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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON US-APWR TOPICAL REPORTS

OPEN SESSION

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THURSDAY, OCTOBER 23, 2008

The subcommittee came to order at 8:00 a.m. in room T2B3 of White Flint Two. Otto L. Maynard, Chairman, presiding.

OTTO L. MAYNARDCHAIRMAN

SAID ABDEL-KHALIKMEMBER

J. SAM ARMIJOMEMBER

DENNIS C. BLEYMEMBER

WILLIAM J. SHACKMEMBER

JOHN D. SIEBERMEMBER

JOHN W. STETKARMEMBER

NEIL COLEMANDESIGNATED FEDERAL OFFICIAL

C-O-N-T-E-N-T-S

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

(8:00 a.m.)

OPENING REMARKS

CHAIRMAN MAYNARD:: This is a meeting of the subcommittee for the U.S. advanced PWR reactor. We are here to discuss selected topical reports and technical reports today.

I'm Otto Maynard, chairman of the subcommittee.

The designated federal representative for today's meeting is Neil Coleman.

Members in attendance, we have Jack Sieber, Dennis Bley, Sam Armijo, Bill Shack, John Stetkar, Said Abdel-Khalik and I believe that's it for the meeting today.

Portions of the meeting will be closed to the public to discuss proprietary information. At that time we will be asking people who are not cleared, who have not signed agreements, to leave for those portions of the meeting.

I think it's important to discuss a little bit the purpose of the meeting and the desired outcome for today. The purpose is for us to get an overview and a basic understanding of topical reports that

Mitsubishi Heavy Industries has submitted for approval by the NRC, and are currently under review by the NRC staff in support of the design certification review.

Now in most cases the topical reports are not necessarily reviewed and approved by the ACRS. In this case we have an opportunity to take a look at some of these topical reports before they are finalized. And I think it's important for us because a number of these will be used as the basis for approval of parts of the design certification document. So this gives us an opportunity to get an overview, identify any areas that we might want to have some additional information or provide some input on at some later date.

What we will be doing after our subcommittee meeting is meeting at the full committee and discuss what if any additional information or actions the ACRS may want to have relative to some of these topical reports and technical reports.

We have a lot of material to cover today, and there is no way that we are going to be able to delve into each one of these in a depth that we would be able to necessarily make any final decision. We are here more to get an overview, and to prove into some areas, but to see if there is any that we need to have more discussion and more detail at some later date. So again, we are not here necessarily to get every answer to every question that we want answered.

One brief item I'd like to discuss: One of the topical reports is on the mass and energy release, and I didn't schedule a technical presentation by Mitsubishi on that. The staff is going to talk a little bit on that. It relies primarily on adjusting approved topical reports and methodologies. So the staff is going to talk a little bit about their regulatory basis on that one, or mention that in their introduction anyway.

And I would caution the presenters, I know that the draft copy I saw of some of the slides had a lot of information, I do appreciate a lot of information, but there is no way we are going to be able to discuss maybe everything that is on some of the slides, so we'll try to keep it to the important points, and we'll move on from there. I guess with that, I'd like to go ahead and turn it over to Larry Burkhart of the staff, to introduce the staff presentation and move on.

OVERVIEW OF STAFF REVIEWS OF MITSUBISHI TOPICAL REPORTS

MR. BURKHART: Thank you, Mr. Maynard.

And I think you have given us a very good summary.

I'm Larry Burkhart, the US-APWR projects branch. I'm here today with my teach primarily to give you a quick overview of where we are in our reviews. And just like Mr. Maynard said, we are in the midst of our reviews. However, even though we are not finalized on our SERs on these topical reports, we thought it would be a very good idea, and we got that idea in part from your staff, for feedback that it's very good for us to continue our dialogue on US-APWR design.

We had our initial presentation by Mitsubishi several months ago on - very quickly on the design. Now we are delving a little bit more into some areas that perhaps are unique and definitely worth discussing. And that comes out in what the topical reports address.

So I appreciate the committee's time and effort on this. I appreciate Mitsubishi's time and effort on this, and also the NRC staff. So again, I would thank the committee for allowing us the opportunity for us to come and discuss where we are in our reviews. And of course as you said the meat of what you are going to hear today and tomorrow are the presentations by Mitsubishi on the topics of these reports.

And just to give you an idea of where we are overall in the design review, we received the application in December, accepted it about 60 days after that. We - this may be a little bit different of a project, because we have more of the pre-app - not the pre-app, but more topical reports to review while we are reviewing the DCD. Perhaps if you compared it to EPR we may have had more time during pre-application. So that's why we're seeing a lot of our concurrent review of topical reports and the design SER at the same time.

So why don't we kick it off. As Mr. Maynard said, we have a lot to discuss today. And I would like to turn it over to one of our chapter PMS, Ruth Reyes, who is managing chapters four and six as well as other chapters. The reason I mention chapters four and six is because those chapters are affected by the topical reports we are going to discuss today.

So I'll turn it over to Ruth to give a very brief discussion on where we are on our reviews, again just to set expectations. We are in the midst of our reviews on most of these with the exception of the LOCA mass and energy release.

So with that I'd like to let Ruth take it from there.

MS. REYES: Good morning, everyone. My name is Ruth Reyes. I am the project manager for chapter four, reactor, and chapter six, and features of the U.S. BWR DCD review.

Like Larry was telling all of you, the purpose of this presentation is to give an overview of the staff review of five topical reports. These topical reports are the LOCA mass and energy release; the advanced accumulators; field design criteria and methodology; field assembly; seismic analysis code; and the thermal design methodology. And we of course will be addressing any questions from the ACRS members.

With the LOCA mass and energy release, this topical report requests approval of the methodology for calculating the steam, the water and the nitrogen releases to the containment building from a reactor type. Basically that methodology uses previously approved methodologies or computer code like SATAN, GOTHIC and PREPLOT. So basically the review for this topical report was focused on the applicability of this approved methodologies to the US-APWR this time.

MEMBER ARMIJO: Let me ask a question.

Were those Westinghouse methodologies that Mitsubishi is applying to the US-APWR, or are these Mitsubishi methodologies?

MR. BURKHART: I think we have to defer to the staff on exactly answering that question. Now from a review standpoint what we have told Mitsubishi is, we will only review the part of the design control document, the standard design certification, what you submit. There were instances in which they told us they have rights to use certain -

MEMBER ARMIJO: Right, I understand that. That was just my question: are these previously approved as Westinghouse topical reports that Mitsubishi has access to or rights to use.

MR. JOHNSON: I am Walter Jensen, NRC staff, our containment and violation branch. And the SATAN and WREFLOOD codese have previously been approved, but there were modifications made to the methodology and the codes for the APWR. And the primary modifications to the methodology - to the code I mean would be the advanced accumulator model that was put in to the code and required a bit of modification.

And the - and the heavy reflector and the reactor core was added to the methodology.

CHAIRMAN MAYNARD: Kind of what I got from this, and from looking at them, is that there were a number of approved codes. And Mitsubishi is taking these and fitting them to their application, and then you are approving it for the Mitsubishi use on the US-APWR.

MS. REYES: That is correct.

CHAIRMAN MAYNARD: Because some of them are EPRI codes, some of them are other codes that have been approved, but customizing them for the US-APWR application.

MS. REYES: And some examples of special features that US-APWR design has that would impact the releases to the containment building are the advanced accumulators, the heavy reflector, and the in-containment refueling water storage.

The staff issued four sets of RAIs, which were answered. And based on the RAI responses, MHI submitted revision one and two of this topical report. The staff has finished the review, and prepared a draft tech evaluation report which was submitted to the ACRS.

If there are no other questions on this topical report I will go to the next one.

CHAIRMAN MAYNARD: Just a clarification

here for this topical report, and one of the adjustments you just talked about was for the advanced accumulator. And I'm trying to understand where we should be putting our focus on the advanced accumulator. There is a separate topical report for that.

MS. REYES: Yes, if I'm not mistaken, this review, Don has the advanced accumulator, because there is another topical report on that.

CHAIRMAN MAYNARD: Okay, so as long as the advanced accumulator does what it says it will do in that topical report, that fits into the LOCA mass and energy release.

MEMBER ABDEL-KHALIK: Excuse me, has the staff done any independent confirmatory analyses after the codes have been modified?

MS. REYES: Yes, but again, I would like to get the opportunity to talk about that.

MR. JOHNSON: Hi, Walt Johnson again. We did not actually run a complete confirmatory analysis, but we compared the mass and energy release that Mitsubishi calculated to what was calculated for similar plants, thinking that the advanced accumulator would have very little effect on the containment mass and energy release, and then also we compared their results with some hand calculations of boil off in the reactor core to test the methodology against standard review plan recommendations.

MR. BURKHART: And that is all discussed in the SER?

MR. JOHNSON: Yes.

MS. REYES: The next one is the advanced accumulator. This topical report requests approval of the advanced accumulator design and the characteristic situations for large and small flow rates for safety analysis.

The review was primarily focused on the applicability of the scale test data to the fuel scale advanced accumulator.

Some RAIs have been issued, and the responses have been received, and again, MHI provided us with revision one to the topical report based on the RAIs.

And right now we are in the process of developing RAIs and reviewing RAI responses, and the safety evaluation report is expected in June 2009.

No questions on that?

CHAIRMAN MAYNARD: We are going to have a presentation on that?

MS. REYES: Yes.

MR. BURKHART: This is kind of just a warmup. All the rest of the things that Ruth is going to talk about, you will hear in detail.

MS. REYES: Like I said before the purpose of this presentation is just to provide another view of the status of the review, and to talk about the specific details of the technical evaluation.

The next one is the field design criteria and methodology. This report requests approval for the Mitsubishi field design criteria and methodology, and defined field rod design code.

The review was primarily focused on the applicability of the empirical database to the exposed field criteria, and also on the ability of the FIND code to model the standard test cases.

And we are in the process of writing RAIs, writing RAIs to the QMHI, and the safety evaluation report. This report is expected in July, `09.

The next one is the FINE, the Mitsubishi fuel assembly seismic analysis code. This report requests approval for the Mitsubishi seismic analysis code. The code is called FINE. And it's for use in the DCD but also in the fuel design criteria and methodology topical report.

The review is prefaced on the

applicability of the empirical database to the APWR fuel design, and also on updating original test data to support the design.

We are also in the process of developing requested evaluation information, RAI, and the safety evaluation report is expected in July, `09.

The last topical report is the thermal design methodology. This report requests approval of VIPRE-01M. It's a Mitsubishi version of the already approved VIPRE-01 code. Some modifications include the DMV correlation and some other minor changes.

The review is focused on the applicability of this code, the 01M, to the PWR cores with MHI or US-APWR fuel.

Some RAIs have been issued. We received the responses. Right now the technical staff is reviewing the RAI responses, and the tech evaluation report for the topical report is expected in April, 2009.

MEMBER ABDEL-KHALIK: Any changes to the method by which subcooled boiling is calculating in VIPRE 01?

MS. REYES: I'm sorry, what was that question again?

MEMBER ABDEL-KHALIK: Were there any

modifications to the method by which subcooled boiling is calculated in 1?

MS. REYES: I don't know the answer.

CHAIRMAN MAYNARD: Is there anybody from Mitsubishi staff? We will be getting into a presentation on that.

MEMBER ABDEL-KHALIK: We'll wait until then.

MS. REYES: Okay. So finally just to summarize this presentation, we have four topical report reviews on the way in house, one that we have finished, which is the LOCA mass and energy release, and we have drafted a tech evaluation report, and that is provided to the ACRS members.

And with that, that concludes my presentation.

CHAIRMAN MAYNARD: Okay. I take it you will be sticking around through some of the presentations. Very good.

So with that, we'll go ahead and turn it over to Mitsubishi now to provide their overview.

OVERVIEW OF FOUR US-APWR TOPICAL REPORTS

MR. PAULSON: If you don't mind, I'd prefer standing unless you can't hear me.

CHAIRMAN MAYNARD: It depends on him over there.

MR. PAULSON: Fine, if you can hear me, fine. If you can't I can sit down.

CHAIRMAN MAYNARD: We can wire you up also.

MR. PAULSON: I'm not wired yet, that's for sure.

(Laughter.)

MR. PAULSON: Okay, can you hear me, everyone? All right, fine.

My name is Keith Paulson, and I'm the design control document representative for Mitsubishi, and I do a lot of the interfacing with the NRC on the completion of certain aspects. I get in on most of the phone calls. I occasionally write minutes, a bit of a jack of all trades so to speak.

In any case I spoke to you last time on overview on the design. I appreciated the opportunity. As you can see we have a significant group of people here. Mr. Kumaki is our lead today. And he will be here, and be listening intently to make sure that Mitsubishi is performing well for their review with the staff.

In any case, you've had an introduction already. I think Ruth did an excellent job of teeing up our presentations, thank you, identifying a fairly significant amount of information that you are going to hear today.

I am going to give you an overall version fo the information that is in the topical reports, and also in a few areas specifically I am going to address some at a higher level than you'll hear later on obviously, but some of the technical information that is specifically in those reports.

Mitsubishi spent the better part of a year supplying topical reports to the NRC, beginning early in 2007. These reports were part of that bevy of about, oh I guess there were probably in excess of 12 topical reports that we submitted on numerous subjects. These tended to go in toward the middle of the year. One of the earlier ones is one you will hear about later on, actually tomorrow in more detail, is the advanced accumulator topical report which has come up already, but we will give you a summary of what is in that topical report.

That report actually was performed, moved in our schedule of submittals to the NRC primarily because it was of significant interest to the NRC, so we moved it up to be one of the early submittals provided, and so it's had a lot of opportunities for a lot of review from different organizations within the

NRC.

In any case, I'm going to start moving forward through the topical reports to give you an idea of what is in them specifically so you know where to go and what to do. I think you probably already have copies of CVs. Those CVs sitting over there, if you don't have them, provide all the presentations that you are going to hear over the next couple of days. So if you grab one of those and would like to have those available to you at some point in time, feel free to do that.

Let's move forward. Like I said, I'm going to do the overview for the topical report. We will look at four specific topical reports. As Ruth mentioned we are going to look at the fuel design methodology, the FINE code which is used primarily for seismic analysis can also be used for certain aspects of LOCA analysis; the thermal design methodology and the advanced accumulator; and specifically in the advanced accumulator we will be going into a lot of the testing information that may be of some interest to you in terms of how performance of that particular device was developed.

Starting out with the fuel design criteria and methodology, we want to give you an indication of the type of information that is in our topical reports, not here, so that if something triggers your interest you will know it's there in the topical report and you can go to it along the way.

But specifically today I'm going to give you an outline of the topical report and the status. This report is specifically for our fuel. The fuel assembly design will be identified in that topical report; some of the specifics of the design. We will look at the design criteria and methodology for the fuel, fuel system damage, fuel system failure, coolability, and so forth. All of those will be addressed, and some of them in overview by me today, but also in much more detail obviously as we get into the presentations that are in the proprietary sessions.

The fuel rod design computations in the FINE code, the FINE code does a lot of design calculations, and we'll go through those. We'll show the applicability of the FINE code to the task at hand. We will look at the models that were utilized in the FINE code. In fact some of the presentation material this afternoon will be very specific in terms of the type of information that is in those codes and the analytical models. We will talk to you a little bit about the verification of those models, and also a comparison that was done with FRAPCON calculations to demonstrate that there is a consistency between something the NRC has seen and what we would normally see with respect to calculations from the FINE code.

First the outline and status. The topical report provides the following technical information: a description of the fuel assembly design - I'll have one slide on that, but certainly there is the capability of more discussion this afternoon; the fuel rod and fuel assembly design criterion to be applied to the US-APWR fuel design; demonstrate the topical - we believe anyway - demonstrate that it's in compliance with 10 CR 50 and 1.206 and of course the standard review plans.

And also a description of the models and verification of the FINE code, and a comparison that is provided there to demonstrate the consistency with prior information that has been reviewed by the NRC and ACRS.

This is a little complicated, but it's not as difficult maybe as you may think, but it does provide you a road map through this whole issue of topical reports, at least as it relates to the fuel area. We did a number of topical reports, and those topical reports are meant to be more or less generic reports that are available and could be used for other applications in many cases. It's just we are reviewing it now, it's being reviewed specifically for the US-APWR.

Those topical reports were the ones that we have been talking about that were submitted last year. In addition to that we have supplied a number of technical reports, or will be supplying a number of technical reports. Some of them are in; some of them are not in yet. In any case what we tried to do in this slide is to identify the different areas of fuel design and analysis that are performed and where you would find information with respect to each of the topics that are in chapter two, 4.2 of our design control document. So coming down this way you look at the information in the design control document, looking this way we can look at the information that is supplied in different topical reports, and then also an identification of the information, additional information that is being supplied starting here, those three reports that are below the technical reports heading that are identified specifically as information coming in in addition to what has already been supplied in the topical reports.

One of the key reports you will be hearing about today is this 07-008. That's on a design basis and includes information on the FINE code. This shows how it relates to specific portions of our design control document. You will also see information in the technical report that was supplied - and this is on the US-APWR fuel system design evaluation. So those are - that's an additional report.

You'll hear some of the information that is associated with that, but those reports are not being specifically discussed here, because we are dealing only with topical reports in these next two days.

The other big report that was supplied was the FINDS code, which was a detailed evaluation of a code that does performance, looks at the performance of the fuel assemblies during seismic events, and also has the potential for doing some evaluations that go even beyond that.

But in any case, as you can see, we've tried to look at two different specific areas that are important, that is, those that are looked at from normal operations, the anticipated operational occurrences, the shipping aspects of the fuel assemblies, and different parts, other different parts of the core; and then look at the seismic analysis as somewhat of a separate issue, because some of the codes that we used relate only to the seismic aspects.

However, the technical reports that are supplied deal both with the seismic aspects and the nonseismic transients and normal operations that are evaluated as part of our optical reports in the design control document.

CHAIRMAN MAYNARD: While it's a little busy, I do think this is an important slide, because when we get into the chapter reviews of the DC it really helps identify which ones of the top technical reports are being relied upon by the staff, and by you to comply with those sections.

MR. PAULSON: That's why I wanted to spend a little time on this, because I know, when you first look at that it looks like a crossword puzzle poorly done, or maybe a checkerboard poorly done too. But in any case, there is a lot of information on that, and it could be of value if you are trying to navigate through our topical and technical reports on a specific subject; hopefully this will help you do that.

Okay, we will get into the fuel design criteria and methodology topical report. The subjects we will be discussing today, me in an overview fashion, and of course in more detail later on, are identified here: introduction, fuel assembly design criteria, fuel rod design computations and conclusions. We won't get much into the appendices. We may touch on those in a few places where we are looking at the modeling and so forth. But the focus is really on the body of the topical reports.

I think some of this information was presented to you in our last meeting. But just as a reminder, and kind of teeing up the fuel assembly to make sure that it's consistent with your understanding of what we are doing, the fuel assembly will be 14-foot long. It will have a 17 by 17 array. This fuel design is going to be very similar to one you've looked at many many times, I'm sure, so it's not very much different at all.

There are some features that take the previous features and take them a little step farther, because Mitsubishi has been able to do that, for example, the data linear content is a little higher possibly than some that you have seen, up to 10 percent. The higher pellet density is a bit higher than what you've seen, I think, in previous designs, maybe more like 95-1/2 as opposed to 97 that we would have in the US-APWR design.

Zircaloy grids for neutron economy, I don't think that that is particularly new for you.

We are going to an 11 grip structure, which reduces the span of the - in the fuel assemblies, which provides additional support. We are going to use corrosion resistant material called ZIRLO. I think maybe you've seen some things on that already, but it's going to be produced specifically for our cladding material.

And I think the other features are, with respect to debris nozzles and built-in filters and so forth, you are familiar with already, but they are consistent with current designs.

One of the I think important features of the design is the low kilowatts per foot for this fuel assembly. One of the advantages I think that you will find in the report is that there's been a lot of margin built into the plant because we have gone basically from the same thermal design, or total output from the APWR that is being built, will be built in Japan at Sakura and gone to the 14-foot core, but we've kept the thermal design power level the same.

So what has happened of course is on our kilowatts per foot it's gone down significantly, and that's provided additional margin for the US-APWR.

MEMBER ARMIJO: You know, I have a question on that. That is a funny unit, that power density and kilowatts per foot. I'm more familiar with kilowatts per liter for core power density. Do you - maybe not know but at some point I'd like to hear what that number is for the US-APWR compared to -

MR. PAULSON: I don't have that off the top of my head, but somebody take that down.

MEMBER ARMIJO: When the time comes.

MR. PAULSON: Moving on, obviously, although much of the design activity goes on in Japan, Mitsubishi has been very sensitive to the design requirements in the United States, and started to follow them and continued to follow them as the regulations when through a significant process of upgrading over the course of the last few years. The design we believe is sensitive to 10 CFR Part 50, specifically the general design criteria listed here, it's 10, 27 and 35. We think we are in compliance also with 1.206, and we've used the standard review plans as the basis for our evaluations for fuel damage, fuel failure, and fuel coolability.

So once again, although you may think of it as a Japanese design, it really has been completely sensitive, not only because of our prior relationships here in the U.S., but also because the Mitsubishi staff has been very sensitive to getting a clear definition either through their own interpretation or from consultants that are familiar with the different aspects of the regulatory process and have built in what they believe to be methodologies and analyses that are consistent with all of the current regulations here in the United States.

Just an indication of what specifically is addressed in this topical report, and the types of fuel damage that are being evaluated: cladding stress, cladding strain, stress and loading limits, fatigue, fretting wear, oxidation, dimensional changes, assembly rod growth, rod internal pressures, assembly liftoff, all of the things I think that you are interested in and are familiar with have been addressed, and probably have been addressed in many cases with the same type of analyses methodologies that have been used and are familiar to you. But we'll talk more about that as we go through the technical reports, or the topical reports over the next few days.

For fuel failure, the potential fuel rod failure modes that we've looked at include hydriding, collapse, cladding collapse, overheating of the cladding, overheating of the fuel pellets, excessive enthalpy, fuel pellet cladding interaction, DCI typically referred to, bursting fuel rod mechanisms for fracturing.

In terms of coolability we looked at embrittlement, violent expulsion of fuel, generalized cladding, melting, fuel rod ballooning and structural deformation.

The reason we are listing these is to say we think we have addressed all of the issues that have been identified here in the United States with respect to fuel, and some that have had to be addressed specifically in fuel assemblies and fuel analyses in Japan.

CHAIRMAN MAYNARD: If you're going to address some of that later, it's fine. My information may be dated, but I believe that most Japanese plants have been on 12-month cycles basically. Most U.S. plants run 18 or 24-month cycles, and I'm wondering what experience Mitsubishi may have with the longer cycles, and how that is factored in.

MR. PAULSON: We'll be dealing with extended burnup calculations. They don't have a lot of experience specifically with longer fuel cycles in Japan. I'm not familiar with any plant that is on 18-month fuel cycles in Japan. Does any of the Mitsubishi people know? I think it's been mostly 12, but they have been familiar and have had the data available for longer fuel cycles here in the United States, and they have used that as the basis for their evaluation. So you will see that, like I said, the extended fuel cycle information has been a process that's flowed primarily from the United States to Mitsubishi.

CHAIRMAN MAYNARD: You will get into that later?

MR. PAULSON: Yes.

The computations that are performed in the FINE code, first of all from an evolutionary point of view, we will deal specifically with how FINE came about in the topical report, the applicability fo the FINE code, the analysis models. For all of these, I don't have to read through them, they are things that are very familiar to you, the fuel models, gas models - gas release models, and so forth.

We will look at in the topical report also the verification of these models, how we've justified them with respect to performance data that is available, and has been compared to the FINE code calculations; and then a comparison also with FRAPCOM that I think is a code that is very familiar and used by the NRC to validate computer codes that do fuel rod calculation design.

With respect to the evolution FINE was developed by Mitsubishi in the 1980s, modifications for high burnup usage have been made up through 2001. Some additional changes specifically in that area that have been looked are the thermal conductivity degradation, the rim microstructure variations, and that has been built into the code, and also models for not only for Zircaloy but also for ZERLO are included in the FINE code.

Mitsubishi developed proprietary models using post irradiation examinations and other tests. It goes a little bit to the question of extended fuel cycles.

MHI has applied the FINE code to the high burnup fuel that does exist in Japan.

Just in terms of the range of applicability, and by the way some of this, especially when you get to the point of rod burnup and so forth, there will be a little bit more in my presentation, but there will be a great deal more discussion of that later on. But fuel pellet type, the client is specifically focused on U02, with gadolinium up to 10 percent. Cladding pipes, both ZERLO and Zircaloy 4, we're looking for the US-APWR to go to 62 gigawatt days per ton. You will see as part of this presentation a summary of some of the information that we have that supports going to 62 gigawatt days per ton. Linear heat rates for normal operation are below the - that available in FINE, as are the anticipated operational occurrence heat rates associated with those events are also well within the bounds of the FINE code.

Finally the coolant temperatures are also bounded by - for the US-APWR are bounded by the information that exists today.

I mentioned that we have and have had data. There have been a number of reactors that have done irradiations, or information that has come out of those reactors that can be used for information for validating the models in the FINE code. The test reactor identified here, Saxon following the RQ, the commercial reactors, are a potpourri around the world. You can see both Japanese data, Spanish data, U.S. data that have gone into providing the database that we use to validate the performance of our FINE code.

Specifically if you look at different

parameters and the burnups, ranges, associated with the validation for those, you see they go from 86 gigawatt days per ton down to the 62, and that was the basis for the 62 gigawatt days per ton evaluation that we are performing on the US-APWR, and believe that that represents a reasonable upper bound for our fuel.

ZIRLO has been irradiated in several plants, so there is a familiarity with ZIRLO performance, and the measure data of each performance parameter covers the design burnup of the US-APWR up to 62 gigawatt days per ton, and that is based on what you see here in terms of support information for the models coming from numerous tests.

Okay, in terms of the FINE code type calculations that are performed, it's a very versatile code in terms of the amount of information, and the types of calculations that are performed. You will see a little more in detail on this in the sessions come in the next couple of days in terms of models and so forth, but just to give you an idea of the types of calculations that are completed in the FINE code, you can see that it is a very broad and I think inclusive set of evaluations. We'll be going through many of these in later presentations, but this is only meant to say that FINE is a code that if you want to see a lot of analysis for fuel performance, you can see them from our FINE tests.

This is once again just a touchstone to say we don't just put in models; we also take information from various irradiations that have gone on, and we've justified the code, the FINE code, to ensure that there is a consistency of that.

Also we've used the comparisons that have been made with FRAPCON to more or less benchmark our code between the fuel rod performance, the instrumented fuel assemblies that have come out of a couple of I guess test reactors, and also some of the operating reactors also where we look at both fission gas release and fuel temperature. The information that has come from those evaluations, and compare our analysis with the results of the fuel assembly information and compare and look to see how the FRAPCON results compare with that also.

The conclusions, I think what we've tried to do is to make it at least - what we've done is up to your expectations. We think we have a very robust code that has a very robust database that the results are based on. That's what I've tried to say here very briefly.

But over and above that we have also tried to ensure that the information that you and the NRC are looking for in terms of evaluation are completed in an acceptable way based on the guidelines that we get from the different U.S. NRC guidance documents.

We look at fuel rod performance models and verify them, and we anticipate using the FINE code for the US-APWR and we are looking to have that approved up to 62 gigawatt days per ton.

That is topical report number one. Like I said, you will hear probably a lot more than that, a lot more than what I did, but it gives you a flavor of what you are going to be looking for and should see this afternoon in a lot more detail.

Okay, moving on to the FINDS, Mitsubishi fuel performance. As I mentioned, FINDS is a computer code that looks at seismic performance, the seismic performance looks at a little bit different environment than we have here in the U.S., where this has to be looked at in a fairly high seismic scenario for essentially all the locations where fuel has to go in in Japan. So consequently you will see that a lot of detail has been paid to doing good evaluations of seismic performance in high seismic locations.

MEMBER SHACK: What is the seismic, your design curve for this? Point three G?

MR. PAULSON: Point three G. Point three, is that right, for the seismic analysis, point three G? But of course it's used in much higher scenarios in Japan. What does it go up to 1.0 in Japan? A little under one?

Summary of the FINDS code, we'll go through that. The contents of the topical report, summary of the report, qualification of the design application and then a few conclusions.

As I said, in Japan you have to look at things a little differently when you look at seismic events because of the high seismic, so the representation of FINDS is fuel inelastic deformation for seismic events, and it tells you a little bit about what they have to do in order to get plants approved in Japan.

The objective of the report is to obtain approval of the FINDS code for Mitsubishi fuel design criterion methodology, specifically in this first case of course for the US-APWR, and is focused on the US-APWR.

The FINDS code is used to analyze fuel assembly response characteristics for seismic and under certain local conditions. The report contains analysis models, associated with the development and tests and verification of the FINDS code. It's to be used to perform analysis with US-APWR in compliance with Appendix A of Section 4.2 of the standard review plan. It's NUREG 0800, and the US-APWR evaluation technical report to be submitted to the NRC in March of 2009 is focused specifically now on the US-APWR as opposed to previous fuel designs. But we have submitted the methodology so that the methodology can be evaluated, so that once they get to the point of doing the evaluation on US-APWR fuel the methodology will be understood and hopefully accepted by the NRC.

The status of this topical report: it was submitted in March of this year. We had it docketed in May. We've already had RAIs issued in July and so far we have responded to the RAIs that have been submitted in July and some additional RAIs that were submitted in August.

I'm not going to go through the listing of all the sections of the topical report, but once again, these are here for use, so if you want to go and pinpoint a specific area that you want to deal with, hopefully you can do that using the table of contents.

The one thing I did want to point out though here in the slide is that after our submittal by the NRC, the NRC did ask us to provide them with a specific deck, FINDS deck, and some input information for it, and that has been supplied also for them to use in their evaluation process.

CHAIRMAN MAYNARD: So let me make sure I understand. So the NRC has a copy of the code basically, they can run it?

MR. PAULSON: And an input that we gave you. I think we also gave them the output, too, but we'll let them run it to see if they get the same output. I hope they get the same output; I anticipate they will.

In any case the FINDS code has been developed for Mitsubishi to analyze fuel response characteristics under difficult seismic conditions. The FINDS code takes into effect nonlinear effects, as opposed to just doing a bounding calculation which can be done I guess in some of these lower seismic when you're looking at some of these higher seismic locations as Mitsubishi has had to, they have gone into a significant evaluation of inelastic events and inelastic behavior. And by the way I'm going to talk a little bit about that, but you will hear a lot about that in the technical presentations coming later.

The FINDS code is also used to analyze

fuel assembly response due to pressure propagation during LOCA. So it has some benefits in LOCA also.

The input for FINDS is information that's necessary with respect to the overall design of the vessel area. Primarily we use the upper core support plate and the lower core support plate as input to FINDS; acceleration during earthquake, LOCA and so forth. FINDS does a dynamic fuel assembly response during earthquakes and LOCA, and the output of FINDS is the fuel assembly amplitude grid space or impact force, and then ultimately stress analysis using an analysis model that is also familiar for evaluation of the fuel assembly.

The description of FINDS code, a description of the FINDS code, the major features of FINDS are described in the report. But it's an efficient and stable calculational methodology using multi-fuel assembly interactions associated with impact. And some of the testing that has gone on and will be described to you later on today is multi-assembly testing, so it's not just a single assembly test. I'm going to describe a couple of the single assembly tests here, but you will also hear some information later on on some of the multiple assembly tests that go on.

There is a strong nonlinear behavior of the fuel assembly that is taken into account for the vibration analysis, and an inelastic impact model to calculate grid space or permanent deformation that occurs after initial grid space or buckling.

I mentioned that there are a couple of tests that I'm just going to briefly describe because these are the simple ones. They don't let me describe the difficult ones; they let me describe the simple ones.

In any case these two tests, first of all, is for the grid spacer. And a simple swing arm test which looks like they had a force delivered to that grid spacer, and what's the deformation based on the amount of force delivered to the grid spacer.

MEMBER ABDEL-KHALIK: And what is inside the grid space during those tests, anything? Rodlets?

MR. PAULSON: Does somebody want to answer that? Dave, do you want to answer that?

MR. SEEL: Fuel tubes.

MR. PAULSON: Fuel tubes? Okay.

And there is also a pluck test performed to look at the vibration. I think it's the first mode vibration characteristics of the fuel assembly.

So those are two individual assembly or

parts of an assembly analysis that are performed, but we'll talk in more detail about some of the testing that goes on as part of the justification for the FINDS model.

The following verifications are described in the topical report. The confirmation with a general purpose ANYSYS code, verification of the grid impact model by lateral impact test of the fuel assembly, and impact tests of single span fuel assembly; verification of multiple fuel assemblies; this is what I was referring to in terms of some additional information you will see; and interaction analyses by shaker table tests of large scale PWR cores internals, with up to 15 by 3 full-scale mockup of the fuel assemblies as part of that testing.

Pluckability to the US-APWR fuel FINDS code has been validated for a larger range of seismic accelerations than is predicted for the US-APWR. That is obvious and necessary for the application that it was originally intended for.

In terms of the length, being constants, damping factors, fuel assembly vibration models, the vibration behavior of the US-APWR fuel is predicted by FEM model, and in this case it's ANSYS which is verified by the comparison with the test results of

12-foot fuel assemblies.

There is another technical report coming in, that comes in in March of next year that will deal specifically with the US-APWR 14-foot fuel.

So but there has been US-APWR is predicting with the finite element analysis methodology of ANSYS, and has been shown to be acceptable.

In terms of grid spacer impact model, the grid spacer of the US-APWR fuel assembly has been tested to obtain the inelastic grid spacer behavior characteristics of the grid spacer, and that has already been completed.

Conclusions for the FINDS code. FINDS code was developed specifically by MHI to determine fuel assembly response and seismic and LOCA conditions, and accounts for the nonlinear effects that can be experienced especially in high seismic areas.

The FINDS code is for multiple assembly fuel vibration and interactions, and can do that type of analysis, and has been validated based on some of the test results that have gone on, verified by fuel assembly lateral vibration tests, that I mentioned, single span grid spacer impact tests, and the comprehensive large scale seismic excitation tests, so that shaker table tests, vibration tests, all of those have been used to validate this model, which is one of the more sophisticated models I think in the industry with respect to evaluation of fuel assemblies.

The FINDS code is applicable to the US-APWR fuel assembly for a lot of reasons, not just because of the work that has gone on, but also because we think the environment that we'll be seeing here in the U.S. at least in most locations is much less severe than what has to be evaluated for.

Okay, on to thermal design methodology - before I go on are there any additional questions? Okay.

The outline - I'll go through an outline of the status of this topical report. Like I said, I think Ruth has teed up some of this already very well, but just to remind you on our interpretation of what's gone on. Our procedure for the thermal design methodology; the different analysis models that are used; transient fuel modeling; rod modeling that has gone on, and qualification of the design application and conclusions.

Once again I want to make it clear here that one of the key things in general we are trying to say is that most of the modeling that may be some of the FINDS stuff because of the details that have been generated in Japan are based on codes that you are familiar with. Some of them we've extended them, we've added features, but we haven't changed the models that are used. We've only added features to them to make it a little more people friendly, or possibly to add an additional model beyond what already exists in the code.

So in any case you'll see in this presentation computer codes and methodologies that I think you are very familiar with.

An outline of the topical report is presented. It's a procedure for the thermal design methodology. The analysis models that we're using, once again I think you'll be very familiar with most of those analysis models.

Qualification of the design for its application. The most important part of this is just our view of the status, and that's submitted. We submitted our topical report last May, so it's been in NRC hands for quite awhile. It was docketed in December of last year.

We've had RAIs already in March, and we've responded to all those RAIs at least to date for the thermal design code, and that was done in April of this year. So we are kind fo up to speed with respect to the topical reports. The NRC has been - we've given them yeoman duty, because they have had to do both review of the DCD and the topical reports. I think, and rightly so, our plan was to try and provide them a comfort level that when they got to the point of reviewing our analyses in the DCD, they had a basis for saying that they understood that the methodology was acceptable either based on work that they've already done for some of the computer codes, or they have had the opportunity to review our unique differences with respect to our computer codes and methodologies we're using.

This I think should be a very familiar slide. We are looking at using the DNB correlations. We do a statistical treatment. We calculate limiting DNBR. We add our own special - any types of design penalties and design margins to that, and we come up with what's considered to be a safety analysis. Back when I was doing safety analysis it was 1.3. I notice now it's changed. Shows you how old I am.

MEMBER ABDEL-KHALIK: Now where do you get the core inlet flow distribution that you use in that subchannel analysis?

MR. PAULSON: Does that come from ?

MEMBER ABDEL-KHALIK: A bundle-to-bundle variation of the core inlet flow distribution.

MR. PAULSON: Allen, do you want to answer that. Get up to the microphone.

MR. HO: The typical way -

MR. PAULSON: Your name.

MR. HO: Allen Ho for MHI. The typical input for the core analysis basically was assuming the uniform core inlet, and then take the penalty like up to 10 percent of flow reduction into hot channels.

MEMBER ABDEL-KHALIK: Do you have any data to support that?

MR. HO: Yes, we do have flow distribution analysis, and realize that it's a been roughly in the range of 5 percent reduction at most at the inlet. But we try to be conservative, so we assume 10 percent of flow reduction at the inlet.

MEMBER ABDEL-KHALIK: Maybe we can get into the details.

MEMBER ARMIJO: Your question was due to variability.

MEMBER ABDEL-KHALIK: A core flow anomaly where you get maldistribution at the individual assemblies. And the question is, what is it for for this large a vessel.

MR. HO: Yes, we can discuss that when we get into the derails.

MR. PAULSON: We'll get into that in the presentation on the codes this afternoon. Or tomorrow morning? Is this tomorrow morning?

MR. HO: Either this afternoon or early tomorrow morning.

MR. PAULSON: In any case, safety analysis limits calculated, we then used an evaluation. You asked about - your power distribution is put in, core operating conditions. Core geometry is put into our subchannel analysis, which is the VIPRE-01M code. I'll spend a little more time on that.

We've got local fuel conditions. We use the WRB-1 and WRB-2 DNB correlations, which I think you are very familiar with, and come up with the minimum DNBR calculated and compare that with the safety analysis limit based on the calculations we did in the statistical procedure.

MEMBER ABDEL-KHALIK: Again, you know, a big issue or question, how does the change in grid spacing affect the applicability of the WRB-1 and WRB-2?

MR. PAULSON: Is anybody familiar with how grid spacing - maybe Allen, do you want to - how does grid spacing affect the difference between WRB-1 and WRB-2?

MEMBER ABDEL-KHALIK: No, the applicability of WRB-1 and WRB-2?

MR. PAULSON: You mean the grid spacing in the US APWR design?

MEMBER ABDEL-KHALIK: Correct.

MR. HO: Okay, I'm Allen Ho again. For the spacer grid distance, because we are using the well known WRB-1 and WRB-2 correlations, and there is a given range. As long as the grid spacing is within that range, it is all applicable. We are not exceeding the applicability range. It has been tested. If you look at the W-caps in the past, and also some of the MHI test reports, you will see that we are well within the range.

MEMBER ABDEL-KHALIK: Is the prediction dependent on the detail design of the grid spaces?

MR. HO: We also did some sensitivity studies. We adjusted the distance of the grid spacing, and it can show that how much DNBR changes. We can discuss that in the detailed session.

MEMBER SIEBER: Grid spacing is roughly the same as a 12-foot assembly because when they increased the length they just added another grid.

MEMBER ABDEL-KHALIK: I just wanted to know the exact difference.

MEMBER SIEBER: It was a good question.

MR. PAULSON: VIPRE, the VIPRE code that's used, the Mitsubishi version of the VIPRE code is a version of the code that was developed by EPRI and has been reviewed I believe by the NRC, which is just the VIPRE-01 code. The solution methods, and constitutive methods, models that were used in VIPRE-01 were not change, so that the basis for the evaluations were not changed.

There were some additional options that were included in the design. Those options are primarily focused on enhancements for the evaluation as opposed to changing any of the methodologies used. The VIPRE version that is used by Mitsubishi provides distributions of mass, axial and later flow rate, enthalpy and DNBR in the core, and limiting subchannel. And the transient and thermal behavior of the fuel rods are analyzed simultaneously.

The application code complies with the NRC. Their SER conditions, we are aware of the SER conditions that went into this reference document and address those specifically as part of the topical report.

MEMBER ABDEL-KHALIK: Is the code also used to get input for analysis of axial offset in terms of local steaming rates?

MR. PAULSON: Allen, once again.

MR. HO: Allen again. We don't use this code for AO analysis.

MEMBER ABDEL-KHALIK: Will you talk about that tomorrow as well?

MR. HO: Yes.

MR. PAULSON: The core is modeled using industry-accepted assumptions. We will as we go through this tomorrow you will see the assumption and some of the analysis models that are used. Some of the things that are also taken into account in the core, in the calculations, are normalization, mixing, turbulent mixing, hydraulic resistance, two-phase flow, engineering factors, core inlet, flow distribution, boundary conditions, and calculation control parameters are available.

MHI intends to use WRB-1 and WRB-2, those correlations, for the plant. WRB-1 and 2 correlations were originally developed based on the THINK code compatibility between WRB-1 and 2, and VIPRE, has been confirmed by Mitsubishi analysis, and the applicability for WRB-1 and 2 to MHI design fuel has been validated, and is shown in the topical report as part of some studies that are demonstrated in that report.

MEMBER ABDEL-KHALIK: Now what do you mean by compatibility of - between WRB-1 and 2 and VIPRE M was confirmed? What does that mean?

MR. HO: Allen Ho again. As we are aware that all the DNB correlations if they want to be used for DNB or calculations in any of the subchannel analysis code, it's required that that specific correlation has to be correlating data using the specific subchannel analysis code. And once it is done, we say the correlation itself is compatible with the subchannel analysis code per se.

MEMBER ABDEL-KHALIK: But presumably WRB-1 and WRB-2 were correlated with VIPRE W.

MR. HO: Yes.

MEMBER ABDEL-KHALIK: Which is identical. So I'm not sure exactly what additional work you did to confirm that it's compatible with VIPRE M.

MR. HO: Okay, WRB-1 and WRB-2 were originally correlated by Westinghouse THINK code, right. So -

MEMBER ABDEL-KHALIK: But they were also

incorporated into VIPRE W.

MR. HO: Yes, but we are using VIPRE-01M. We want to make sure that our version would not cause any discrepancies, that is, do any harm to the so-called compatibility.

MEMBER ABDEL-KHALIK: I still don't understand what you mean by that. I mean the correlation that you implement in the code, it's based on local conditions.

MR. HO: That's correct.

MEMBER ABDEL-KHALIK: And the local conditions are calculated by the VIPRE M code. So what do you mean by compatibility? Do you go back to the original database.

MR. HO: That's correct.

MEMBER ABDEL-KHALIK: - the local conditions using VIPRE M?

MR. HO: Yes.

MEMBER ABDEL-KHALIK: All right, thank you.

MR. HO: Welcome.

MR. PAULSON: I guess there is a need for consistency to make sure that the data that is supported when used in the VIPRE are in the WRB-1 and WRB-2 are consistent with what it was based on, so that there is a consistency requirement that's necessary I think.

MEMBER ABDEL-KHALIK: But the point, that's already been done before.

MR. PAULSON: Well, but I'm not sure it was done when we started using VIPRE. It may have been built in later on, and then we're just looking for that consistency.

Transient fuel model for the fuel rods are modeling in VIPRE and are used for the transient analysis. This is primarily, you look at the fuel rod temperatures, fuel clad temperatures. The key parameters for the fuel rod model are described in the topical report. Properties, gap conductance, heat transfer coefficients. And these are water reactions. So that this has - I think - I don't know if VIPRE-01 did fuel clad temperature calculations. But in any case it's done here.

General application of VIPRE-01 was demonstrated by EPRI. The qualification of the version that Mitsubishi has updated are focused on validation of the application, and the newly incorporated features that we mentioned, representative calculations for typical steady state transient analysis were compared with NRC-approved codes, so that there is a validation process which goes on in the topical report, and it's available for you to examine if you are so interested.

Conclusions: Mitsubishi's thermal design methodology is based on NRC-approved computer program and methodology. It uses the revised thermal design procedure. It uses VIPRE and WRB-1 and WRB-2, all of those I think are familiar by the NRC and are used as part of the VIPRE code. VIPRE is an extension of the code that has been approved by the NRC, which is VIPRE-01 for subchannel analysis. The use of WRB-1 and WRB-2 has been validated on VIPRE, those analysis results, and it's applicability to the Mitsubishi fuel design have been demonstrated as part of the topical report.

VIPRE-01M and WRB-1 and 2 have been verified for thermal hydraulic design, and on LOCA safety analysis requiring DNB evaluation, so DNB evaluations can be performed and are used in comparison with the limiting DNB values, and that is used as a basis for the approval of our transient analyses. And MHI submitted a topical report last May that is well on the way, we think, based on questions that we had and responses we're getting, staff concurrence with that specific design.

MEMBER ABDEL-KHALIK: Well, back to the

issue of the compatibility between WRB-1 and 2 and VIPRE M, when that recalculation was done, was there any change in the uncertainty associated with the correlation predictions?

MR. HO: Allen Ho again. We did the analysis and realized that the test data contribute to limit error band, or uncertainty range, so to answer your question it did not give us different conclusions why the WRB-1 and WRB-2 would not be able to be used.

MEMBER ABDEL-KHALIK: But I'm asking, was there a specific change in the uncertainty band of the correlation predictions after the parameters were calculated with VIPRE M versus the original uncertainty bad with the correlation when the parameters were calculated using the THINK C code.

MR. HO: To that specific question I think we need to consult the person who did that specific analysis about the uncertainty band. I don't have that answer to you now.

MR. PAULSON: We can get an answer to that. You were asking if there was a difference in the uncertainty.

MEMBER ABDEL-KHALIK: Yes, I mean that's why you're doing that calculation.

MR. PAULSON: Okay, we can get you that.

Okay, the last topical report we are going to provide an overview of, and I'm pretty sure this presentation will be tomorrow on the advanced accumulator. But the topical report is one that has been in to the NRC for quite awhile now, and has provided a lot of interesting questions, and so we'll go through the topical report, at least the overview today. But we have two experts here as to how it's used for safety analysis and how the original testing that went on, and the tests that went on that I'll describe in fairly broad concepts right now, but you'll hear a lot more about those tomorrow.

US-APWR has adopted an advanced accumulator which incorporates passive flow switching from a large flow rate at refill to a small flow rate for reflood activities during LOCA. The advanced accucmulator design is based on four-scale tests which you will hear a lot about tomorrow; you'll hear a little bit about it from me, but a lot more about it tomorrow.

Principal and performance of the advanced accumulators was evaluated as part of the test, because there was a difference. Each of these tests has a specific focus where they look at certain elements of the advanced accumulator performance, and provide results as to how the advanced accumulator will look - will perform during the various stages of performance as the accumulator drains.

And we looked also at scalability so that we were able to confirm the application of this to the US-APWR.

Empirical formulae were developed for these test results and are applied to the LOCA analysis of the US-APWR. Specifically you will hear a lot about that too as to how this information was put in a form that could be used in the LOCA analysis for - that ultimately will be in the DCD.

The present status, as I said, the topical report, this was the one that we essentially changed the schedule on because the NRC was specifically interested in looking at this change. So we had that to the NRC in January of 2007. The acceptance letter was in March. The first set of RAIs were issued in June, and the second set of RAIs were issued in August of 2008, and the responses for both those that were issued in 2007 and 2008 have been supplied to the NRC now. So we don't know if there are going to be additional ones, but today we are kind of up to speed with respect to both questions and answers.

Contents of the report include an

introduction, characteristics, design details, confirmatory testing, concept of the safety analysis model, how that was developed, and conclusions with respect to performance of the advanced accumulator.

The advanced accumulator was incorporated into the safety design of the US-APWR to provide the low pressure injection function of the conventional emergency core cooling system. The emergency core cooling system in typical four-loop plants, and we'll talk more about this as you know, has both low-head and high-head pumps. There are several good reasons for adding the advanced accumulator. One key one is to reduce the number of active components in the primary system. We were able to reduce the number of primary components in the system by eliminating the low-head pumps. The low-head pump function, as we'll see as I go through the presentation, is supported by the performance of the advanced accumulator.

The advanced accumulator functions basically as a passive system, but looks like an active system because you see two flow rates. The flow rates changes partway through the LOCA evaluation, and we'll talk a little bit about that.

There was another advantage too, and that was the desire to utilize gas turbines, the emergency gas turbine generators as the basis for power. That was done as an availability improvement. These are highly reliable gas turbines, and we've had NRC very interested in the gas turbine performance also, and have looked at top technical reports associated with the gas turbine. It's been done.

But the gas turbines don't start up quite as quickly as the emergency diesel generators do. Emergency diesel generators, we believe, are much less efficient as the gas turbine generators that we provided, so that provided as second benefit for utilizing the advanced accumulator because we can justify utilization of the gas turbines even though it takes a little longer for them to get up to full power and be operable as part of initiation and operation of the ECCS system.

This - I think I said all of that, kind of, I kind of summarized that a little more broadly in what I just said, so we can move on.

This chart identifies the performance in fairly simple graphic as to how the advanced accumulator flow changes, and how it relates to the necessary flow associated with large break LOCA. There is automatic switching of the injection flow rate by a flaw damper. I have some pictures of that as we go along.

We'll have a little more about that. The red line here shows the necessary flow in order to meet ECCS criteria, specifically clad temperatures and so forth. The blue outer line shows the flow associated with the advanced accumulator, and I think you can see this. If you look down in here, this is the flow from the safety injection pump with the safety injection flow starting up at this point in time. This flow has not been added to this flow; this is only the flow coming from the advanced accumulator. So if you want the total flow to the core you would have to add this yellow piece up to the blue line, but that hasn't been done. But just to give you an idea as to what the total flow is at that point in time into the vessel, it's the sum of those two.

What happens of course is that the advanced accumulator triggers provides a very rapid flow, high flow rate, into the downcomer region during the blowdown and refill time period. At a point in time that that flow switches, switching in this case, I'll talk a little more about that. It's a very simple process as to how that happens, and it's a passive process. It goes to a much lower flow rate which continues on for a certain period of time, and then flow from the advanced accumulator stops, and all the flow that is necessary to maintain long-term cooling is supplied by the high-head safety injection pumps.

So those are the regions to look at. The red line is what you need. The blue line is what comes from the advanced accumulator, and the yellow box shows the amount of flow from the safety injection pumps once they're started up an in operation.

MEMBER SIEBER: For auxiliary power start, the largest break LOCA is the most important break. Have you done these for smaller break LOCA sizes to see what the response will be and make sure everything matches?

MR. PAULSON: Right, we've done a spectrum of breaks.

MEMBER SIEBER: Are they in the report or not?

MR. PAULSON: Are they - is the -

MEMBER SIEBER: The only one I saw was this one.

MR. PAULSON: This is our typical chart. But have we done in the topical report a spectrum of breaks?

MEMBER SIEBER: Different pressures,

different back pressures.

MR. PAULSON: We are going to talk about, by the way, the testing that went on with different back pressures tomorrow.

MR. HAMAMOTO: This is Hiroshi Hamamoto. And I took the liberty of including such a step transposes small line break LOCA, mid-line break, and larger line break LOCA. So include topical lab report, such spectrum analysis.

MEMBER SIEBER: That is in the topical report then? I saw at least three different flow regimes, I mean break sizes, in the results.

MEMBER ARMIJO: A general question, when this thing operates is the water temperature high, low, and secondly, what happens with nitrogen at the end of that discharge period?

You don't have to answer it now, but that is something -

MR. PAULSON: That will be covered, but the nitrogen, the design is to prevent nitrogen from getting into the primary system if that is your question. But we also looked at dissolved nitrogen as part of the testing, which has had - we've looked at basically saturated water, saturated nitrogen. It had no effect, or very minimal. But you will hear more about that tomorrow.

But this chart then just compares what you would normally see in the current U.S. four-loop plant. I think I have covered most of these things already, but the point is that the advanced accumulator really takes the place of those low-head pumps, and based on this performance - and of course this performance overall, the spectrum of breaks, has to be verified, but it does very effectively substitute for the performance of the low-head pumps.

So ultimately, and then the high-head pumps come into play and maintain flow that is necessary for long-term cooling, which is true for the US-APWR. Here you have both the low-head and the high-head pumps supplying water for long-term cooling.

MEMBER SIEBER: So you have to lay the decay heat curve on top of all this to make sure that it's appropriate.

MR. PAULSON: Are acceptable, that's right.

MEMBER SIEBER: Or the BWR folks, accumulators have been used in PWRs for some time. The unique part of this is a variable flow. It's much larger, and it has a variable flow rate associated with it.

MR. PAULSON: Right, in the next couple of slides I show some of that, how that happens.

Just as a reminder, I think I have presented this to you already, but it's to show you that if you look at the flow from the accumulators, it goes directly into the cold legs. If you look at the flow from the high-head safety injection pumps, it's direct vessel injection. Direct vessel injection is another one that we evaluate, where we evaluate the break in one of those lines. That's a part of the spectrum of breaks going all the way down to the direct vessel injection.

But this just shows that the flow comes from the in-containment refueling water storage pit. It's supplied to the safety injection pump. When it's the safety injection pump, it goes directly into the vessel. When the flow comes from the accumulators, of course the accumulators are loaded in and of themselves with water, that goes directly into the cold legs.

This is a model of what the advanced accumulator looks like, and includes the device that is inside the accumulator that causes the flow switching. It has some very basic systems to it, and is a very simple principle actually. What happens is, the flow switching occurs because early on in the transient there are two flows coming together to provide flow that goes in to the vessel through advanced accumulator connected to the cold leg. So you have two flow rates coming in. One of those flow rates is shut off as part of the reduction in the amount of water in the advanced accumulator. The advanced accumulator level comes down and reaches this point in the accumulator. This is - it's called a standpipe. It's a standpipe which contributes a substantial amount of flow early on, because you get flow coming that goes down directly into the standpipe, and then directly into this vortex chamber. I'll talk a little more about the vortex chamber, but it is one of the two sources of water that are available for direct injection into - or ultimately injection into the vessel, and provide basically the water to refill the downcomer.

So that is a dominant source. But once the level of the water goes below that standpipe there is no more contribution from it. There is water still in the standpipe for a little while, but it stays there. About the only contribution then is from the water coming in from this small flow pipe which is down here at the bottom which joins together in the vortex chamber with some of the tube, being the total flow early on. So you get the high flow coming down the standpipe, and the small flow coming in from the side of the vortex chamber, the sum of those two providing the water that ultimately goes into the vessel and then into the core. So it's the sum of those two that are contributing total flow early on, but only the small flow pipe later on once the level falls below the standpipe.

MEMBER ABDEL-KHALIK: Now check valves at the inlet to accumulators for current BWRs are known to leak, so how do you control level during operation for this accumulator?

MR. PAULSON: Is there a way to add, or is the level in the accumulator checked during shutdowns?

He will step up. She's translating for him.

I think the question is, how can we be assured that the water level is maintained in the accumulator, and how that is verified.

MR. HAMAMOTO: This is Hiroshi Hamamoto. The concreation to the injection lines is same as current BWR. So the leakage from the check barrels seldom occurs, but some leakage occurs into the accumulator. We can check by the water level in leak to the advanced accumulator by the water level.

MEMBER ABDEL-KHALIK: So how do you maintain that level within tech specs?

MR. HAMAMOTO: We describe water level limit in the - described in the tech spec.

MEMBER ABDEL-KHALIK: How do you maintain that - how do you assure that the level meets the tech spec requirement? I presume it's the same way it's done in current accumulator.

MR. HAMAMOTO: Our experience is the same as normal operations, it does not change at such a level even if we - even if leakage occurs, we maintain the water from the accumulator.

MEMBER ABDEL-KHALIK: All right, thank you.

MR. PAULSON: In any case that is basically the function. So can you back up a slide?

So when you see this switching here at this point of the blue line, this rapid falloff, that's when the standpipe level, the level of the water goes below the standpipe. This is now the small flow coming in the side of - into the vortex area.

All right, we can move on. Was there any additional questions? There was one component I didn't mention you will hear a lot about tomorrow, but it's the cap on that standpipe, and that is to reduce a vortex from forming once the change occurs, actually, as a way of significantly reducing any type of vortices that occur at that time, and you'll hear more about that tomorrow.

CHAIRMAN MAYNARD: And you will probably get into it tomorrow. Also you get some overshoot or undershoot from momentum in that standpipe too, and I think that is accounted for or at least discussed in your topical report.

MR. PAULSON: It is. It is. The other thing, too, I didn't mention in that vortex chamber, the flow in that vortex chamber when you have flows coming from both the standpipe and the side entrance, it rushes into that vortex chamber. The vortex chamber essentially doesn't see anything other than a stream of water going directly up to the pipe into the vessel.

But once there is that change the vortex is designed so that flow goes around the vortex and then into the line, and that flow around the vortex is what is part of the design process to ensure that the flow goes up to and into the core during the small flow part of the transient.

CHAIRMAN MAYNARD: And there will be some discussion tomorrow on it, I believe it will take just a little bit of time to get that vortex started, once you have the big pipe and the small pipe coming in there with no vortex, and that big pipe ends, that vortex isn't going to form just immediately there, so there has to be some time delay there.

MR. PAULSON: I suspect there is some water residual in the vortex chamber, it's still there that goes in. But Shiraishi-san will talk to you about that tomorrow. He's the expert on that.

MEMBER ARMIJO: What happens if one of these things discharges during normal operation?

MR. PAULSON: The pressure is too low. It's about 640 psi. System pressure is 2,250.

MEMBER SIEBER: So if it leaks during operation -

(Simultaneous speakers.)

CHAIRMAN MAYNARD: - behind a check valve, and if the RCS pressure drops below 600 pounds -

(Simultaneous speakers.)

MR. PAULSON: Tomorrow you will see four tests. And these are actual tests; they are not animated tests; that occurred that Dr. Shiraishi-san will show you tomorrow. But these tests were performed specifically to look at performance, the type of performance you would see by the advanced accumulator under different conditions, both conditions where you would have flow coming from both locations, standpipe and from the side, and also confirmation of how the impact once there is that change occurring at the standpipe what happens at that point. We also look at what happens inside the vortex chamber, which I think is obviously, based on the questions, of interest to all of you. And we will actually - some of it was demonstrated using visual testing, some of the initial testing, some of this smaller testing. This actually is a test in a system that you can carry around with you. I mean you don't carry it in a suitcase or anything, but you can take it to different locations to demonstrate the performance of that.

But then we had roughly a third scale test, one over 3.5, one over 5, each of these looking at different aspects, whether it was the performance of the caps, numerous types of caps for the standpipe, and also for a flow characteristic, both the flow characteristics, both flow from both locations, and then flow characteristics during low flow, based on the vortex chamber. And then we actually had a full high pass scale test, which really provides us data as to the applicability of this and scalability of the results to a full scale system, and that was performed also.

MEMBER ABDEL-KHALIK: Is there a need to seismically qualify the standpipe?

MR. PAULSON: Seismically qualify the standpipe?

MEMBER ABDEL-KHALIK: Within the accumulator?

MR. PAULSON: Yes, I think there is.

(Simultaneous speakers.)

MR. PAULSON: This is a model of the full scale tests, nitrogen tank, evaporator. This is the test tank in which the test was performed. This is where some of the testing goes on. And then the discharge tank or the exhaust tank where the ultimate flow ends up.

So it's a fairly elaborate system, and although it's called half scale, it was a full height test, so that the effects of the level were consistent with what you would see in the advanced accumulator.

MEMBER ABDEL-KHALIK: Back to the issue of seismic qualification, seismic qualification of the accumulator as a unit including this standpipe, what is failure?

MR. PAULSON: What defines failure?

MEMBER ABDEL-KHALIK: Right.

MR. PAULSON: What would define failure? I don't know, Dave, do you have any idea? I presume it has something to do with the performance and maintenance of that specific system to perform. But I don't - I don't think there is any major deformation expected based on the supports, but it would be failure to perform its function during a LOCA, but I don't know what that is.

(Simultaneous speakers.)

CHAIRMAN MAYNARD: Can we take that as a take away for tomorrow's session? Because typically you're right, failure is defined as when it can no longer perform its design function, but I think some more clarification of that.

MR. PAULSON: That's the best I can do, but we can come back. If we don't have the answer, we may be able to get it tonight.

Okay, so this was I think a critical test for getting to the point of demonstrating essentially applicability of the design to a full scale application of it.

These were the cases that were performed, the testing, you will see some of the testing that went on defined in terms of case one, case two, case three, case four. You will see what was looked at was variations of the tank pressure, and variations of the exhaust tank pressure. The exhaust tank provides a back pressure essentially to show you variations of flow over a range of back pressures, and pressures inside of the accumulator. And so we obtained data for all of those, and there will be more discussion of that later, or tomorrow I think.

The type of data, it's too hard to read, but it does give you some idea of the type of data that was collected as part of the process. It looks at and provides you, shows you the level of the vortex at the vortex cap. It shows you some additional information just to give you an idea of the type of data that was collected, and how it was collected.

MEMBER SIEBER: What is the normal operating pressure in the accumulator during normal operations?

MR. PAULSON: About 640 psi.

The correlations were critical, because if you couldn't correlate the data you have to put in data some other way. But we found a very - that the data was very correlatable based on a couple of nondimensional quantities. That will be discussed in detail tomorrow, but this shows you the data, and that the data can be easily represented using the dimensionless quantities, this cavitation factor and flow coefficient, and that will be discussed in detail tomorrow also.

MEMBER SIEBER: What is the design pressure of the accumulator shelf?

MR. PAULSON: Seven hundred I think.

MEMBER SIEBER: The design pressure of the shelf.

MR. PAULSON: The outer shelf.

MEMBER SIEBER: If the check valve fails, the reactor coolant pressure goes in there, is that an automatic LOCA?

MR. PAULSON: I think there are two valves. Are there two valves?

MEMBER SIEBER: There is a manual valve.

MR. PAULSON: Are there two check valves? So it's redundant. The protection is redundant.

So the conclusion is, the advanced accumulator design has been validated for four different scale tests. These test evaluations have been demonstrated that the results of the advanced accumulator, and the features of the advanced accumulator are consistent with what has been built into the LOCA calculations, and that the test data taken in the experiments covered a wide range of expected performance, and the applicability of the system installed in US-APWR under the conditions for a LOCA.

MEMBER ARMIJO: This is just a request: when you get to the detailed presentation, some of us are not as familiar with accumulators in general, if your presenters could give a little brief tutorial about the normal operating pressures, the normal boric acid, how it's filled, what the concentrations are, just to get a feeling for how this machine normally operates, not just in the accident condition.

MR. PAULSON: All right. It doesn't operate; it just sits there.

MEMBER ARMIJO: It's got to get filled. It's got to get filled, it's got to get pressurized, all of that.

MR. PAULSON: One thing I didn't mention, it's a nitrogen gas, it's pressurized with nitrogen gas.

MEMBER ARMIJO: But the initial water, the water that is inside the accumulator comes from somewhere, and is it a special source. Is the boron different?

MR. PAULSON: Those are good questions. We will try and get the answers to those.

Okay. The tests investigated the features of the advanced accumulator, and we believe demonstrated performance consistent with what we were both looking for, what we needed in terms of key parameters with respect to performance during LOCA evaluations. We were thankful that empirical correlations do work, because it makes it a lot easier with respect to putting that type of information into the LOCA codes as opposed to trying to enter data.

And the MHI submitted a topical report last January, and have had extensive review. I think several branches have reviewed that, from different perspectives, I think both research and the technical branches have reviewed it and have provided us questions, and we have provided responses.

That's it.

MEMBER ARMIJO: I believe this pretty much ends the open session. The rest of the presentations are going to be closed.

MR. COLEMAN: We have a section for public comments on the agenda for right now.

MEMBER ARMIJO: Any problem moving that up before the break?

CHAIRMAN MAYNARD: I would suggest just having a little longer break and keeping to that if we can.

MEMBER SIEBER: That's a good idea.

(Laughter.)

MEMBER SHACK: Since we've got a minute let me ask a question. We've gotten copies of your topical reports, as PDF files. We now have a big something to carry in case we need exercise. But those PDFs are scans. Could we get real PDFs? These are searchable, because at least the ones we've got, they have done an optical character recognition, so you can do that. But as Sam says, if there are color charts in here and we are looking at a black-and-white scan, you are losing information.

MR. PAULSON: Is that possible? Can we do something like that?

(Off the record comment.)

CHAIRMAN MAYNARD: The ones we have are scanned. They came out of ADAMS, so you submitted these presumably, then somebody at the NRC scanned them and put them in to ADAMS. Those are the official agency recoreds.

MEMBER SIEBER: I think we are probably more interested in user-friendly versions.

(Simultaneous speakers.)

MR. PAULSON: If it is all right with the

NRC, I think we could probably send you a PDF file. But I don't want to do anything that is inconsistent. We'd want it to be the same as what went into the ADAMS file.

MEMBER ABDEL-KHALIK: If we have a minute, if you could go back to the accumulator in leakage possibility during operation. I understand that you can maintain level control through drainage, but how do you maintain boron concentration, especially near the end of life, if the in leakage is water with low boron concentration, and if that is significant, then the boron concentration in the accumulator would change significantly.

How do you maintain boron concentration within the accumulator within tech specs?

MR. PAULSON: Hamamoto-san may need a translation, but the question is, boron concentration -

MR. HAMAMOTO: How to maintain the boron concentration, we make tech specs requirement for the boron concentration. So we make sampling in accumulator boron concentration. So we control the boron concentration by sampling.

MEMBER ABDEL-KHALIK: So if you have this leakage you bring the level down by drainage and somehow you inject -

MR. HAMAMOTO: If over the limit, we drain and if we can't control within tech spec requirement, we need to shut down the plant. That's the requirement of -

MEMBER ABDEL-KHALIK: So there is no way of increasing boron concentration in the accumulator during operation; is there or isn't there?

MR. HAMAMOTO: You are asking our experience -

MEMBER ABDEL-KHALIK: Let me ask the question in a more direct way.

Is there any way to increase the boron concentration in the accumulator following a dilution due to in-leakage through the check valve?

MR. HAMAMOTO: Through the check valve? The reactor coolant systems are boron low. So we are comfortable within the tech spec requirements by the sample. If leakage occur, and deviate from tech spec requirement, we try to control the boron concentration. But even if we can't do the - keep such a limit, we tech spec request to shut down the plant.

MR. PAULSON: I think that is a good answer. We can feed and bleed is the answer.

CHAIRMAN MAYNARD: That's the way the current ones do. You can add, and you can drain, so it's basically a feed and bleed operation. You may be having to take an allowed outage time, you may be into a tech spec action statement while you are doing that evolution; you would have a certain amount of time. But you can feed and bleed basically and change the boron concentration.

MEMBER ARMIJO: Otto, that's during operation? That's typical.

CHAIRMAN MAYNARD: During operation.

MEMBER ARMIJO: That's typical, so you can add borated water to maintain whatever concentration you want?

CHAIRMAN MAYNARD: Yes.

MEMBER ABDEL-KHALIK: And the injection that is done for this feed and bleed operation is done with which pumps?

MR. HAMAMOTO: From our safety injection pump from the liquidating water feed.

CHAIRMAN MAYNARD: I don't know what their design is, but the designs typically have a charging pump available.

MEMBER ABDEL-KHALIK: That is why I asked him.

MR. HAMAMOTO: Generally we use feeder pump is used by the safety injection pump. So the concentration by the - if the change of the concentration is very little we use the safety injection pump. But if the concentration changes a lot, we use charging pump.

MEMBER ABDEL-KHALIK: I'm just trying to understand how gradual this process is. So if you are using the safety injection pump in a situation like this, in a feed and bleed operation, to adjust both inventory and the boron concentration, so what is the capacity of the safety injection pumps when the discharge pressure is 640 psi?

MR. HAMAMOTO: It would depend - I need to check.

CHAIRMAN MAYNARD: It usually exceeds what your drainage line capability is for your accumulator, and especially for this, and you are talking about a very large accumulator, and your leak rates allowed for check valve leakage is extremely low, so this is not something that is going to happen quickly. You do - are required to take chemistry samples periodically.

MEMBER ABDEL-KHALIK: Well, I'm concerned about the opposite problem, where the flow rate of the SI pumps may be significantly higher than the out-leakage rate, and then you get into a situation where the pressure inside the accumulator would actually oscillate up and down significantly, and may exceed the design value of 750 psi.

CHAIRMAN MAYNARD: I think for a large accumulator even with a higher psi pump load you still have that nitrogen blanket. You are not going to be changing pressure rapidly, and it is a very controlled - I think those are good questions when we get into the actual primary system design and the CVCS, the chemical volume control system and how that works. I think those are very good questions, and exactly how that can be done.

MEMBER ABDEL-KHALIK: Thank you.

MR. PAULSON: And I think it's probably done very similar to the way it's done on current BWRs. An accumulator is an accumulator, and it's about the same pressure.

CHAIRMAN MAYNARD: I would agree. We just can't make that assumption.

MR. PAULSON: That's right. But they are good questions.

MEMBER SIEBER: And the accumulator is not used for reactivity control.

CHAIRMAN MAYNARD: No.

MEMBER SIEBER: You have other systems.

(Simultaneous speakers.)

CHAIRMAN MAYNARD: Okay, do we have any other questions for the open session here?

With that, according to our designated federal representative here, we are going to end up with a longer break here. We will come back at 10:30 I believe is what the schedule calls for, to see if there is any public comment. And then right after that we will go into the closed session.

(Whereupon 9:53 a.m. the proceeding in the above-entitled matter went off the record and resumed at 10:30 a.m.)

PUBLIC COMMENT

CHAIRMAN MAYNARD: Okay, I'd like to call the meeting back to order, and we are on the agenda for members of the public to make comments.

Do we have any members of the public who would like to make comments? No comments?

Well if we have no comments from the public then we are ready to move into the closed session. So I would like our federal representative and Mitsubishi to identify and make sure that we have the room clear of anyone who doesn't have an agreement.

MEMBER ARMIJO: How about the phone? Is there anybody on the phone?

CHAIRMAN MAYNARD: is there anybody on the phone?

MR. BROWN: No.

(Whereupon at 10:31 a.m. the proceeding in the above-entitled matter concluded.)

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Overview of Staff Reviews of Mitsubishi Topical Reports

To:
Advisory Committee on Reactor Safeguards

By:
Ruth C. Reyes, Project Manager
U.S. Nuclear Regulatory Commission

October 23, 2008

Purpose

- Provide overview status of the NRC staffs' review of five US-APWR Topical Reports
- Address the Committee's questions

LOCA Mass and Energy Release

- Topical Report requests approval of methodology for calculating the steam, water and nitrogen releases from postulated reactor coolant piping breaks.

- The methodology in the topical report is based on previously approved methodologies

- Review focused on applicability of the previously approved methodologies to the US-APWR design

LOCA Mass and Energy Release (cont'd)

- Special features which would impact the discharge to the containment building during a LOCA include the advanced accumulators, the heavy neutron reflector within the reactor vessel and the in-containment refueling water storage pit
- Staff issued 4 RAIs, received timely and complete responses
- Revision 1 and 2 submitted in response to RAIs
- Draft Safety Evaluation Report prepared and provided to ACRS

US-APWR Advanced Accumulator (ACC)

- Topical Report requests approval of ACC design and the characteristic equations for large- and small-flow rates for safety analyses
- Review is focused on applicability of the scaled test data to full scale ACC
- RAIs issued, responses received and under review
- Revision 1 and 2 submitted in response to RAIs
- Safety Evaluation Report expected in June 2009

Fuel Design Criteria and Methodology

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

- Topical Report requests approval for the Mitsubishi fuel design criteria and methodology and the FINE fuel rod design code
- Review is focused on applicability of the empirical database to proposed fuel criteria and also on ability of FINE to model standard test cases
- RAI process underway
- Safety Evaluation Report expected in July 2009

FINDS: Mitsubishi Fuel Assemblies Seismic Analysis Code

- Topical Report requests approval for the Mitsubishi seismic analysis code, FINDS, for use in the DCD and also in the Fuel Design Criteria and Methodology topical report

- Review is focused on applicability of the empirical database to APWR fuel design and on obtaining additional test data to support the design

- RAI process underway

- Safety Evaluation Report expected in July 2009

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

Thermal Design Methodology

- Topical Report requests approval of VIPRE-01M, a Mitsubishi version of the approved VIPRE-01 code
- Modifications include addition of a DNB correlation and minor changes
- Review is focused on VIPRE-01M's applicability to PWR cores with MHI fuel
- RAI issued, responses received and under review
- Safety Evaluation Report expected in April 2009

Summary

- Four topical report reviews underway
- Draft Safety Evaluation Report prepared for LOCA Mass and Energy Release Topical Report