turns out, we had a status in RAI specifically regarding fibrous materials and cables or other components in the containment. As part of that RAI response, they committed to not putting fibrous components in anything, additional fibrous inventory as part of an SSC that's added to containment.

So we, it's our expectation that the design as is will not have any fibrous material or source term material that is not considered as part of this analysis.

As you know, a COL could change that but

they would have to come in with asking for a license amendment at that point, so.

MEMBER SUNSERI: Yes, well, I don't know. I don't know that the full circumstances behind how it was discovered, but it seemed to me it was not something they had planned to do but had stumbled into, I'll say that.

So all I'm suggesting is do we need to do something to not have to have the COL applicant stumble into an issue here by putting a flag or something in there to --

MR. LU: I think from the perspective of the margin, I think they have sufficient margin. If you look at the, go through the slide, this other 6.93, we can take another, double the amount of debris.

MEMBER SUNSERI: Yes, but doubling a very small amount doesn't take very much more --

MR. LU: Yes, yes, but it's also of course the, if we postulate anything then can happen but that means as Boyce mentioned, that they do have different configuration and different source term, then that's an amendment.

MEMBER SUNSERI: That's fine. I've raised a point and I think that's all I need to do with that.

MR. LU: Okay. Thank you. All right. The available driving head, this part has really nothing to do with actual debris. It's really the configuration of the geometry of the core and then the downcomer, the geometry, and the steam generator.

So we just think about doing the long-term cooling stage with the decay heat at the boil-off stage, how much water, would it go through the core, how much, what's the DP available driving head.

Do you have a, if you assume you have a debris bed then you have cross debris, you know, at the bottom or you have head loss, then you just still want to maintain the minima flow rate for the given --- the rate going to be available to drive the flow to drive the boil-off flow rate going through the core.

And then based on that, they come up with developing the available driving head. We asked the other's calculations, this was four and a half years ago. And so for the initial round we did see something there so we made comments and maybe why that, it wasn't a very small delta change there but it was just additional two-phase acceleration term of the pressure loss through the core.

It's not, during the boil off it's small so that part, they correct that one actually and the

before and after correction does not make too much difference there. But we have a lot of margin there.

So based on our review, we found their standard and they followed standard procedure to come up with the available driving head available through the system to overcome the DP across the potential debris area. All right. That's available driving head.

Next slide, talk about in-vessel downstream effects testing. Okay. This normally for any applicant so far, we asked for specific fuel bundle head loss testing. And for the given debris loading, measure the DP across and for the given flow pattern. And either from the flow going downwards or going upwards. Ended up with this case is really just two actions there.

And then what they did instead of using 6.93 or 7 grams of fiber, we used 15 grams. They used, they doubled the amount of the debris loading and then, you know, then what they have.

CHAIR CORRADINI: These were single assembly tests?

MR. LU: Yes, single assembly head loss testing. So they did follow the standard testing protocol. We asked all the, both the operating fleet

and the new reactor applicants to follow and then they performed that one test.

And we all did them twice and I had one QA inspection. We did find something but I think the finding turned out to be that it's not a factor in terms of the magnitude of the change of the available, all of the DP across the debris bed, because the loading of 15 grams of fiber into a space going off of PWR fuel bundle, based on the past experience and the, you know, the current experience, it does not really able, you know, it is not able to fuel, what we call the steam bed, after you add the chemical precipitates.

So therefore, the finding for, we find that we have a sufficient margin in terms of available driving head to drive the core, drive the flow through the core for the given loading of the fiber loading.

So that's the fuel assembly head loss testing. And you can look at the SER and the SER would document that the inspection findings, they found that the end point is still okay, right. Next slide.

The LOCA deposition model which is, you know, for what the assumption is, all the applicants are required to address this during the 30 days of the

long-term cooling.

You have the fiber debris and you have the chemical precipitants plus the particulate assuming it's all deposited on the surface of the fuel rod, what can be the crud thickness and then also the peak cladding temperature.

And then it should be less than 50 mill and they demonstrated it's less than 50 mill and then also less than 800 degree Fahrenheit.

And we, at the during our Phase III presentation, we actually identified this as an open item because at that time we just received the RAI responses. We asked for detailed input for the calculation and after that we performed our in-house confirmatory analysis. Basically we followed the applicant, the methodology and then we used that as same methodology to calculate how much should be crud thickness.

So staff performed the independent analysis, confirmed that the 50 mill is okay, so less than 50 mills. And then of course there is no PCT issue there.

So therefore, from LOCA DM perspective, there's no issue and then this open item has been closed. I think that three months ago I talked about

this one too.

So with that, I think that goes to my conclusion. In terms of long-term cooling, core cooling during post-LOCA long-term core cooling, even up to 30 days, the staff found that the applicant's analysis testing are conservative and that there is no reason to doubt that they're going to have any issues related to, you know, exceeding 800 degree Fahrenheit or have a core blockage.

So that's our conclusion into this part from our perspective. We are done. We approve. Any questions? Okay.

MEMBER BALLINGER: Thank you.

MR. LU: All right. That's it, we're done.

MEMBER BALLINGER: I think we should pick up and get the KHNP folks in to talk about the large break LOCA.

(Off the record comments)

CHAIR CORRADINI: Hang on a second.

MEMBER MARCH-LEUBA: I don't think we can start until 2:30.

CHAIR CORRADINI: I think the topic run is scheduled to start at 2:30.

MEMBER BALLINGER: Okay. So full

committee, so we have to wait?

CHAIR CORRADINI: We'll have to wait. Why don't we take a break?

MEMBER BALLINGER: Okay. So we'll begin, never mind. Until 2:30.

CHAIR CORRADINI: I was going to say let's gather at 2:2o and we can, all right?

MEMBER BALLINGER: Okay. Yes.

(Whereupon, the above-entitled matter went off the record at 2:02 p.m. and resumed at 2:23 p.m.)

CHAIR CORRADINI: Okay. Why don't we get started a little bit early? So the staff had a clarification they wanted to make on the record regarding the debris loading.

MR. TRAVIS: The debris bypass test, yes. So for clarity, the initial test sweep to clean the pool is performed with the one micron filter. The actual whole size of the bag is, the number is proprietary but it's on the order of, you know, a millimeter, millimeters.

CHAIR CORRADINI: The bag?

MR. TRAVIS: The bag. The capture bags for the fiber bypass test. And so the clean pool sweep is a one micron filter, the actual fiber bag is on the order of single digit millimeters. The number

itself is proprietary, so.

PARTICIPANT: So a millimeter instead of a micron.

CHAIR CORRADINI: So that's only a thousand times difference.

MR. TRAVIS: For reference, the approximate size of a fiber, diameter of a fiber piece is around seven millimeters so if that gives you any --

CHAIR CORRADINI: That must be the length. That's not the width. A diameter is not seven millimeters.

MR. TRAVIS: You're right. Yes, you're right. I'm sorry, excuse me. The average size of a shredded piece of fiber that's going to be in the test matrix is about seven millimeters, yes. Apologies.

CHAIR CORRADINI: Okay. All right. With that, let's proceed and I'll be sent to prison for five minutes. Let's go.

MEMBER BALLINGER: Somebody drops a dime on you?

MR. SISK: So this will be a discussion on -- this is Rob Sisk, Westinghouse -- discussion on the large-break LOCA and Mr. Juhyun Park will lead through that discussion.

MR. PARK: Good afternoon. My name is Juhyun Park and from KHMP. I will explain about large-break LOCA Topical Report.

This page shows table of content and I'll explain about the elimination of Condition (1) and revision of Condition (4) in CAREM Topical Report of this SER and summary.

First elimination of Condition (1). In advanced SER, NRC staff imposed the Condition (1) as below. Should changes to the APR1400 configuration, Evaluation Model, or design input result in large-break LOCA flooding rates lower than 10 centimeters per second, the CAREM analysis shall require additional justification and NRC approval.

The background of Condition (1) is code assessment results against low flooding rate tests of FLECHT-SEASET 31805 and 34006.

This figure shows code assessment results and measured data for FLECHT-SEASET CAREM ASER 34006 at the same elevation.

In this figure, green line means a nominal calculation result calculated by best-estimate minima and red lines mean measured data.

As you can see, total result calculated by best-estimate minima underestimate underpredict for

maximum measured data, but total result will predict certain temperature trend of all measured data. Next.

Experimental data covering as in Step 9 of CAREM evaluates best-estimate with uncertainty propagation because CAREM is a realistic evaluation methodology with quantifying uncertainties.

This figure shows code result calculated by best-estimate with uncertainties and the maximum measured data of FLECHT-SEASET 34006.

In this figure, green line means nominal case as is shown in figures here and black line is the maximum measured data. And blue and red line means best-estimate with uncertainty propagation, the maxima and minima, respectively.

As you can see, best-estimate with uncertainties result covers the maximum value of measured data even though the case will result on the (unintelligible) of maximum measured data.

For the other low flooding rate tests of FLECT-SEASET, in these figures, green line is nominal result. Red and blue lines are (unintelligible) and the black line is the maximum value of measured data in common.

As you can see, all of the code results calculated by best-estimate with uncertainty cover the

maximum value of measured data. And these are results described in Appendix C of Topical Report.

Therefore, based on the code assessment results, it was confirmed that best-estimate with uncertainty propagation of CAREM has conservatism for the prediction of PCT regardless of flooding rate. So it is concluded that Condition (1) was not needed.

CHAIR CORRADINI: Can we go back to that, go back a slide, please? I want to make sure I understand.

So when you did the analysis, you were underpredicting? I want to make sure. Yes, can you start there and help me again with this?

So the RELAP calculation was predicting too early of a quench?

MR. PARK: Yes.

CHAIR CORRADINI: And so what did you do to modify it? You fit it to the data?

MR. PARK: Yes. This code result we already modified to use already with --

CHAIR CORRADINI: Oh. But prior to that what was the prediction? That's what I don't remember. You were under predicting? You were predicting quench too soon before you modified the RELAP5 calculation?

MR. PARK: Yes.

MR. JEONG: Yes, and so -- but for this calculation we used the multiplied version.

CHAIR CORRADINI: So you decreased the heat transfer coefficient?

MR. JEONG: Yes, right.

CHAIR CORRADINI: Which then, in our methodology, changes the transition point between transition boiling and film boiling?

MR. JEONG: Yes.

CHAIR CORRADINI: Okay.

MR. JEONG: But for this calculation we used, you know, the modified version and Mr. Park said that the green line under predicts the maximum value of the precipitate. But our RELAP5 calculation predicts, you know, where the average value of the measured data.

CHAIR CORRADINI: Okay. And then if we go onto slide 3, that's the data spread?

MR. JEONG: No, no.

CHAIR CORRADINI: Oh, I'm sorry. Sorry. That's the minima maxima calculation in RELAP5. And how'd you get the minimum and maximum?

MR. JEONG: We quenched the uncertainties.

CHAIR CORRADINI: Oh, okay. All right.

Excuse me. And the point being that as I change the injection rate, I don't see a big change in the uncertainties? I'm trying to understand now the next slide, Number 4. What do I take away from that?

MR. JEONG: This is the result of the various flooding test result. There are various flooding they test in FLECHT-SEASET so we evaluate all of the flood test data. So this result is code assessment results for various, all flooding they test.

CHAIR CORRADINI: And this was with the same modification that was seen in Slide 2?

MR. PARK: Yes.

CHAIR CORRADINI: Okay. All right. I've got it now. Thank you. Thank you very much.

MR. PARK: Next? In case of Condition (4), revision of Condition 4 as below. The limiting loss-of-offsite-power --

MEMBER BLEY: I'm sorry to interrupt you but following up on what Mike was asking, on that last set of pictures? Go back to 4, yes. And on 3 you showed a best-estimate calc. On these, the green one is base. Is that the best-estimate?

MR. PARK: Yes.

MEMBER BLEY: That's the same as best-

estimate on the other one?

MR. PARK: Yes.

MEMBER BLEY: Thank you.

CHAIR CORRADINI: I just want to make sure that I understood it. So their modification is the consistent modification and then they do and predict the flex head test as a group with different flooding.

MR. PARK: Okay. Page 6. Revision of Condition (4) as below. The limiting loss-of-offsite-power, also called LOOP, assumption shall be utilized and justified for the appropriate type of limiting PCT calculation, or blowdown PCT or reflood PCT, while performing Step 1 of Element 1.

Specific step to determine the limiting condition on LOOP assumption is introduced in the revision of Condition (4).

Step 1 of CAREM is Scenario Specification and in this step the limiting conditions there is a limiting scenario for the break location, pressurizer location, and with or without LOOP Assumption are determined by sensitivity testing studies in CAREM. And following step, step 2 through last step 14, are used for specified scenario in this step 1.

In summary, CAREM has conservatism for the prediction of PCT regardless of flooding rate based on

the various code assessment results. Therefore, we concluded that Condition (1) was not needed.

And second, specific step to determine the limiting condition of LOOP assumption is imposed in Condition (4).

MEMBER MARCH-LEUBA: Let me settlement if I understand.

MR. PARK: Yes.

MEMBER MARCH-LEUBA: The staff SER in both the old conditions, are you proposing these modifications from this staff based on your new analysis? What's the process here? Maybe I should ask the staff.

MR. JEONG: This is Jaehoon Jeong --

MR. DRZEWIECKI: This is Tim from the staff design. Yes, so what this was is that after they had received their draft of the SER, they were confused about some of the meaning of that condition.

And so after a discussion we had realized that he could make it more clear in order to get a mark point because it looked like the way it read in 4 is that after you would go through and run 181 calculations, if your limiting case ended up being something else than what you had assumed, then you may have to go back an rerun 181 cases again.

That was not the intention of this condition. It was to basically go through, make sure that you find what you think it, what's your value case based on a based set of initial conditions, find that case and then use that and 181 calculations.

MEMBER MARCH-LEUBA: So they provide additional information and you are happy with it and you're modified the textile plate?

MR. DRZEWIECKI: That's right.

MEMBER BALLINGER: Does that complete your presentation? Other questions? Then we should switch out for the staff.

MR. GILMER: Okay. Jim Gilmer.

(Off the record comments)

MR. STECKEL: Yes, this is Jim Steckel again. I'm going to introduce the technical reviewer, Jim Gilmer for the large-break LOCA full report redo.

And I think we have everything. We did send the updated report through the committee. It was late yesterday because we needed to, we felt we needed to get OGCs NLO on the revised version and that took a little longer than expected.

And so we do have in that report indications in the report and I have a copy here, where Condition (1) was deleted, but we kept the

original numbering of the conditions so it would be less confusing to read in the future.

And it's pretty clear in there where we deleted and then in the summation where the numbering is of those conditions. And now I'll introduce Jim Gilmer to complete the review and presentation.

MR. GILMER: Thank you and good afternoon again. You may recall or likely recall from the May 3rd Full Committee Meeting that we needed to come back here because we had not finalized the wording of those two conditions because literally right before the subcommittee meeting KHMP brought it to our attention that there was some concern about the first condition on the original wording was ten centimeter per second flooding rate and anything less than that then any license application would have to provide further justification of the flooding rate.

And we had that condition originally because the initial issue of the top of the report. We did not provide the convincing evidence that it was conservatively predicted for the lower flood rates.

So as the slide says, the information provided in Appendix C which is where the FLECHT-SEASET benchmark in the Topical Report. The recent supplemental information provided further clarity by

showing the uncertainty band which provided the staff more comfort in eliminating that, the original wording of that condition.

CHAIR CORRADINI: The original wording of the condition though now confuses me given what they've done. Is it, where did the ten come from? Can you help? I mean, it's not there anymore and I'm happy but help me. Where did the ten come from to begin with?

MR. GILMER: Well, that was more than a year ago that we had this detailed discussion. A contractor, Walter Tauche --

CHAIR CORRADINI: Okay.

MR. GILMER: -- I think is on the line still. Walter? Yes, Chris is going to get him back on.

CHAIR CORRADINI: Because I mean, this is now more for historical purposes on my part to understand. Because what I think, if I understand what they did seems quite reasonable now that they've shown against all of the results between RELAP and the FLECHT-SEASET test, so.

MR. TAUCHE: Jim, this is Walter Tauche. Can you hear me?

CHAIR CORRADINI: Yes.

MR. GILMER: Did you hear the question?

MR. TAUCHE: Yes, it's the background of the ten centimeters per second in the original condition.

CHAIR CORRADINI: Yes, please.

MR. GILMER: Right.

MR. GILMER: Okay. You've got to remember, this issue evolved over a long period of time and the history is convoluted.

It originally started with the fact that the table in Appendix C had the wrong flooding rate listed and that table led to the conclusion that they had not examined.

And the concern has always been once you get into low flooding rate conditions, those approaching the old appendix case see a cooling limit of about one per second or 25.4 millimeters per second.

Once you get into those conditions, there was always a concern about whether or not you're able to adequately predict the heat transfer coefficient properly.

And when we first began examining this issue, there was Table 4-6 in the Topical Report which shows the FLECHT-SEASET and test matrix. And of the

twenty tests that they'd predicted in that table, there were twenty cases.

Five of the cases were over-predictions and 15 cases were under-predictions. And so there was initial concern that perhaps there was something that was not being adequately covered by the RELAP calculations.

And so we first examined the very low flooding rate cases, the case, flooding or Test 31805 and Test 34006 were the two tests of concern. They also had flooding rates were also considered also in the Neptune Test and four THCF tests.

There were relatively low flooding rates in two of the seven Neptune case tests but those also were not well-predicted.

So the concern was of course whether or not you were adequately predicting the low flooding rate tests. So eventually a limit of ten centimeters per second was determined based upon the response to an audit issue 22b.

That audit issue, they supplied the flooding or the liquid velocity at the core inlets. And while it was oscillatory, the liquid velocity was generally above 12 and a half centimeters per second.

And so that seemed like an adequate limit

that the plant would have sufficient capability to always be above a ten centimeter flooding rate per second.

In fact, it was determined as we went through that the ten centimeters should probably have been ten millimeters because that, ten millimeters per second, because that would be a significantly low level. But the ten centimeters carried through.

I think we then had additional discussions as was pointed out and we examined the range of the uncertainties and the uncertainty calculations through the FRS calculations and determined that it really wasn't reasonable to have a flooding rate limit to cause them to go back and have to re-perform the test again.

Does that provide some idea of what we went through?

CHAIR CORRADINI: Yes. That's very helpful. Thank you very much.

MR. TAUCHE: Yes, sir. You're welcome.

MEMBER MARCH-LEUBA: So Jim, can you explain to me what this slide, the Slide Number 3 is? Is this the original calculations?

MR. GILMER: Yes.

MEMBER MARCH-LEUBA: They look very good

to me. They look good to you too?

MR. GILMER: It does. It's harder to see in black and white then on the color but.

MEMBER MARCH-LEUBA: It's pretty good.

MR. GILMER: Yes.

MEMBER MARCH-LEUBA: So what they have done is -- go to Slide Number 4. They have run the base or best-estimate and then run another full CSAU about minimum and maximum extreme ranges to see that really there is no significance to the deviation between the two.

MR. GILMER: Right. At various flood rate tests.

MEMBER MARCH-LEUBA: And they led you to believe that they can measure, they can predict because they're going to pick the conservative one, they will predict the conservative temperatures.

MR. GILMER: Right. So staff is confident that the original condition was unnecessary but further questions on this condition?

MEMBER KIRCHNER: Jim, could you just then re-summarize in light of both your comments to Mike and Jose and what we heard over the wire, phone? So you're removing the limit which was erroneous to begin with?

MR. GILMER: Well, I wouldn't say erroneous but I overly restricted.

MEMBER KIRCHNER: But ten centimeters per second is the easy one to calculate. It's the lower ones, one centimeter per second that's problematical.

MR. GILMER: Right.

MEMBER KIRCHNER: Okay. But you are, notwithstanding that, you think this is good enough agreement so you're not going to have any limit?

MR. GILMER: Right.

MEMBER KIRCHNER: Okay.

MR. GILMER: And the intent of the condition was just that if any future license calculations came up with that low flow rate, then they would have to provide further justification in the submittal.

MEMBER KIRCHNER: Okay. But the original ten centimeters per second was a mistake?

MEMBER MARCH-LEUBA: Are we telling you some sort of a --

MEMBER KIRCHNER: No. A mistake.

MEMBER MARCH-LEUBA: A mistake.

MEMBER BALLINGER: A mistake. Actually a typo.

MEMBER MARCH-LEUBA: A typo.

MEMBER KIRCHNER: That's what I'm referring to. It was meant to be one centimeter per second. The higher the flooding rate, the easier it is to predict these things. You see that in the chart that the applicant supplied. So when you get to the lower range of the flooding rates then the deviation and predictions starts to expand.

MR. GILMER: Right.

MEMBER KIRCHNER: Okay.

MR. GILMER: Any further questions on this issue? The next slide? On the Condition (4) you just heard the explanation from Tim Drzewiecki and staff that in discussions with KHMP we learned that they had a different interpretation then what staff intended on the need to repeat the entire 181 cases that for whatever reason they reflect heat, where it's found to be more limiting than the blowdown.

So the only change to the original wording is adding the mention of the Element 1 Step 1 which is in the CSAU methodology is the scenario definition which includes a loss of oxide power or the break size site and location, et cetera. So that was the only change to that condition.

MEMBER BALLINGER: This is an administrative change.

MR. GILMER: Yes. Clarification, right. Are there further questions on that one? Okay. That's all, then.

MEMBER BALLINGER: Yes, I think we probably now should ask for comments from the audience from the room.

(Off the record comments)

MEMBER BALLINGER: Okay. So nobody is bounding up to the microphone? So line's open. Is there anybody on the outside line that would like to make a comment or statement? You have none?

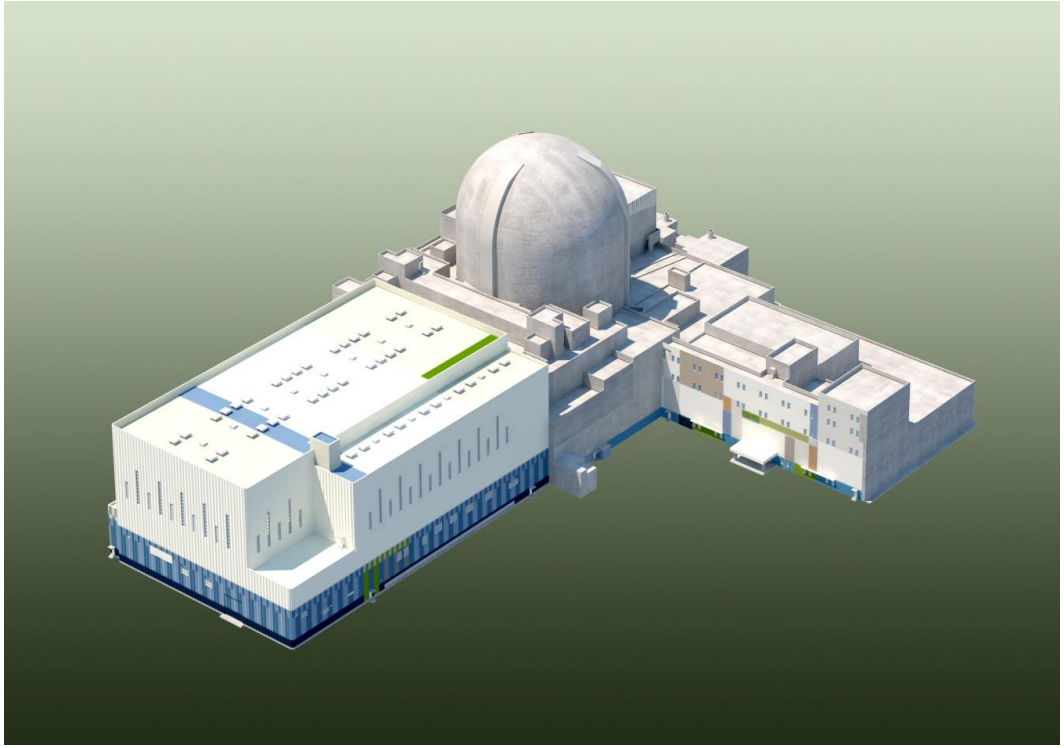
Back to you, Mr. Chairman.

CHAIR CORRADINI: Okay. Thank you, Ron. So we're going to go off the record, okay? And we'll take a short break. Let me thank the APR1400 folks and the staff. We're going to go off the record, take a short break as we reconfigure to look at some draft letters. Thank you.

(Whereupon, the above-entitled matter went off the record at 2:49 p.m.)

Non-PROPRIETARY

APR1400 DCA
LBLOCA Topical Report



KEPCO/KHNP

June 6, 2018

ACRS Meeting (June. 6, 2018)

Contents

- Elimination of Condition (1) in CAREM TR advanced SER
- Revision of Condition (4) in CAREM TR advanced SER
- Summary

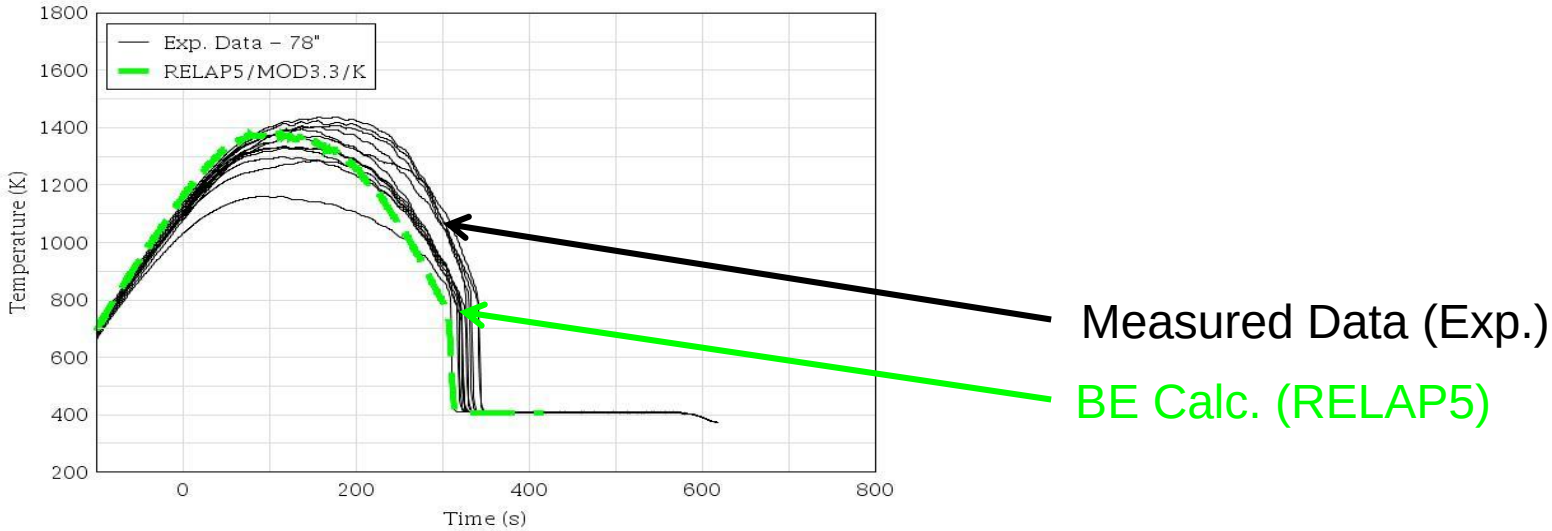
CAREM: Code-Accuracy-based Realistic Evaluation Methodology

Elimination of Condition (1)

- The NRC staff imposed Condition (1) on the use of CAREM in ASER:

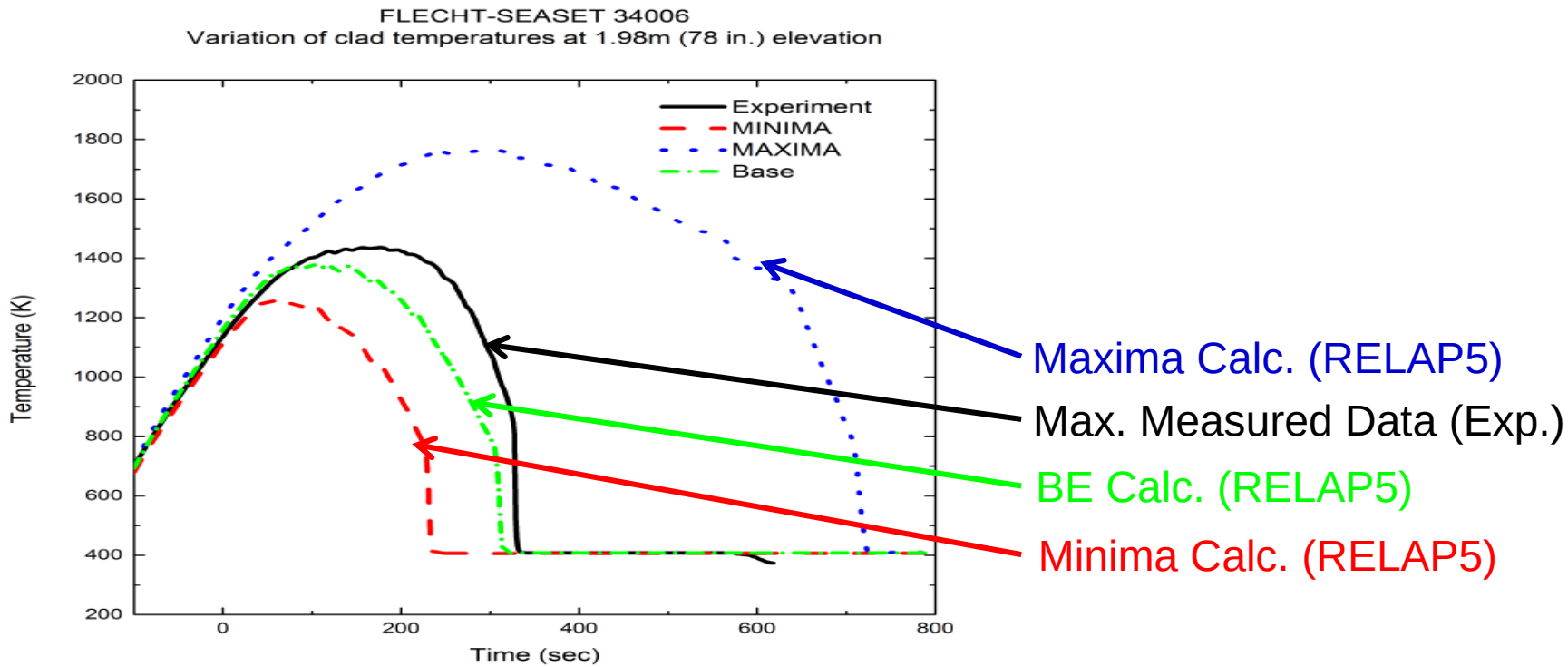
Should changes to the APR1400 configuration, Evaluation Model, or design input result in large break LOCA flooding rates lower than 10 cm/sec, the CAREM analyses shall require additional justification and NRC approval.

- Background of Condition (1)
  - ✓ RELAP5 under-estimates the maximum measured data for low flooding rate tests of FLECHT/SEASET 31805 (2.1 cm/s) and 34006 (1.5 cm/s).



Elimination of Condition (1)

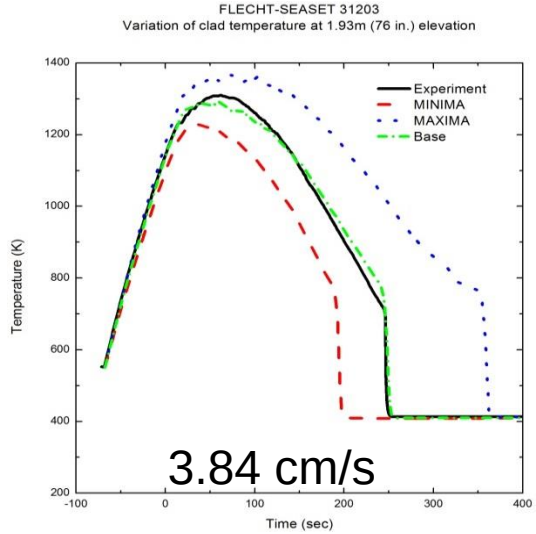
- Experimental Data Covering (Step 9 in CAREM)
  - CAREM is a realistic evaluation methodology with quantifying uncertainties.

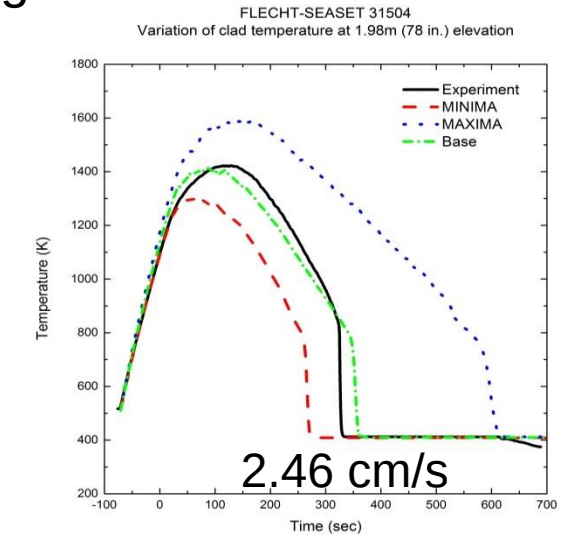


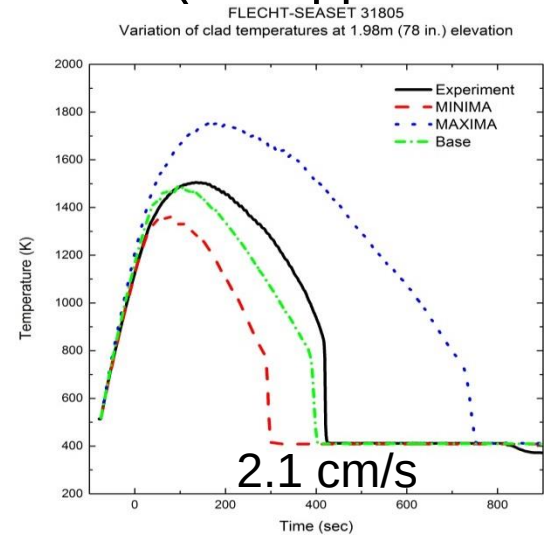
BE with Uncertainty Propagation (TR Appendix C)

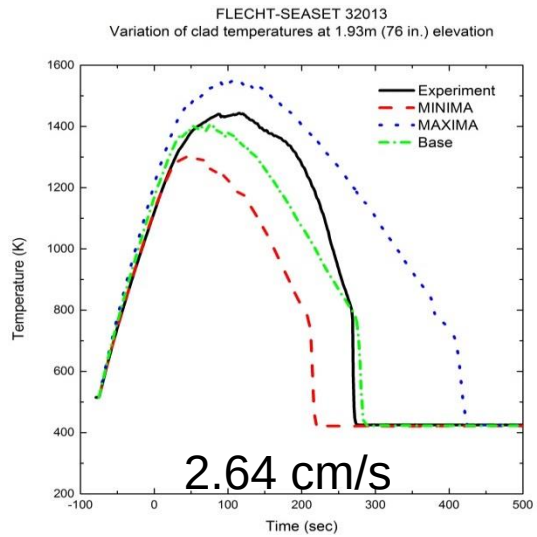
Elimination of Condition (1)

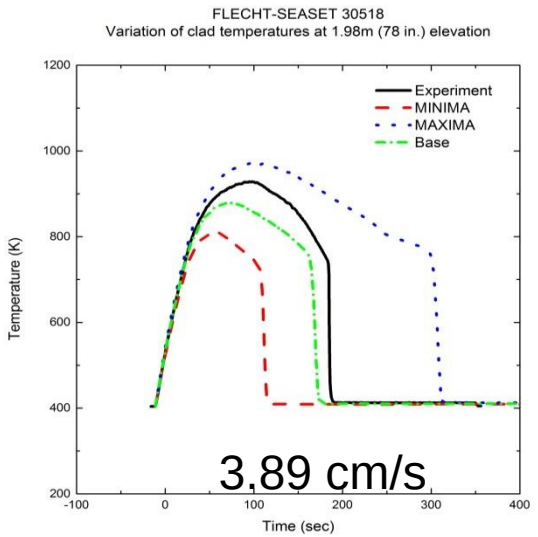
For the other low flooding rate tests of FLECHT-SEASET (TR Appendix C)

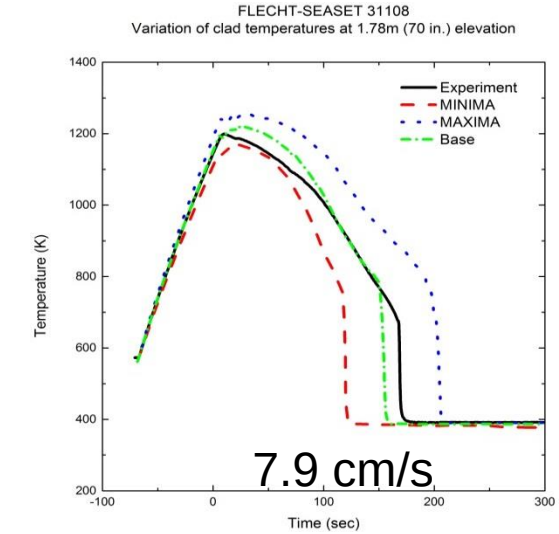












Elimination of Condition (1)

- Based on the code assessment results against various test data, it was confirmed that best-estimate with uncertainty propagation approach of CAREM has conservatism for the prediction of PCT regardless of flooding rate.

  → Condition (1) does not needed.

Revision of Condition (4)

- Condition (4) of Advanced SER:

  The limiting loss-of-offsite-power (LOOP) assumption shall be utilized and justified for the appropriate type of limiting PCT calculation, i.e., blowdown PCT or reflood PCT, which is used for comparison to the 10CFR50.46(b)(1) acceptance criterion.

- Revision of Condition (4):

  The limiting loss-of-offsite power (LOOP) assumption shall be utilized and justified for the appropriate type of limiting PCT calculation, i.e., a blowdown PCT or a reflood PCT, while performing Step 1 of Element 1.

  - Specific step to determine the limiting condition on LOOP assumption is introduced for clarify.
  - Scenario Specification (Step 1) in CAREM
    - ✓ The limiting conditions for break location, pressurizer location, and with/without LOOP assumption are determined by sensitivity studies.
    - ✓ Based on the specified scenario, following steps, step 2 through 14, are conducted.

Summary

- CAREM has conservatism for the prediction of PCT regardless of flooding rate based on various code assessment results.
  - It was concluded that Condition (1) does not needed.

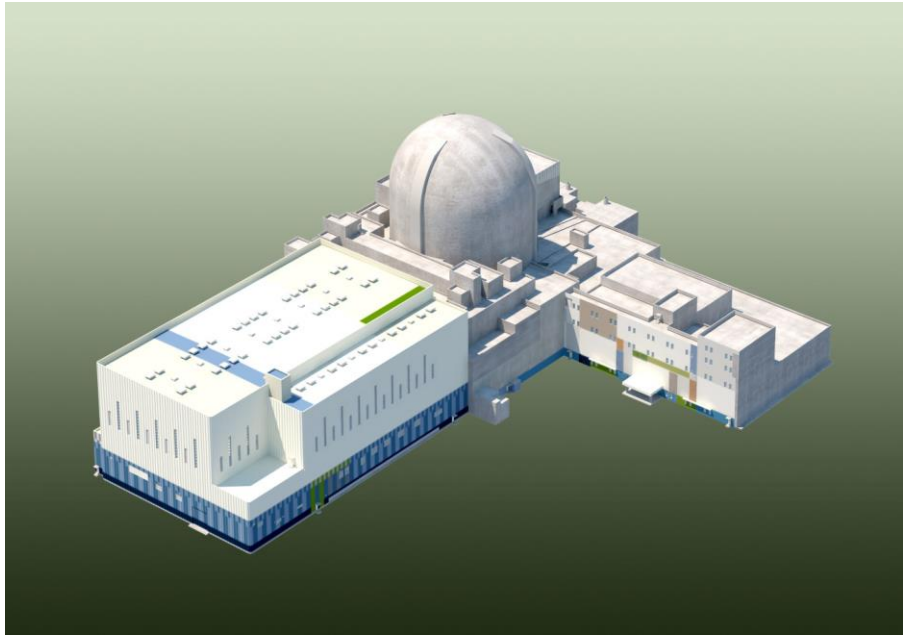
- Specific step to determine the limiting condition on LOOP assumption is imposed in Condition (4).

Attachments : Acronyms

APR1400	:	Advanced Power Reactor 1400
BE	:	Best Estimate
CAREM	:	Code-Accuracy-based Realistic Evaluation Methodology
CSAU	:	Code Scaling, Applicability and Uncertainty
CWO	:	Core Wide Oxidation
LBLOCA	:	Large Break Loss-of-Coolant Accident
LOOP	:	Loss Of Offsite Power
KHNP	:	Korea Hydro & Nuclear Power company
NRC	:	Nuclear Regulatory Commission
PCT	:	Peak Cladding Temperature
PLO	:	Peak Local Oxidation

NON-PROPRIETARY

APR1400 DCA
Long-term Core Cooling



KEPCO/KHNP

June 6, 2018

ACRS Meeting (June 6, 2018)

Contents

- **Overview of Long-term Core Cooling**
- **Main Topics**
  - Boron Dilution
  - Containment Over Pressure Credit
  - Gas Formation
  - Sump Strainer Performance
  - In-vessel Downstream Effects
- **Summary**
- **Acronyms**

Overview of LTCC

❖ List of Submitted Documents for LTCC

Document No.	Title	Revision	Type	ADAMS Accession No.
APR1400-E-N-NR-14001-P & NP	Design Features to Address GSI-191	3	TeR	ML18057B532
APR1400-E-N-NR-14002-NP	IRWST Sump Strainer and Trash Rack Structural Analysis	1	TeR	ML17094A124
APR1400-K-A-NR-14001-P & NP	In-vessel Downstream Effect Tests for the APR1400	2	TeR	ML17094A123
APR1400-F-A-NR-14003-P & NP	Post-LOCA Long Term Cooling Evaluation Model	1	TeR	ML15009A201
APR1400-F-A-NR-14001-P & NP	Small Break LOCA Evaluation Model	1	TeR	ML15009A202

Boron Dilution Analysis

❖ Background

- RAI 8455 requires that the core should not reach a recriticality when the boron dilution event occurs.
- KHNP showed why a start of natural circulation and restart of one RCP will not cause core recriticality by a simple mixing calculation.
- The assumption of simple mixing calculation uses the maximum unborated water volume can be accumulated in the system.
- The unborated water moved to the core will be mixed equally with the borated water initially existed in the core region by the geometry of system.
- The reactor core is maintained 4,000 ppm of boron concentration coolant initially.
- Boron concentration in the core region needs to be maintained above CBC (Critical Boron Concentration) of 970 ppm to avoid the potential for recriticality.

Boron Dilution Analysis

❖ Analysis Results – Mixing Calculation

- Assumptions:
  - The initial 4,000 ppm of borated water in the lower plenum region of 664.2 ft^3 is assumed to be mixed with the delivered unborated water.
  - Unborated slug volume (984 ft^3) of four loops with 0 ppm is delivered to the core. (Natural circulation)
  - Unborated slug volume (246 ft^3) of one loop with 0 ppm is delivered to the core. (Restart of one RCP)
- Results:
  - Natural circulation: 1,612 ppm > 970 ppm(CBC)
  - Restart of one RCP: 2,298 ppm > 970 ppm(CBC)

Containment Over Pressure Credit

- **$NPSH_a$ for SI and CS pumps**
  - Credits the CAP for the IRWST temperature equal to or greater than 212°F with the assumption that the CAP is equal to the IRWST liquid vapor pressure
  - $NPSH_a = h_{atm} + h_{static} - h_{loss} - h_{vapor}$
    - $T_{IRWST} \geq 212^oF$, $h_{atm} = h_{vapor}$
    - $T_{IRWST} < 212^oF$, h_{atm} = initial containment pressure before LOCA
- **CAP Analysis**
  - Used GOTHIC containment model
  - Used conservative assumptions for CAP based on SECY-11-0014
- **Result of CAP Analysis**
  - Containment pressure during accident maintains higher than IRWST vapor pressure.
  - The NPSHa calculation has conservatism.

Gas Formation

- **Strainer vortexing**
  - No visual observation during prototype testing
- **Flashing in debris bed**
  - No flashing occurs in debris bed because the strainer submergence is greater than pressure drop across debris bed.

    - Strainer submergence height: 2 ft under LOCA conditions (IRWST minimum water level of 86 ft – Strainer top level of 84 ft)

    - Maximum strainer head loss of 1.06 ft-water at 140 ^{o}F
- **Deaeration of sump fluid at strainer**
  - No deaeration of sump fluid occurs at the strainer.
  - Increase in solubility of air due to the static pressure increase of the water above the strainer is more than the decrease in solubility of air due to the head loss across the strainer.

Sump Strainer Performance

- **Sump strainer performance evaluation according to NEI 04-07 and SE**
  - No fibrous insulation
  - RMI assumed 75% small fines and 25% large pieces
  - All particulate, fiber, and miscellaneous debris assumed to reach sump strainers
  - 100 ft^2 sacrificial strainer surface area due to miscellaneous debris
  - Latent fibrous debris of 15 lbm
- **Ex-vessel downstream effects according to WCAP-16406-P**
  - Pump evaluations according to ASME QME-1-2007 endorsed by RG 1.100 Rev.3
  - Heat exchanger plugging, performance, and wear
  - Blockage, settling, and wear of valve, orifices, and pipes
- **Chemical effects evaluation by using NRC approved methodology (WCAP-16530-NP)**

In-Vessel Downstream Effects

❖ Three LOCA scenarios were chosen

- **Core flow rate and its direction affect the behavior of debris in the core**
- **Break location affects the driving force of injected ECCS water**

LOCA scenario	Core flow direction	APR1400 flow rate	Flow rate/ FA*	Remark
HL Break	Upward	4,940 gpm	20.5 gpm	Max. safeguard flow rate of four SIs
CL Break	Upward	880.2 gpm	3.65 gpm	Boil-off flow rate at 700 sec
CL Break after HLSO	Downward	2,470 gpm	10.25 gpm	Max. safeguard flow rate of two SIs

*** 1/241 of the maximum flow rate for the scaled tests**

In-Vessel Downstream Effects

❖ Input for In-vessel Fuel Assembly Test

- Input for In-vessel Fuel Assembly Test

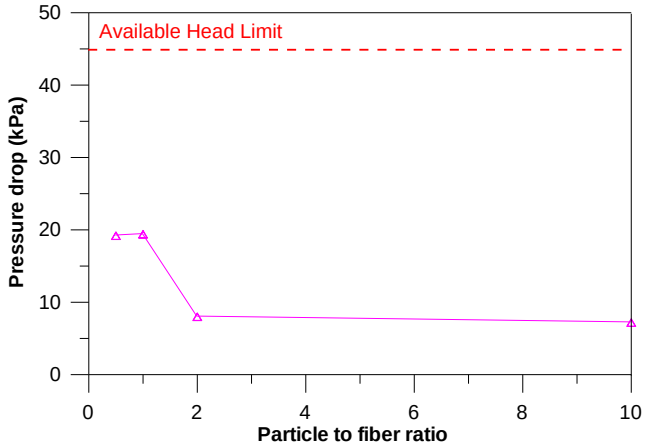
Debris type	Specific type	Debris generated in containment	Assumed bypass debris	Per FA* (g)
Fibrous	Latent fiber	15 lbs (6.8 kg)	3.68 lbs ** (1.67 kg)	6.93 **
Particulate	Coating debris	3.1 ft^3 (280.5 kg)	3.1 ft^3 (280.5 kg)	1,164
	Latent particle	185 lbs (83.9 kg)	185 lbs (83.9 kg)	348
Chemical compounds		408.0 lbs (185.1 kg)	408.0 lbs (185.1 kg)	768 (70 liters)

***** 1/241 of the assumed bypass debris amount
** Result from the APR1400 strainer bypass testing
*** 15 g is applied for actual test.

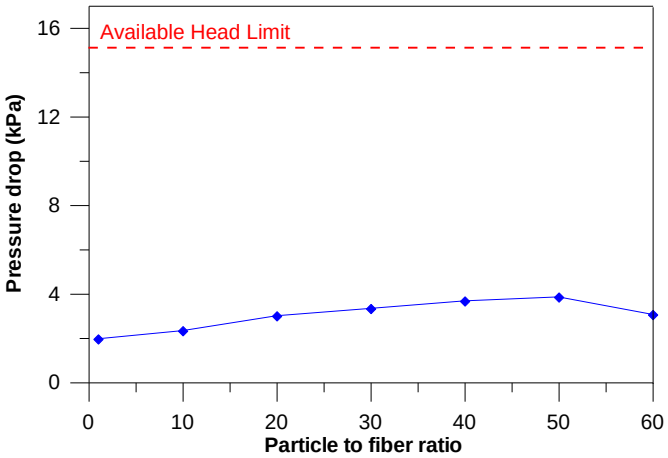
In-Vessel Downstream Effects

❖ Test results

- 5 Tests had been run to evaluate hot-leg(HL) break conditions
- 7 Tests had been run to evaluate cold-leg(CL) break conditions
- HLB: Meet the acceptance criteria(42.7 kPa) with sufficient margin(54.6%)
- CLB: Meet the acceptance criteria(13.2 kPa) with sufficient margin(70.8%)



[Pressure drop vs. p/f ratio: HL Break]



[Pressure drop vs. . p/f ratio: CL Break]

Summary

- **LTCC is complete.**
  - KHNP continues to monitor LTCC to assure any conforming changes are addressed.

- **APR1400 design provides sufficient margin to maintain long-term core cooling during post-LOCA conditions.**

Acronyms

APR1400	Advanced Power Reactor 1400
BDA	Boron Dilution Accident
CAP	Containment Accident Pressure
CBC	Critical Boron Concentration
CS	Containment Spray
DCD	Design Certificate Document
DEDLSB	Double-Ended Discharge Log Slot Break
ECCS	Emergency Core Cooling System
HL	Hot Leg
IRWST	In-containment Water Storage Tank
LOCA	Loss of Coolant Accident
LTCC	Long Term Core Cooling
RCFC	Reactor Containment Fan Cooler
RCP	Reactor Coolant Pump
SI	Safety Injection

United States Nuclear Regulatory Commission

Protecting People and the Environment

Non-proprietary

Presentation to the ACRS Full Committee

Korea Hydro Nuclear Power Co., Ltd (KHNP)
APR1400 Design Certification Application Review

Post LOCA Long Term Core Cooling

By

Shanlai Lu
NRO/DSRA/SRSB

June 6, 2018

Main Topics

- Post LOCA Boron Dilution
- In-vessel Downstream Effects

Boron Dilution During LOCA Long Term Cooling Phase

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Description:

- RAI 8455 Question 15.06.05-22 was issued based on Reg. Guide 1.206 regarding GSI-185 to request specific analysis for APR1400 conditions
- The phenomenon is possible due to the presence of a loop seal

Closure:

- KHNP responded to the RAI and performed APR1400 specific analysis
- Conservative assumptions were introduced in the calculation to determine the loop seal fresh water slug discharge based on PKL tests
- The calculated Boron concentration in the core has sufficient margin to maintain sub-criticality during post LOCA long term cooling phase. Therefore, the shutdown margin is maintained

Conclusion:

Open Item 15.6.5-6 is closed. No re-criticality due to Boron dilution

Debris In-vessel Downstream Effects

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1. Debris source analysis and fiber only bypass testing
2. Available driving head across the debris bed
3. Fuel assembly head loss testing
4. LOCA deposition model

Regulatory Requirements And Precedence

- 10CFR50.46, GL 2004-02, RG 1.82 Rev.4
- SER for WCAP16793 "Evaluation of Long-Term Core Cooling Considering Particulate Fibrous and Chemical Debris in The Recirculating Fluid" Rev. 2, ADAMS #ML121020118, December, 12, 2012)
- 15 gram/assembly fiber loading clean plant criteria has been approved and used for US operating PWR plants (Reference only)

Debris Source and By-pass Testing

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Non-proprietary

- Reflective Metallic Insulation (RMI) is used
- Removal of all fiber insulation from ZOI
- Limit latent fiber amount to 15 lbm at the strainer
- Fiber only by-pass testing was conducted using the in-line filtration system
  - The same prototypical strainer head loss testing facility was used to preserve the 1:1 approaching velocity ratio through the strainer surface
  - Staff audited and observed the actual test
- Only 6.93 g fiber per assembly is predicted. However, 15 g was used in the fuel assembly head loss testing and the core DP analysis

Staff findings, Debris Source Analysis

- Debris source analysis and bypass testing are conservative

Available Driving Head

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Non-proprietary

- All limiting core flow conditions have been identified
- Conservative debris arrival time is assumed
- Limit latent fiber amount to 15 lbm at the strainer
- Core two-phase flow friction loss, acceleration term, and liquid density are determined properly in response to staff RAIs and audit questions
- As part of the available driving head, the water column height in the steam generator tube is conservatively treated to add margin

Staff findings, Available Driving Head

- Available driving head across the core has been conservatively determined

Fuel Assembly Head Loss Testing

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- A new test facility was deployed by KHNP to measure the head loss across PLUS7 fuel bundle with the presence of debris
- The facility and the testing protocols have been adjusted in response to three staff inspection findings
- 15 g/assembly fiber insulation material was introduced including all the particulate and chemical precipitates
- For all the limiting flow conditions, the measured head loss values were significantly less than the core available driving head

Staff findings, Fuel Assembly Head Loss Testing

- The head loss tests were conducted properly and the measured bundle head loss was less than the available driving head

LOCA Deposition Model

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Non-proprietary

- PWR Owner's Group LOCA deposition model was used to predict the cladding temperature with the presence of crud build up
- Very conservative fiber and other debris loading was assumed
- The results show that the crud thickness is significantly less than the limit value of 50 mills. The PCT is much less than the 800°F limit
- RAI was issued to obtain more detailed information about the inputs

Staff findings, LOCA Deposition Model

- During 30 days of the long term cooling, the crud formation shall be less than the thickness limit and the PCT shall be less than 800°F pending on the final closure of the RAI. Open Item 15.6.5-7 has been closed with staff confirmatory analysis further confirming the calculated crud thickness and relevant PCT

Conclusion

KHNP has adopted conservative methods and testing protocols to demonstrate that US APR1400 design has sufficient safety margin to evaluate its in-vessel downstream effects as the result of existence of latent debris in the containment during the post LOCA long term cooling phase up to 30 days.

United States Nuclear Regulatory Commission

Protecting People and the Environment

Presentation to the ACRS APR1400 Full Committee

Staff Review of Korea Hydro & Nuclear Power, Ltd. (KHNP) Topical Report APR1400-F-A-TR-12004-P

Realistic Evaluation Methodology for Large-Break LOCA of the APR1400

June 6, 2018

ACRS Question:

Takeaway from the May 3, 2018, ACRS meeting:

Question – What is the basis for the removal of Condition 1 from the SER?

Response – Information provided in Appendix C of the TR and supplemental information provided in letter dated April 25, 2018 shows that application of RELAP5/MOD3.3/K in accordance with CAREM methodology results in conservatively high estimates for fuel temperatures and quench times.

Appendix C

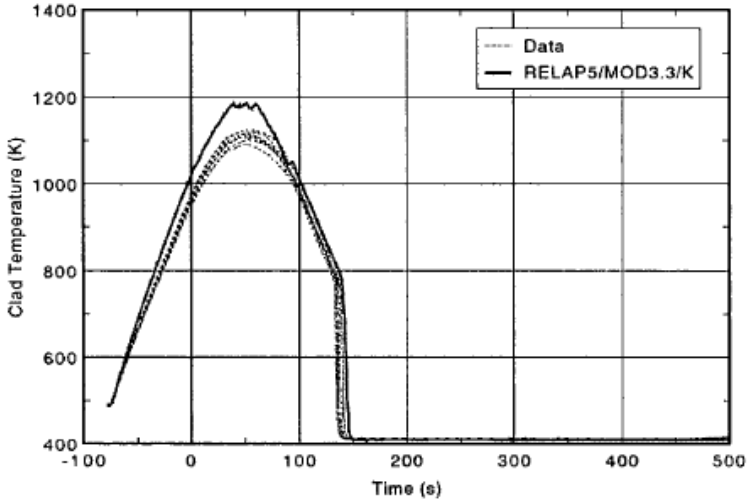

Figure 2-7 Rod Clad Temperatures at 48 in. from the Heated Bottom: Test 31805

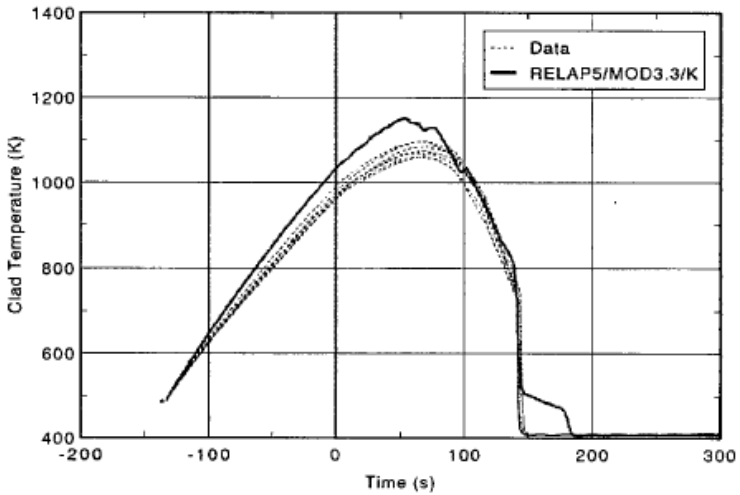

Figure 2-87 Rod Clad Temperatures at 48 in. from the Heated Bottom: Test 34006

Reflood Rate = 2.1 cm/s

Reflood Rate = 1.5 cm/s

April 25 Letter

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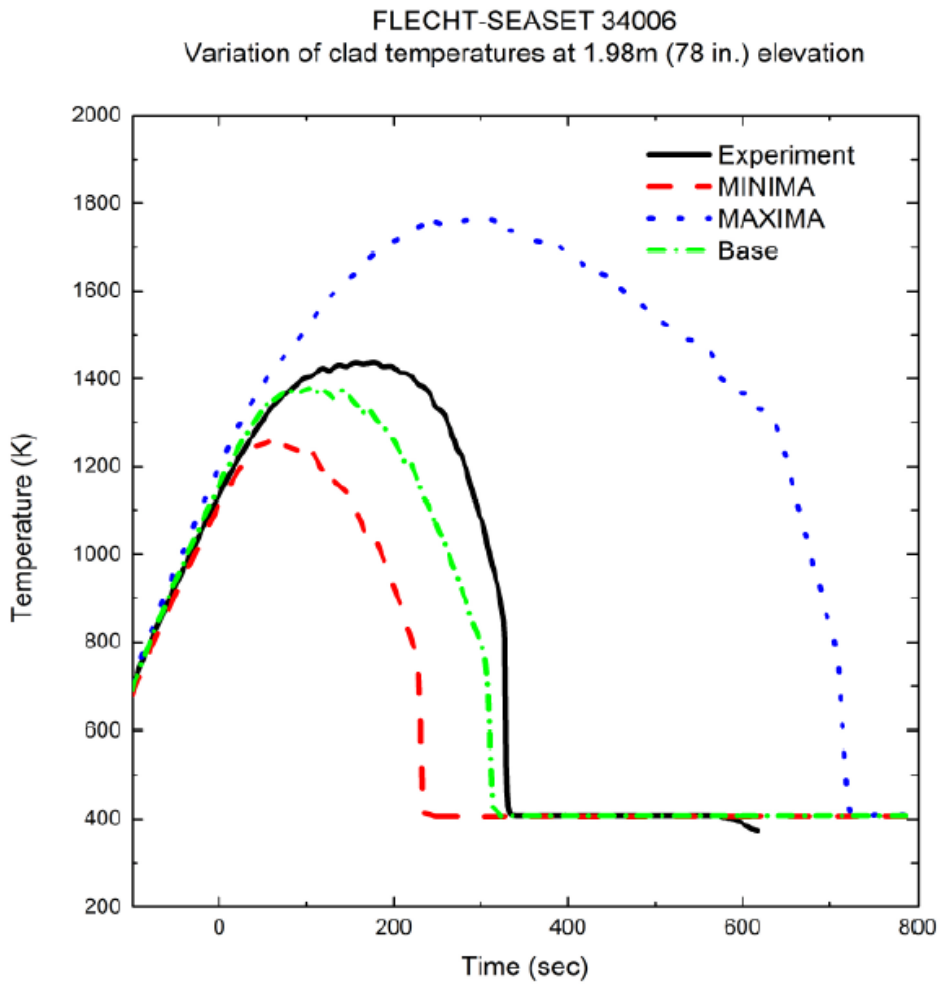
For example: Test 34006 (Flooding rate of 1.5 cm/sec)



Condition 4 revision

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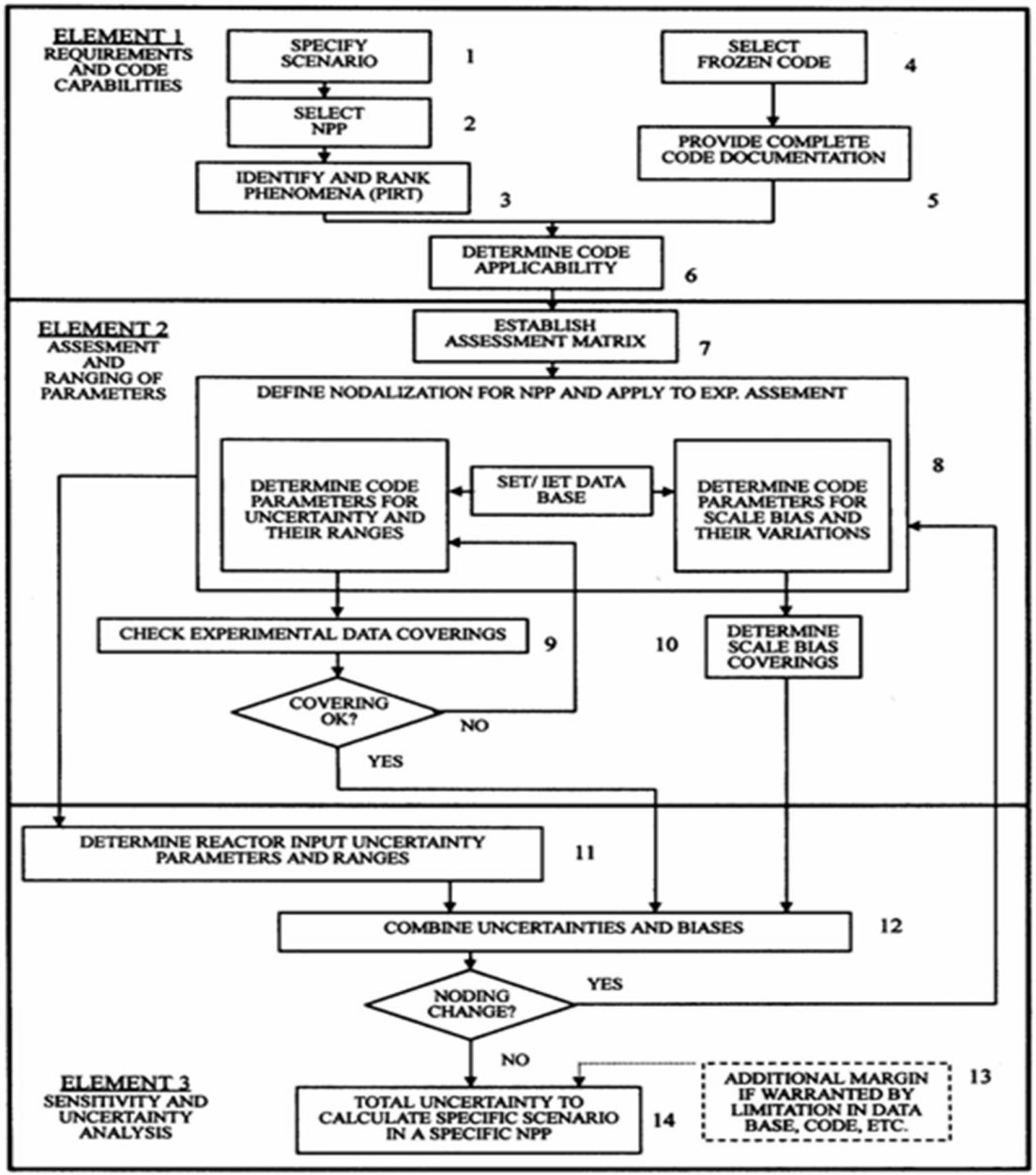
- Original wording led to unintended interpretation that further iteration is needed if, depending on the LOOP assumption, the reflood PCT result is more limiting than the blowdown PCT result.

- The phrase “while performing Step 1 of CAREM Element 1” was added to clarify that the LOOP scenario need only be defined once during the iteration process. As in the approved CSAU method, LOOP assumptions are considered an inherent part of the overall scenario definition.

Backup Slide



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CAREM Iteration Process