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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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JOINT METALLURGY AND REACTOR FUELS AND THERMAL-HYDRAULIC PHENOMENA SUBCOMMITTEE

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TUESDAY

MAY 17, 2016

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 12:32 p.m., Gordon R. Skillman, Chairman, presiding.

COMMITTEE MEMBERS:

GORDON R. SKILLMAN, Chairman

DENNIS C. BLEY, Member

MICHAEL L. CORRADINI, Member

JOY REMPE, Member

PETER RICCARDELLA, Member-at-Large

JOHN W. STETKAR, Member

DESIGNATED FEDERAL OFFICIAL:

DEREK WIDMAYER

ALSO PRESENT:

STEPHEN HAMBRIC, Consultant

WALTER KIRCHNER, Invited Expert

TIMOTHY LUPOLD, NRO

JOSE MARCH-LEUBA, Invited Expert

RICHARD MORANTE, Consultant*

THOMAS SCARBROUGH, NRO*

ANDREA D. VALENTINE, Executive Director, ACRS

YUKEN WONG, NRO

SAMIR ZIADA, Consultant*

*Present via telephone

A G E N D A

P R O C E E D I N G S

12:32 p.m.

CHAIRMAN SKILLMAN: Good afternoon. This meeting will now come to order. This is a joint meeting of the Advisory Committee on Reactor Safeguard Subcommittees on Metallurgy and Reactor Fuels and Thermohydraulic Phenomena. I'm Gordon Skillman. I'm a member of the Metallurgy and Reactor Fuels Subcommittee, and I'm chairman of today's meeting.

ACRS members in attendance are Dr. Peter Riccardella, Dr. Michael Corradini, Dr. Joy Rempe, the distinguished John Stetkar, past ACRS Chairman and Dr. Dr. Dennis Bley, the current ACRS Chairman. Derek Widmayer of the ACRS staff is the Designated Federal Official for this meeting.

The purpose of today's meeting is for the NRC staff to discuss the final draft Regulatory Guide 1.20, Comprehensive Vibration Assessment Program, for Reactor Internals During Pre-Operational and Start-up Testing, Revision 4. The Subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate, and make a recommendation for further consideration by the full Committee.

The rules for participation in today's meeting were announced as part of the Notice of this meeting published in the *Federal Register*. Detailed proceedings for conduct of ACRS meetings was previously published in the *Federal Register* on October 1st, 2014.

The meeting will be open to the public. We have no -- we've received no written comments or requests for time to make oral statements. A transcript of today's meeting is being kept and will be made available as stated in the *Federal Register* notice.

Therefore, we request that meeting participants use the microphones located throughout the meeting room when addressing the Subcommittee. Participants should first identify themselves and then speak with sufficient clarity and volume so that they can be readily heard.

A telephone bridge line has been established for this meeting. To preclude interruption of this meeting please mute your individual telephones and lines during presentations and the Subcommittee discussion. A separate phone line is also open for the participation of contractors to support the NRC staff on this Reg Guide revision.

I want to also recognize that we have two invited consultants with us today. They are Dr. Jose March-Leuba and Dr. Walter Kirchner. We welcome these consultants. At this time I ask that attendees in the room please silence all cell phones and other electronic devices that would make noises that would disrupt the meeting.

I remind speakers at the front of the table to turn on the microphone indicated by the illuminating green light when speaking, and likewise to please turn it off when not speaking. We will now proceed with the meeting, and I call on Tim Lupold, Branch Chief in the Division of Engineering, Infrastructure and Advanced Reactors of the Office of New Reactors, to make introductory remarks. Tim?

MR. LUPOLD: Good afternoon. I had to figure out how to -- which button to push here, the only one. All right. My name is Tim Lupold. I have recently become the branch chief in the Mechanical Engineering Branch in the Office of New Reactors, and I have the pleasure of addressing you today.

I'd like to thank you, the joint committee here today for asking us to present the changes that we are making to Regulatory Guide 1.20, the Comprehensive Vibration Assessment Program for Reactors Internals During Pre-Operational Start-Up Testing. This is the revision. It is Revision 4, and I have with me today two members of my staff, Mr. Tom Scarbrough and Mr. Yuken Wong, and we also have Dr. Stephen Hambric from the Pennsylvania State University.

On the line we have Richard Morante of Brookhaven National Laboratory and Dr. Samir Ziada from McMaster University in Canada. The revisions made to Reg Guide 1.20 incorporate many lessons learned over the years, and so without any real further ado, I'm going to turn it over to Tom Scarbrough to start the presentation.

MR. SCARBROUGH: I'm Tom Scarbrough. First, I'd like to --

CHAIRMAN SKILLMAN: Light on. Thank you.

MR. SCARBROUGH: There you go. I'll try again. I'm Tom Scarbrough. First, I'd like to introduce our team. Some of you may know our consultants and some of you may not. So I thought I'd take this moment to do that. First, Yuken Wong. He's the senior mechanical engineer in the Mechanical Engineering Branch of New Reactors.

Yuken's responsible for the evaluation of reactor internals in new reactors, and has participated in the ESBWR design certification in South Texas combined license steam dryer reviews. I'm also a senior mechanical engineer in the branch. I participated in the Quad Cities and Dresden steam dryer failure evaluations, and several of the BWR extended power updates and ESBWR in South Texas reviews.

Here with us today is Dr. Stephen Hambric, who is a professor of Acoustics at Pennsylvania State University. Dr. Hambric has published over 120 papers in the areas of acoustics and flow-induced vibration and noise. He is the associate director of the Penn State Center for Acoustics and Vibration, and a fellow of the ASME and Institute for Noise Control Engineering.

Dr. Hambric has provided technical assistance to the NRC review of all of the BWR extended power uprates since the Quad Cities steam dryer failures, and the ESBWR steam dryer design certification application.

Also, we have Mr. Richard Morante, who is a principal engineer in the Nuclear Science and Technology Department of the Brookhaven National Laboratory. Mr. Morante has 25 years of experience in providing technical assistance to NRC for static and dynamic structural analysis, vibration and stress evaluations and numerous other engineering areas.

Mr. Morante has participated in the ESBWR steam dryer design certification review, specifically the evaluation and resolution of General Electric Hitachi's fatigue analysis procedures. Also on the phone is Dr. Samir Ziada, who is a professor of Mechanical Engineering at McMaster University in Hamilton, Ontario Canada.

Dr. Ziada has published over 200 papers in the areas of flow-induced vibration and industrial arrow acoustics. Dr. Ziada has participated in the NRC review of all of the EPU applications, the South Texas combined license and the ESAPWR and ESBWR design certification applications.

So first, next slide please. Thank you. Just trying to give you a brief overview of our agenda. We're going to talk about the Regulatory Guide 1.20 and what its purpose is, the reasons for Revision 4, the summary of those revisions, the specific lessons learned that we've included in Revision 4, the public comments received and our responses, and a summary and conclusion statement.

Okay, next slide. Overall, the Reg Guide

1.20 has several applicable regulations at 10 C.F.R. Part 50, Appendix A, DDC-1, which is quality standards; DDC-4, which is environmental conditions and Appendix B regarding quality assurance.

As you know, the BWR steam dryer is not classified as safety-related in the classic sense, but it serves an important safety function to maintain its structure integrity and not generate any loose parts as we've had that happen before in the past. Regulatory Guide 1.20 provides guidance on acceptable methods for developing and implementing a comprehensive vibration assessment program, which I refer to as CVAP for reactor internals at nuclear power plants.

Particular attention is given to the avoidance of adverse effects from flow-induced vibration, FIV, acoustic-induced vibration, AIV, and mechanically-induced vibration, MIV. We're going to talk about those particular flow-induced vibration effects, those vibration effects later in the presentation.

CHAIRMAN SKILLMAN: Tom, let me ask when --

MR. SCARBROUGH: Sure.

CHAIRMAN SKILLMAN: When is the right

time for the members to ask specific questions about the emerging guide, because some of the comments I have actually are affected by the words that you just spoke, but I don't want to be premature in asking my questions?

MR. SCARBROUGH: Why don't -- why don't we -- let me get through the sort of general introductory and Dr. Hambric will take over, and that might be the appropriate time to ask those questions.

CHAIRMAN SKILLMAN: Okay, okay. Thank you.

MR. SCARBROUGH: Thank you. Standard review plan 3.9.2 is undergoing revision to be consistent with Revision 4 to the Reg Guide 1.20. In terms of the Reg Guide 1.20 overall, it provides guidance in sort of three main areas: the classification of reactor internals, prototypes or limited prototypes or non-prototypes.

It talks about multi-unit plants, individual component replacement, the analysis procedures, the 14 functions, response modeling, convergence of the stress calculations and benchmarking, and then also guidance in measurement procedures and in-plant measurement issues we've had.

The reasons for the revision of the Reg

Guide 1.20, Revision 3 we updated in 2007, and it incorporated the Quad Cities and Dresden lessons learned, and also the Vermont Yankee EPU start-up and the actions taken to address their dryer.

Prior to that, the earlier version Rev 2 was a 1976 revision. So there's 30 years of lessons learned that we pulled in. But when we were working on Revision 3, there were several areas that we saw that needed to be further updated. One was the prototype definitions. There were eight different classifications of prototype definitions in Revision 3, and that carried over from the earlier revisions.

It was very confusing at the time. I was involved with that Revision 3. We just didn't want to tackle that problem. That was bigger than we had time for at the time. So we took this opportunity with Revision 4 to condense those classifications down from eight to three, and I think you'll find they're much more understandable.

We've reorganized the Reg Guide in the various sections to make them more concise and useful. We've added numerous lessons learned because of all the activities that have occurred since Revision 3. The BWR extended power uprate applications, there have been several of those since then.

The ESBWR design certification, that whole issue with the steam dryer. Also South Texas with the ABWR. We have lessons learned there as well. We also wanted to pull in the applicability of small modular reactor applications. For example, the control rod drive mechanisms may be more inside the reactor vessel, there being more interaction with those reactor internals than previously with the large reactors.

A lot of that is proprietary, because we're just now starting to look at some of these smaller reactor designs. But suffice to say everything's much more condensed in terms of what -- where things could be affected by vibration. In the next slide --

MEMBER CORRADINI: So can I stop you there?

MR. SCARBROUGH: Sure.

MEMBER CORRADINI: So what I think I just heard, just to make sure is basically bringing the guide up to speed relative to the practices that applicants have provided to the staff, and the staff's review of those applications, to make things a bit more regularized. Is that a fair way of saying it?

MR. SCARBROUGH: Yes sir, yes sir.

MEMBER CORRADINI: Okay. The only thing I didn't understand is the last statement you made about the CRDs for the small modular reactors. Is there something particular there that starts concern with you all or a different methodology that you want to modify the Reg Guide for that, or are you just anticipating something?

MR. SCARBROUGH: We're trying to anticipate that. We wanted to alert applicants and licensees that when they start thinking about potential vibration effects on reactor internals for SMRs, there may be a lot more internals that are involved than previously involved, you know. In the past, the CRDMs were up, you know, weren't even in the picture for the evaluation.

Here, we wanted to make sure that there may be additional reactor internals that they may not be thinking about if they had previously worked with a large reactor.

CHAIRMAN SKILLMAN: Okay. And then so maybe you're going to answer this later. But so I'm curious about is there a particular phenomena that would appear in an SMR that wouldn't appear in current reactors, and the reason I ask the question is usually the mass flux is the flow rates are much lower, and they're usually in natural circulation-driven flows.

So I think we're less in a problem, but maybe there's something about the length and the spacing that I don't understand. So whenever it's appropriate, I'd be curious as to what's the phenomena that's new here that concerns you, or that might be a concern?

MR. SCARBROUGH: Okay. Well what -- we can get more into that later. What I was thinking more about was the steam lines and feedback from the steam lines. Where the lines are smaller, there may be more -- there may be additional possibility of more acoustic affects from the steam lines being smaller lines that come back, and might come back directly into the reactor vessel. Whereas before, it would be hitting the steam dryer in the large reactor. But --

CHAIRMAN SKILLMAN: But all the SMR -- oh wait. Maybe I'm forgetting the design. But all the SMRs with steam generators, we're talking secondary side effects. So there's some sort of acoustic coupling they're worried to the primary system?

MR. SCARBROUGH: Yeah. There may be

something that -- coming back that way. We just don't know yet in terms of all the --

MEMBER CORRADINI: Okay, fine.

CHAIRMAN SKILLMAN: Building on Dr. Corradini's question, my thought was the smaller machines, these smaller reactors are jointly now or they have lower, smaller diameters probably by portion lower flow rates, and some lower driving functions. So my first reaction is I wonder what in the SMRs they're concerned about.

I would think if there's any place where they will not be a concern it will be in the smaller machines.

MR. SCARBROUGH: Yeah, it might be so. We didn't want to, you know, ignore those smaller reactors because of the additional reactor internals that are involved. Now they may find, based on analysis, that the flows and such are -- there's not an issue here. But we didn't want to ignore it and then have something pop up later. We wanted them to take a look at it and make sure that there was not an issue there.

CHAIRMAN SKILLMAN: Is the guidance clear enough that an SMR must have some form of a vessel model flow test or a monitor test, so that that small reactor becomes, if you will, a certified prototype?

MR. SCARBROUGH: Well, they could follow the guidance in the Reg Guide, to make sure that it was a prototype. They did look at this. I know there's a lot of work going on with the NuScale reactor. They have a lot of small scale type evaluations going on.

So there may be areas where they can look at this and look at the Reg Guide, look at the guidance and say okay, we're going to check this out and make sure we don't have a potential issue here with our smaller reactors.

So that will be the goal, just to alert the new vendors that this is an issue for the large reactors, and make sure that we don't have an issue occur that we're not anticipating for the smaller reactors.

CHAIRMAN SKILLMAN: Okay. So correct me if I'm not accurate here. The Reg Guide is really intended to provide guidance for the NRC staff. It's used by the vendors. It's used by the manufacturers, that the true purpose of a Reg Guide is to guide the regulators in their overview of the product.

MR. SCARBROUGH: That's the -- both actually. It provides guidance for the staff, because we're going to reference it in 3.9.2, because we're trying to pull in all of the lessons learned at the one document. And then also it provides the guidance for the vendors and such. They know what the staff is thinking in terms of what the staff would be asking questions about. So it provides guidance for actually both groups.

CHAIRMAN SKILLMAN: Okay, thank you.

MR. WONG: This is Yuken Wong. I just want to clarify. Revision 3 only addresses light water reactors. So we want to mention the applicability to SMR as well.

CHAIRMAN SKILLMAN: Thank you.

MR. SCARBROUGH: Great, okay. Next slide.

CHAIRMAN SKILLMAN: Just hold, just hold.

(Simultaneous speaking.)

MEMBER CORRADINI: We'll wait because you'll come back.

CHAIRMAN SKILLMAN: Go ahead.

MR. SCARBROUGH: Okay, thank you. Steam dryer lessons learned. We've had meetings with ACRS in the past, and just talked about this in quite a bit of detail. But the BWR steam dryer lessons learned, there's been significant improvements in the evaluation process for this since the picture is the picture of the Quad Cities Unit 2 in June 2003.

Quad Cities Unit 1 had an even larger break in November of 2003. But we're trying to apply these lessons learned in the one document, to make sure everyone understands what the latest lessons learned are.

The second paragraph there has to do with minor adjustments. As you know, minor adjustments in geometry and structural properties in conditions can lead to significant changes. A prime example of that was the Quad Cities Dresden issues.

You would think they would be identical plants, but their acoustic response to the steam dryer was significantly different, in terms of how, and it had to do with how the standard, the safety relief valves were connected to the main steam lines, in terms of when the acoustic resonance occurred for those.

Quad Cities unfortunately had to happened right when they're at 116 percent power or as Dresden, they passed through it on the way up. So small changes that you would think not make a difference can make a big difference in terms of --

MEMBER REMPE: So at some point today, I

browsed through the backup slides and your main slides. But at some point today, I am very interested in what happened with Peach Bottom Unit 3, based on the model that was developed using Unit 2 data. So I would like you to discuss that, because some o f the text in the Reg Guide seems to pertain to that example, although it doesn't tell me what happened and I'm curious.

I'll let you decide when to discuss that later in your presentation. But I just want you to be aware that I'm interested in that.

MR. SCARBROUGH: Thank you. Why don't we wait? We're going to get through this a little and then -- and I didn't work on the Peach Bottom one, but this gentleman did, and so we can talk about that, okay. All right.

MEMBER BLEY: But before you go on, I want to follow on what Mike and Dick were asking you about. We learned a lot from the steam dryers on the BWRs. Have there been other places since then where what we've learned there has proved valuable, such that you brought up we're thinking about SMRs and we want to look there.

But I'm just curious if there have been other areas where we've applied what we learned on the dryers to other systems?

MR. SCARBROUGH: Well you know what's interesting, a long time ago power Palo Verde had an issue in their coolant system, in the weather system in a branch line, and there was a lot of discussion of what was causing this valve to vibrate downstream or, you know, in the cooling line.

It turned out to be a phenomenon of a resonance, and now we think back and say well of course that's what that was. But at the time, there was a lot of discussion. What is causing this valve to vibrate itself, and that's what it was.

So I think now we have a much quicker understanding of what can happen with the resonance and the vibration effects than we did before.

MEMBER BLEY: So a place to look for problems, if something odds comes up?

MR. SCARBROUGH: Yes, yes.

MEMBER BLEY: Okay, thanks.

MR. SCARBROUGH: Okay, so next. I just wanted to kind of tell you our technical revision summary has like three main areas, the prototype, the analysis procedure and measurement procedures. That was all contained in that slide was.

Now the prototype definitions. We've

crunched this down to three definitions, to try to make it more clear. We have a prototype. It's first of kind, it's unique and it can be validated and I'll call it a valid prototype if it's completed, it's CVAP, what I call CVAP program with no adverse in-service vibration phenomena, and NRC accepts the program.

So now it's a valid prototype that you can reference in your analysis. It's a limited prototype, which would be like the same shape, maybe a different size, some small differences. But you could use less instrumentation. Maybe use a smaller amount of instrumentation on the dryer itself, or use the main steam line instrumentation that what you've had to use before.

This comes into play a lot of times with a steam drier for a two unit plant, where you have one of the dryers is the prototype and the other is called limited prototype, and that use much reduced instrumentation just to confirm that in the main steam lines and such and the dryer are all consistent. So that's what a limited prototype --

MEMBER REMPE: This is the example that I'm curious about, because again Unit 3 only had instrumentation on the steam lines, and as opposed to

Unit 2 at Peach Bottom. What happens if you're going to try and justify it's a limited prototype? You didn't instrument it.

This is based on what's in the Reg Guide and then something unexpected happens, and I didn't see that really covered well in the Reg Guide. So I'm just curious on what happens.

MR. SCARBROUGH: But what we -- we could always clarify that more. The intent was so that if you do it, if you go down the path of a limited prototype and you do not, are not able to show which are instrumentation or less significant instrumentation, that it's following the same pattern as the prototype.

Then you're -- that's back to a prototype. You've got to -- now you've got to instrument it more.

MEMBER CORRADINI: So can I state it back to you. I want to make sure I understand. So who decides on the definition? The applicant comes in and says for one, I have a Nordic steam dryer and it's identical to my plant-wise identical to Plant X. That's a prototype, and the staff would review that and confirm that they treat it as a prototype?

MR. SCARBROUGH: Yeah. First, they could

come in and say you have a prototype. They've already conducted their CVAP program. It had operating experience. It was acceptable to the staff.

MEMBER CORRADINI: In Plant X and Plant Y and it's identical?

MR. SCARBROUGH: Yes. Now what they would come in and say we think it's -- we think we can classify this as a limited prototype because everything's the same. The steam lines are all the same. The construction was all the same, you know.

MEMBER CORRADINI: So that's the difference between a limited prototype and a prototype? That's what I'm struggling with.

MR. SCARBROUGH: A limited prototype, you could put instrumentation in the steam lines, and not instrument the dryer at all.

MEMBER CORRADINI: I understand what you do. I'm asking how do I know it's under the first bullet versus the second bullet?

MR. SCARBROUGH: The applicant would come in in their application and describe the differences, right, and the similarities, and justify that yes, it's very similar and the staff would say yeah, we agree. You could classify this as a limited prototype because of all of the similarities.

But it's applicant's decision to classify it that way. So now they're going to instrument it in a reduced fashion.

MR. LUPOLD: So but Tom, it's a -- it's a prototype when it's the first time it's used, right?

MR. SCARBROUGH: It's a prototype -- the prototype is the one that can perform all these limitations and you validate its performance, right. Now you have another steam dryer let's say that's very similar; it's in a very similar system --

MR. LUPOLD: And that will either be then a limited prototype because it's the second in the series?

MR. SCARBROUGH: Right.

MR. LUPOLD: Or it could even be a non-prototype?

MR. SCARBROUGH: It could, it could.

MR. LUPOLD: If your system's exactly the same, your dryer's exactly the same.

MR. SCARBROUGH: It could, it could. Now --

MR. LUPOLD: I think to answer your question as the prototype is when it's used the first time. Okay.

(Simultaneous speaking.)

MR. LUPOLD: Do I have that correctly? A prototype is when it's used the first time.

MR. SCARBROUGH: The first time.

MR. LUPOLD: I'm in Plant X. I'm using dryer A and it's a prototype. Now I'm in Plant Y, I'm using dryer A. It's a limited prototype or is it just another prototype?

MEMBER REMPE: It's a limited prototype.

MR. SCARBROUGH: It depends.

DR. HAMBRIC: So if I may, on the second bullet there are differences between the prototype and limited prototype, but you have to prove those differences have no impact.

MR. SCARBROUGH: Well truly there's no difference. They're cookie cutter, they're the same.

MEMBER STETKAR: What I think they're asking is I forgot your alphabet soup. Plant X -- X and A is a prototype because it has never, that combination has never been used before, okay?

MR. SCARBROUGH: Yes.

MEMBER STETKAR: Now Y and A, one would normally think would be a limited prototype. But from what I'm hearing from you is there might be some conditions where Y and A could be characterized as a prototype. Is that correct?

MR. SCARBROUGH: That's correct.

MEMBER STETKAR: Okay. What are those conditions?

MR. SCARBROUGH: For example, let's say they came in and they said it's an identical plant, but we built our steam lines differently. How we connected the safety relief valves are completely different. You know, in one set they're eight feet long, in one set they're four feet long, the lines. So the performance is going to be different.

MEMBER CORRADINI: Okay, that I get. So let me tell you why I'm asking the question. When I'm asking questions, if I'm an applicant I'm still confused, unless there's more clarity, because I'm not sure what I come in with. If I was an applicant I'd say you know, that's limited.

And you say well, the steam line's one foot off to the left and this thickness is a quarter inch bigger or smaller. No, it's not limited. It's a non-prototype. You've got to start all over again. I'm sensing still vagary in here, which is okay as long as we're clear about that it's vague.

CHAIRMAN SKILLMAN: Well, let me jump in. I'm not okay with it, and here's why. In your document on page ten, you make clear that after the prototype has been run through the ringer and shown to be acceptable through the CVAP, it is now anointed as a valid prototype. Okay, in other words, it is the article. It is the reference.

MR. SCARBROUGH: Right, okay.

CHAIRMAN SKILLMAN: On your third bullet, it says "non-prototype," and it says by golly, it's the same as the valid prototype. My view is what's missing is the clarity of what is a valid prototype and what is a replica valid prototype. I'm confused like Dr. Corradini is confused. I can be educated.

I can figure it out, but in my view, it's obscure and in this case words matter. Let me go one step further so that you can see what I'm confused with. On pages 9, 12, 38, 40 and 42, you use the words "internals important to safety."

For my 50 years of nuclear, every internals is important to safety. None are not important to safety. Now I can get carried away in Reg Guide 1.26. I can get carried way in quality classifications. But at the end of the day, anything that's bolted inside that reactor vessel has a safety importance.

We can say well, we're really over into witness into that kind of a definition. But I think the copious words used on those pages, internals important to safety, combined with what's a prototype, what's a limited prototype and what's a non-prototype, is confusing.

MEMBER CORRADINI: And so just so to -- excuse me, just apply a line. I looked at the comments and there were two individuals that had like 95 percent of the comments, and the sense of it is that they were confused.

So that's where I'm -- which is to say if the real process is I come in and it's not first of a kind, clearly not first of a kind. Therefore, it's not a prototype.

Now I have to decide is it limited or not, and I'm coming in in Plant Y with steam dryer A. If I come in, it strikes me, hearing this discussion, a better have a discussion with the staff before I start making a claim that it's under Bullet 2 or Bullet 3, because it could be either.

MR. SCARBROUGH: That's correct.

MEMBER CORRADINI: Correct, okay. Does that provide clarity to what's happening?

MR. SCARBROUGH: That's really the message that we're actually trying to make, is that it's not a simple decision as to when you come in and you -- you're pointing to another plant, can you call your steam dryer a prototype or limited prototype or non-prototype? What should you call it? It's not a simple question. That's why we're sending -- really getting that message across.

MEMBER RICCARDELLA: If it's a non-prototype, then you don't have to do anything, any testing or any instrumentation?

MR. SCARBROUGH: That is what would happen, yeah. But that -- I don't think we're quite there yet until we learn more about what the differences are. Now the other reactor internals, yes. I mean but for steam dryer, I don't -- I don't we're quite there yet.

I think typically what you see is for a dual unit site, they'll have one of the steam dryers will be their prototype, and the other one will be their limited prototype, and they'll do a lot less testing of that.

MEMBER CORRADINI: That goes back to Dr. Rempe's question about two versus three in PB. We'll have to get to that.

MEMBER REMPE: Before you leave that discussion, that you said well okay, if they fail the limited prototype path, well they'll have to put more instrumentation on the dryer. My impression from the EPUs is that licensees aren't going to like having to go back and put more instrumentation on a dryer after it's been operated.

I mean when you put the replacement in, you can put the instrumentation on. But to go back and put more instrumentation on after it's operated? Has anyone done that?

MR. SCARBROUGH: Yeah. Actually, when they did Vermont Yankee, they decided -- because it was radioactive, they beefed up the dryer itself. But they put a lot of instrumentation in the main steam lines.

MEMBER REMPE: Yeah, you can put it on the lines --

MR. SCARBROUGH: Exactly, right. They did that.

MEMBER REMPE: --and they did that with Unit 3, but it's not so easy to go back and say well okay, I'll put some more instrumentation on the radioactive dryers. No.

MR. SCARBROUGH: That's why it's very important up front to decide, I mean are your two units identical, you know because --

MEMBER REMPE: And Peach Bottom wasn't.

There were some small differences and so --

MR. SCARBROUGH: And we've had lots of discussions with licensees in terms of are you sure that they're the same, and you know, Quad Cities, you know Dresden. They would look at their steam lines and their design and convince themselves it's either, you know a prototype. Each one might be a prototype or one can be a limited prototype.

For those cases, they were able to do it. Now I want to talk about Peach Bottom, but that's in terms of just that is the challenge that the licensees have, to make sure that they won't have a failure at the other unit that they decided was a limited prototype, and they ended up their steam lines were so different they had completely different responses in their steam lines.

MEMBER CORRADINI: So then a way to ask the question might be if I'm not under Bullet 1 but I could be 2 or 3, is there a screening, a technical screening process that is offered in the Guide, that helps me decide where I sit? It would seem to me there ought to be some first principles or maybe more complex screening process that says I've fallen to under two or I've fallen to under three.

Or I'm going to wait for Professor

Hambric to answer this, because I know acoustics is kind of complicated, because there's small pressure perturbations where geometry really matters. Or is there no screening criteria and it really comes to a discussion? That's what I'm trying to sort out.

MR. SCARBROUGH: Right. Well that's a good -- I think we should go back and look at this section, and clarify it more right, and then -- and look at the possibility of putting this in screening criteria in this section because, you know, we do want this to be clear, you know.

It's going to be a challenge and that comes across. It's a challenge to decide which group you're in, right. You know so we went from eight categories to three, but we still have to make sure to give them guidance as to what's the best path for them to take.

MEMBER BLEY: So at what point in the process does the applicant have to convince the staff that how they've done this make sense before they actually install the hardware? Where does that happen?

MR. SCARBROUGH: Very early, you know. When they start thinking about an EPU, they come in and talk to us. I mean they're just thinking about it, and they have to decide okay, you know, and before they come in they've done a lot of thinking about what should they call these two dryers --

MEMBER BLEY: Which means they've done some analysis or done some testing themselves?

MR. SCARBROUGH: And looked at their steam lines, looked at how the steam lines are set up and that sort of thing.

MEMBER RICCARDELLA: I mean they're all doing analyses aren't they? So I mean don't you use your analyses as part of this decision-making process?

MR. SCARBROUGH: Yeah.

MEMBER RICCARDELLA: Wouldn't a utility use their analyses?

MR. SCARBROUGH: Right. They probably do an analyses to look to see what the steam lines and the shape and see what they have. But also in terms of just a pure geometry for the two units.

MEMBER RICCARDELLA: And the differences in, you know, limited versus non-prototype would just be whether you need to do instrumentation to validate your analyses, right?

MR. SCARBROUGH: Right. If they came in, it would be a challenge for them to come in and say it's a complete non-prototype and we're not going to do anything, right? That would be quite a challenge for a steam dryer.

MEMBER RICCARDELLA: We're not going to do any testing and instrumentation?

MR. SCARBROUGH: Yeah, we're not going to do any. We've just done some analysis and we're done. That would be a challenge because there's so much small changes in geometry and such that can make a difference.

But definitely prototype and limited prototype could come in and say we're going to instrument this dryer and this other one in the units, and the units are identical the best we can tell, and we're going to put instrumentation on the main steam lines to show that the performance of these two steam lines are --

MEMBER RICCARDELLA: But not on the dryer itself?

MR. SCARBROUGH: Not the dryer itself.

MEMBER RICCARDELLA: But then you said something about well but if it fails that -- I could fail. It fails because the instrumentation on the steam line don't match your analysis?

MR. SCARBROUGH: Well for example, let's

say that there was something that they -- for the instrumentation of the steam lines, and they found severe Quad Cities types of resonances at 150 hertz, and we know that the Quad Cities dryer failed from that type of severe.

Now something happened in their lines. There was a branch line they missed or something, right. And so they've had to go back and say okay, what do we do now? One, they might even put in like Quad Cities, put it in the side branches, to cut down that resonance. There might be something like that they do, which is what Quad Cities and Dresden ended up having to do.

So but they'd have to go back and look at -- go back to the drawing board and say okay, what caused this severe resonance that we didn't think was going to be there? That's where the limited prototype.

You're just -- you're checking to make sure that the performance of the steam lines and such that would affect the dryer are in the same realm as what your prototype was. That would be your goal.

But we will go back and look at these sections. We want to make sure that they're clear and revamp these sections.

CHAIRMAN SKILLMAN: Tom, it seems to me that there is perhaps a larger issue here. The title of this document is the comprehensive testing for the internals during start-up. But as you accurately pointed out, the Palo Verde, it wasn't internals.

It was actually a whistle effect on a RHR line, and that RHR line was moving about three-quarters of an inch, if you recall. It was actually swaying, and it was also vibrating the RHR right fluent system isolation valve, the number one valve off the system.

MR. SCARBROUGH: Right.

CHAIRMAN SKILLMAN: But that whole pendulum was excited and was actually imposing cyclic fatigue. Is this really aimed at the reactor coolant system versus the internals? For the boilers, the dryer is one piece. We're talking a lot of other pieces in play for this document.

MR. SCARBROUGH: That's true.

CHAIRMAN SKILLMAN: I'm wondering if, for instance, as John said, you can have reactor X with dryer A in reactor Y with dryer A. One's the first of a kind, it's a prototype. The next is the non-prototype. It's supposed to be the same but it's behaving completely differently.

Reason: It has nothing to do with the dryer. It has everything to do with the whistle effect on your main steam safety valves or some peculiar piping arrangement that is causing a rare effect or some form of acoustical feedback that's exciting maybe the dryer and maybe the surveillance and other tubes down in the reactor vessel.

So it seems to me that you're really pointing to a much broader target than just the internals.

MR. SCARBROUGH: Yes, and we do mention that possibility, that in the sort of background discussion that there could be other phenomena that are different types of aspects related to this phenomena that we're talking about, that's true.

CHAIRMAN SKILLMAN: But words matter, and here we are. We're saying here's this things about internals and what we're really talking about is perhaps two absolutely robust, one design of say a dryer, an RSD replacement steam dryer, extremely robust. All of us would say boy, that thing's really fit for duty.

Put it in two different plants and in one plant vibrates, in the second plant it doesn't, and we say well, it's not the RSD. It's what the rest of the system is causing the RSD to do. So why isn't this more broadly focused?

MR. SCARBROUGH: Uh-huh, yeah. We could do that. We could to that. I mean we could -- we could look at this and see how we make this more broad in terms of the guidance and information that we're trying to pass along to the licensees.

MEMBER RICCARDELLA: But there's also the O&M code, the SME operating and maintenance code, and there's some sort of an interface with that, isn't there?

MR. SCARBROUGH: Typically, in O&M, we're really looking at operating components, pumps and valves and snuppers (phonetic). We're looking at, and this is more looking at -- this is actually more looking at like pre-service testing, evaluation. I mean this would be more along that lines rather than --

MEMBER RICCARDELLA: For a new plant, there's an operational vibration, a start-up vibration test on their piping.

MR. SCARBROUGH: Yes, they do.

MEMBER RICCARDELLA: What effect, what governs that? Is that -- is there another Reg Guide or --

MR. SCARBROUGH: Actually, there's a Reg Guide. Is it 1.61? But there's start-up, there's start-up, and actually we've added some of this to make sure that they look for things like that, because as you know, it ended up Quad Cities, the bigger problem of Quad Cities was their safety relief valves failing because of this acoustic resonance problem.

And so we've added some guidance in those start-up test programs, and so that when they're starting the plant up and they're monitoring lots of different aspects of the plant start-up, that they're looking for vibration effects in some of these lines, these steam lines for their components.

So we've added, we've beefed up some of those other Reg Guides, that guidance in those areas.

MEMBER RICCARDELLA: So then is that the answer to Dick's questions, is that there are other Reg Guides that cover the reactor coolant system?

MR. SCARBROUGH: There are. There are places that we add like that. But this is a place where we actually talk about the phenomenon. We don't really talk about that. We're just telling them to go check that. But here actually we're giving them discussions of what's happening in this, int his Reg Guide of this phenomenon.

So we have to go back and think about how we might want to make this a broader discussion of this phenomenon. I think this is -- it tends to be, you know, like internals. So I think we have to keep that in there. But I think we could look at how we give guidance to the licensees for other areas that are also covered.

Maybe there's a way we could make it more broad in terms of how overall, but then this is specifically talking about the reactor internals portion of it. But in terms of the phenomenon, make sure that the readers know that the phenomenon is something that could affect a lot of other components, rather than just reactor internals.

CHAIRMAN SKILLMAN: Well, I guess my parting shot is words matter, and if you recall when the Fukushima task force sent out its first Recommendation 1, its first Recommendation 1 was the regs are so complicated, it's so hard to work one's way through them. I'm paraphrasing, but that's kind of what it said or what was written there.

I used to be a user of these reg guides, and I could recall just straining to try to put the pieces together, and here is what I'm going to call a cardinal reg guide for phenomenon that we've learned in the industry is one that we must be very, very careful with.

It seems that this is an opportunity to really get this one right. It's more than just the internals on a boiling water reactor. It is internals in a P, a big P, a small P, a small P, an SMR and any other machine that we put together.

The phenomenon, the phenomena are approximately the same, and how we write this, how this is written can guide users to, if you will, to get it. And so you know, we've got to be mighty careful here.

MR. SCARBROUGH: Right, right. Our goal was to take our sort of collective knowledge that we have of the people working on this problem for many years, and get it -- get this guidance out to the staff, who's going to come behind us and the applicants and the licensees who are going to be using it.

So if there's a way we can make it more clear and more useful yeah, yeah. I'm all for that.

CHAIRMAN SKILLMAN: It just seems like it has a preponderance of guidance for replacement steam dryers and boiling water reactors, when in reality, at least from my perspective, there's a whole lot more at play than just that, and that's important. I agree with that, that there's more than that, that is affected by this revision.

MR. SCARBROUGH: Right, right. Okay. Good, thank you. We'll go back and we'll think about that and see how we could look at that.

CHAIRMAN SKILLMAN: Please take a look at the term internals important to the safety.

MR. SCARBROUGH: Yes. I wrote down the page numbers. We're going to back --

CHAIRMAN SKILLMAN: And I think, at least I read that. Why is that distinction being made? Aren't all interanls practically speaking, important to safety?

MR. SCARBROUGH: Yes.

CHAIRMAN SKILLMAN: This is not about quality classification.

MR. SCARBROUGH: Right.

CHAIRMAN SKILLMAN: It's a broad term. I think all internals are important to safety.

MR. SCARBROUGH: We will do a search on that term and make sure that it's clear, because I agree. I think if it's a reactor internal, it's important to safety for some reason inside the reactor.

CHAIRMAN SKILLMAN: Consider where there are P's where internals have fallen apart. Not P's, P's, and that is a terrible job to retrieve the broken pieces. If it's outside the core barrel, then you have a double or triple problem because pulling the core barrel out probably taller than the fuel pool is deep, and you've got some serious radiological issues that you've got to contend with to finally get into the broken part of the internals. They are normally affected by vibration.

MR. SCARBROUGH: Right, right. Great. This is all good feedback. Thank you so much. We will work on that. So basically that was it for my discussion. I'm now going to turn it over to Dr. Hambric.

CHAIRMAN SKILLMAN: Steve welcome. Go ahead.

MEMBER CORRADINI: So since you're up, I want to ask your opinion about the slide we just passed. So is there a screening process that is used in other industries to decide what is or isn't important, or is it really so geometrically dependent that it's more a matter of the discussion?

DR. HAMBRIC: I could go back to what they do on Navy reactors.

MEMBER CORRADINI: Okay.

DR. HAMBRIC: And there it is very specific --

MEMBER CORRADINI: As long as you say it out loud.

DR. HAMBRIC: Sure. There, it's specific to each application. Every component has its own set of screening. But any time they change anything, it's just jumps back to prototype, and they're much more rigorous than in a commercial nuclear power plant.

We had struggled with exactly the comment you had. This isn't a steam dryer reg guide. This is a reactor internals reg guide. We use a lot of steam dryer examples, because that's where our lessons learned have come from over the past ten years.

We looked at the prototype, limited prototype, non-prototype. We didn't want to turn it into here's how you do it for dryers. We believe it or not tried to make it more generic than that, and talked about trying to put a decision tree in there. It's like how do you do that for every type of reactor internal?

You can't, and we'll go back and think

about it. Maybe there's a generic way we can put together some things for an applicant to consider, you know, flow rates and geometric differences and things like that, drop frequencies on the machinery. I think we can come up with a few things that we can put in a decision tree like that.

It will be a guideline, and I think we also went through great pains to put in there several locations. The staff will evaluate on a case-by-case basis, because we can't turn this into a spec. So I don't know if that's a helpful comment or not.

MEMBER STETKAR: Well, I think some of the concerns are that -- you read the history of this reg guide, that it was 30 years between Rev 2 and 3 I think or something like that. So you have to think about, regardless of what you say that this is guidance to the industry; it's guidance to the staff.

That's what it's written for, and if you're walking the staff into a position where you and I as two responsible reviewers would reach different conclusions for two different applicants about the level of rigor that needs to be applied to them because this is musky and you exist today and I exist some years from now, then we ought not to do that.

We don't need necessarily, you know, engineering-specific criteria, which there has to be some latitude. But if there's so much latitude that they'll be a natural tendency of staff reviewers to ratchet people into doing more and more and more, that's some of my concern, because it's the easy path out for the reviewer and of course, well you know, it's always better to have people do more testing and put on more instrumentation.

So at least some, if the way you've characterized it as guidance, you know, based on principles or things that -- where we know that the differences may make a difference, to focus people on those issues, it might help.

DR. HAMBRIC: Right, right. So this slide puts some more definitions behind the new terms we've added to the Reg Guide. Before in Rev 3, we had the term "FIV," flow-induced vibration, and that's really where most of the focus was. I think we understand that pretty well, although we're still learning things as we proceed with new reactor reviews.

But basically the idea is you have fluent flow over, across, through some sort of a component, and there are certain special flow speeds that coincide with the dimensions that give you a strong response. If that also happens to line up with the resonance, then you've get a big response and a big excitation. So we call that FIV.

But sometimes that response is acoustic in nature, and that's really what happened in Quad Cities and is continuing to happen in some reactors today. You've got that flow resonance, but it's really a resonance associated with a flow over an opening and it sort of self-reinforces, it gets strong.

But if you have an acoustic mode next to that, and maybe another acoustic mode in a pipe next to that and they happen to be resonating, then you have an acoustically-induced vibration issue. It's flow-induced and acoustically-induced, so they're combined and that's where acoustic pulsation theory and all of that come into play in an analysis, that sort of a response.

And then it doesn't happen as often, but we have been spending a lot of time over the past several years looking at reactor recirculation pump excitation, and those are strong tones that occur not only in the drive frequency but more importantly at the vein passing frequency, the number of impellate (phonetic) veins multiplied by the drive frequency.

When we first started looking at these dryers, and again this isn't just a dryer reg guide but we used that as our example, they would acquire a bunch of data and say oh, we took out this frequency. Why did you do that? Oh, that's the vein passing frequency. We don't care about that.

MALE SPEAKER: That's the what frequency?

DR. HAMBRIC: The vein passing frequency of the reactor recirculation pump. We don't care about that, and then we reviewed Susquehanna and were surprised to see that the first time they had a dryer failure back on that in the 80's, they blamed it on a vein passing frequency.

So there are plenty of -- the industry's kind of gone back and forth on that. One of the comments was it wasn't necessarily a vein passing frequency. Some of it might have contributed, fine. Since that point, we've been looking at the pumps pretty regularly, to make sure that those tones are accounted for.

MEMBER CORRADINI: So let me say it back to you again so I make sure I got it. The FIV is flow-induced. So row V squared over some strange geometry.

DR. HAMBRIC: With a non-linear term in that "some strange geometry" remark.

MEMBER CORRADINI: Sure, sure. The second bullet, is that coupled with something that's going at the speed of sound and the unusual geometry could reinforce? Okay.

DR. HAMBRIC: Those frequencies are identical and they reinforce each other.

MEMBER CORRADINI: And they reinforce each other. The third one is a mechanical piece of equipment that essentially creates a (sound).

DR. HAMBRIC: Faster than that, but yeah.

MEMBER CORRADINI: Faster than that, but something such as that that is essentially the forcing function that would cause the third bullet?

DR. HAMBRIC: Uh-huh.

MEMBER CORRADINI: But not interwoven with acoustic waves or flow? It's just strictly a propagation of that mechanical vibration through the system?

DR. HAMBRIC: We have worried about the combination of all three, a fairly recent application.

MEMBER CORRADINI: But the other two don't have a piece of mechanical equipment. The third one is clearly some -- you have a forcing function by a piece of mechanical equipment.

MEMBER RICCARDELLA: Yes. You characterize that as structure boom (phonetic). I guess I'm --

DR. HAMBRIC: It can be both.

MEMBER RICCARDELLA: And I though vein passing frequencies could be flow formed as well?

DR. HAMBRIC: It could be both. But we call that collatomechanical (phonetic) source and it can propagate acoustically and structurally. If you look at the path that it takes to an internal, it's a lot more tortuous to get there acoustically and there are a lot more locations along the transmission path where they can be a really big attenuation, where structurally it could just get anywhere.

MEMBER CORRADINI: But isn't that putting pressure pulses in the fluid, the vein?

DR. HAMBRIC: It is, but it's putting pressure pulsations in the recirculation fluid, not necessarily up in the steam lines or into the RPV acoustic volume or --

MEMBER CORRADINI: Ah, okay, okay.

DR. HAMBRIC: So we've looked at both and in fact applicants just go ahead and leave the signal in their acoustic part, but they also will propagate the forces through the piping, into the RPV, apply the forces to the mounts of any internals, see what the excitation forces are, try to come up with conservative ways of estimating the response. So that's become routine now, that they'll assess that pump MIV excitation.

MEMBER RICCARDELLA: That's why you always make odd numbers of veins isn't it?

DR. HAMBRIC: Historically.

MEMBER RICCARDELLA: So they interact. So they -- well, I was going to say so they cancel each other out.

DR. HAMBRIC: Well, it depends on what inflow you have. So if you've got a bunch of struts on the inflow and you have an even number of struts, you want an odd number of spinning blades. So that's one of the major changes in the Reg Guide, is we now spell all those pieces out a little more rigorously, a lot more rigorously.

All right. So this is just literally an outline of the Reg Guide, and these are the headings, subheadings throughout. This first slide is a block of analysis procedures. It talks about structural, hydraulic and acoustical modeling. Three sub-bullets there, the modes of vibration. That's pretty important.

Structural dampening, also extremely important. We argue to this day with applicants about what appropriate dampening levels ought to be, and then something we call frequency response functions, you know, how the overall system responds, the functional frequency to a given drive.

And that's actually the easier part. The hard part is the forcing functions, and we did the best we could to come up with as an exhaustive list as we could. But we also stressed in the write-up that that doesn't guarantee you've caught all of them. Any new plant, any new internal has to consider all the potential forcing functions.

There may be others besides just the ones we're listing here. These are just examples. So we have the flow excitation or the feedback. Several applicants have used scale model testing to try to emulate that or simulate that. So we have guidance on that which we'll get to.

CFD, the future may or may not involve a lot more use of CFD for determining these forcing functions. So we give guidance on that.

MEMBER CORRADINI: So can I stop you

there?

DR. HAMBRIC: Yeah.

MEMBER CORRADINI: So I'm in single phase most of the time, and whether it be a liquid or a gas, and I'm going to do a CFD. Where do you believe it versus wanting to validate it based on some sort of scale model testing or extrapolation? That is, would you, you know what I'm asking?

I'm asking where does the belief stop and it gets to be I need some sort of scale model testing? Is it complex geometries? Is it -- what is the -- when you're presenting something to review, when do you start doubting what's calculated versus what is shown to have matched an experiment, or worse tuned to an experiment and then extrapolated?

I find that -- for me, I find it very hard. So that's why I'm curious, particularly a lot of your examples are single phase examples. So maybe there's something there that I don't.

DR. HAMBRIC: So I understand your question. I've made a note of it. What I'd suggest we do is go through some of the lessons learned so we might be in a better position to talk about that.

MEMBER CORRADINI: Right, thank you.

DR. HAMBRIC: But that's an excellent

question. Actually, the fourth sub-bullet there is maybe part of the answer to that question. We've had applicants fairly recently with PB-2 and PB-3 have to use inference approaches to back out what the effective forces actually were when in spite of best intentions, things go wrong.

Analyses weren't right, measurements give us unexpected results. We have to go to a Plan B and work with the applicant on making sure it's constructive and appropriate. And then the RP force issue. Then there's a section on benchmarking. So this is also getting to what you're asking. How are we proving that the procedures are indeed conservative, and to make the key point here, it's to make sure the procedures are conservative, not right.

So it's perfectly okay to do an analysis that you know is wrong, but it's conservative, as long as you can prove that to us. In some cases, that is much cheaper and easier to do than a full-on coupled CFD mechanical response, which is unreasonable to expect of all our applicants.

But a very powerful approach to proving to us things are okay is something we're calling end-to-end benchmarking. So we'll talk about that in fair bit of detail. When we first started all this, there was a lot of piecemeal benchmarking, combined by SSR and now we've hopefully in the future switched to end-to-end, just to really give us confidence that the procedures are conservative.

And then -- and even though everything we have gone through maybe proved to be conservative, stress convergence is always sort of the last step. It's hard to prove that with measurements, and so we talk about ways of making sure that stress concentrations are properly handled.

And then the final issue there is what are our acceptance criteria? We turn the thing on and we start measuring things. How do we determine yes, you're okay versus no, you need to go back and evaluate more rigorously? And then finally a section on pre-operational and testing analysis.

So oh, and I left one out, a very important one, how you can make the measurements. Going into a lot of our reviews over the past several years, we've had to evaluate a lot of sort of seat of the pants measurement procedures, and part of that is because the reg guide did not give a lot of detailed guidance on that.

So we've tried to correct for that, tried to bring out a lot of in-plant measurement issues we've discovered over the years, just so that future applicants and future staff evaluators know what to look for. Tried to make sure that there's a decent documentation plan there for instrumentation, power extension, acceptance criteria, test duration.

Finally, in spite of all of these procedures, there has to be inspections, just to make sure that there was no whoops somewhere. We give guidance for what criteria need to be looked at.

All right. All of that was for prototypes, and that's a tall hurdle and there's a lot of stuff. They have to do their analysis, measurement, benchmarking. But when it comes to limited non-prototype, the bar gets lowered quite a bit.

Presumably if either a limited prototype proven it (a) changes your system, lead to minor response variations or it's cookie cutter plan. Plan B is exactly the same as Plan A, subject to whatever uncertainty stackups we have.

So they're much simplified. The analyses don't have to be as rigorous measurements, much less instrumentation, in some cases almost not instrumentation for non-prototype. But in both of these sections we point out that hey guys, we've been there before. What you may think is a minor change may not be. It could lead to some sort of an issue with FIV, MIV or AIV and we have to look at these things on a case-by-case basis based on our experience.

CHAIRMAN SKILLMAN: All right, let's back up. Let's consider that the plant says I really am what I believe to be a non-prototype, so I don't think I need to do anything. You say no, not so fast there. You really do, and I say I'm following the rules. Well, where does that leave me? I'm following regulations. I'm following the guidance, I got it.

But since it isn't a regulation, it isn't required, I say I'm doing what the Reg Guide told me to do. I'm exactly where John was saying, doing what I think the Reg Guide guided me to do.

I kind of look like them. I've got about the same flow rate. I've got the same rugged dryer. I've got virtually the same internals. I've got the same fuel, I've got the same vein passing frequency on my recirculation pumps. Why are you making me do more?

DR. HAMBRIC: Well, I think what we would do -- let me say it again. When they come in and would say we think this is a non-prototype, we go through all the things you've just talked about. But we'd also talk about what about your steam lines. Are your steam lines identical in terms of how they were constructed?

Were the branch lines all attached in the exact same fashion as the other plant, and all of these questions. If they can come back and they can show that yes, it's exactly the same. It was like you couldn't be more exact, then we'd say yeah, you're right.

We can't find anything. Everything's the same. You have the same contractors, the same, you know, builders came in and built these steam lines exactly the same way. They used the same technique of welding the steam line, the branch lines onto the steam lines. Everything's identical.

We'd say yeah, we can't find anything that's different, right. But so far, because every plant out there in the United States is built a little differently, that's a hard thing to prove. Now what we might do is we might say yeah, we don't -- we're not quite there, non-prototype.

But we think this is a pretty clear case of a limited prototype, and if you can show that your steam lines perform in a similar or at least less resonance phenomenon than your prototype, yeah we're calling this a limited prototype.

CHAIRMAN SKILLMAN: But I won't know that until I operate the plant.

DR. HAMBRIC: For, for, for, this is for EPU. Yes, you would have to do an EPU. You know, if it was an EPU, you'd be operating the plant. You could put those steam lines in as they were operating and show that it's very quiet, because you can see that now with Quad Cities and Dresden.

Whereas before you saw these significant peaks in terms on their main steam lines, and after they put in their acoustic side branches, they were like flat. There was like nothing going on. So you can see it and that sort of thing. So you may be able to from the plant operating, if it's an operating plant, that it's that way.

Now for -- now what we've done with the ESBWR design certification, there's an ITAAC that says that once you build the plant and you -- they're going to do a Struhold (phonetic) analysis to show that, and they're going to build it the very best possible way to show that there's no sheer issues going on with these -- with the main steam lines, right, and they have ITAAC to demonstrate that once they start the plant up and start running steam through, that they would demonstrate that they have -- that the phenomenon is -- there is no acoustic resonance that's occurring in those steam lines.

So they could do it that way, and then if they show that there isn't any, the next plant, like first would be Fermi and then the next one would be another plant, they could say yes, we've done the exact same thing as we did with Fermi 3, and we're going to build it the same way and we're going to do the same analysis the same way, and we think that would be a non-prototype.

So I think at that point we would say yeah, we probably can go along with that, right. But right now with the current fleet of U.S. operating plants, they always seem to have some, at least some differences in terms of how the plants were constructed, because it's a long period of time and there are so many different things that can happen over that time.

But that's -- it would be a discussion. They would come in and say this is what we think, and this is typically what happens with EPUs right now. They come in and they say this is what we think, and when we think about it, we gave them some questions and such and they go back and think about it.

And sometimes they come in right off the batt and they'll say we're going to do this, because we just think that's a more conservative, safe way to go and, you know, that's -- it's usually a discussion we have back and forth with them, to come with some agreement as to what's the best most efficient and effective way to try to accommodate the guidance in the Reg Guide.

MEMBER CORRADINI: So might I ask a little bit different question, but if you need to go on, you can hold me on. Where you may get a point of telling us that this is not just for dryers, and you try to be general, but all your examples come back to dryers.

So then from a technical standpoint, is it essentially just the combination of the pressure and the high velocities that drive me to that, combined with essentially the dryers in terms of robustness, in terms of rigidity of the structure?

They tend to be on the outlying region and there's other pieces of internals that we would worry about or could worry about, but they just don't see the forced velocities, the inertial effects and are much more robust in size. You keep on coming back to these examples, and they all tend to be the same structures. So what is it? Is it strictly that, those characteristics?

DR. HAMBRIC: We had other examples, but getting back to your comment, this was an internals thing. So SONGS is a prime example, right. Something bad happened there, there was a surprise in flow-induced vibration, fatigue, rubbing. We left it out. I think we're thinking about maybe putting it in a different reg guide or other guidance somewhere down the line.

But there were a lot of lessons learned that maybe indirectly made it into here because of that experience. We don't call it out, because of SONGS we did this. But we thought about it. I guess another area we thought about but didn't include a specific example is the drawback on the 362, and that's the LOCA issue and what happens if you have a jet coming out of a break that's impinging on nearby structure.

You've get a lock in there too sometimes. So some of the CFD stuff and forcing function stuff that run up in here, that came from lessons learned about that. So the industry came up with some clever ways to do a conservative assessment. It wasn't right, but it was conservative, and we sort of thought about how to put that in --

MEMBER CORRADINI: And this was -- I remember that we talked about this, but was it within the context of ESBWR, if memory serves me?

DR. HAMBRIC: We had ESBWR. That gave us some guidance. We also had the ABWR I believe from AREVA, the EPR, and everybody had sort of different ways of going about it. But it was a lock-in issue. Different one, but I think some of the thoughts that went into the forcing function part were at least somewhat inspired by that.

But we didn't want to call that out as the example. So the example that we could call out was, you know, the dryer experience.

MEMBER CORRADINI: Okay, thank you.

DR. HAMBRIC: And if we had one, we certainly put them in.

MEMBER CORRADINI: So again, if you're coming to it you hold me off. I'm still back with the long control rod drives in an SMR, and I'm guessing that high density, much lower velocity. So the mass flux is lower, but maybe it's just the length and the robustness of the structures that are leading you to cough that out?

DR. HAMBRIC: Right. It's never been done before. I don't know how much detail I can get into here without getting proprietary.

MEMBER CORRADINI: That's fine.

DR. HAMBRIC: But you've got long beams with moving masses on them, varying boundary conditions, resonances changing depending on their heights, flows that are coming from Lord knows where. It hasn't been evaluated, and we certainly haven't done the calculations ourselves. But until we see them, it's a concern. We just raise it as a potential issue, that's all.

MEMBER CORRADINI: Okay.

DR. HAMBRIC: And it could be when an application comes in they say hey, the flow rates are like .01 meters per second. We don't care. Okay, fine. But until we see that, we don't know.

CHAIRMAN SKILLMAN: Since we raised the question or raised the issue at least in my mind, for the SONGS steam generator, would the replacement generators have been a prototype or a limited prototype or a non-prototype? Just entertain the thought for a minute, think about it, based on these definitions.

MEMBER RICCARDELLA: And plus there were

two of them, and they behaved extremely different because of some very, very minor manufacturing differences, as I understand it. So you know, would one of them be a prototype and one of them a non-prototype? That's the thing.

(Simultaneous speaking.)

MEMBER RICCARDELLA: It seems -- that's the thing. If we can tie that down, I think we've got a language we can agree on, as crazy as that seems. I'm back to words matter. They really do in a fundamental document like this, I kind of think in my mind.

Okay, we're going to have an RCOL (phonetic) reference plant and then we're going to have some SCOLs, and if all the SCOLs are absolutely 100 percent identical down to the millimeter, we're going to call those limited prototypes?

Are they going to be knockoffs of FO8K and if the FO8K one well, they're going to be valid prototypes that don't need anything? It seems to me that that's what needs to be addressed in these terms. Does that make sense?

DR. HAMBRIC: Yes. We're definitely going to go back and look at that, and try to make it more clear.

MEMBER RICCARDELLA: But these requirements don't apply to steam generators right, and if there were, I mean if there were such requirements, hopefully might have been avoided. They've had some instrumentation in there and it affected the excessive vibration shortly.

DR. HAMBRIC: Right.

MEMBER RICCARDELLA: I'm not suggesting it should be, but I just --

(Off mic comments.)

CHAIRMAN SKILLMAN: Let me make an admin comment here just for a second. Dr. Hambric, I understand you need to exit at 1500 or 3:00 p.m.

DR. HAMBRIC: I can squeeze it to 3:15, but yeah.

CHAIRMAN SKILLMAN: Okay. I just wanted my colleagues to know that you do have a time clock, and if we want to entertain these questions about CSD or vibration or FIV or MIV, we should get those on the table before your exit time.

DR. HAMBRIC: Yeah. I've been keeping pretty good notes here, so that we can come back to a lot of the questions --

CHAIRMAN SKILLMAN: Thank you. Okay, let's continue.

MALE SPEAKER: And we want to make sure that we answer the question on Peach Bottom. If you could answer that before you have to leave. Okay. Great, thank you.

DR. HAMBRIC: We'll get to them as we go through some of these. So I'm not going to read all these, but the next big block of slides is a specific lessons learned, and what we're giving you are the highlights. There are more, but these are the ones we thought were the most important, and they address a lot of the topics we've been talking about.

So I'm just going to go to the next slide. Let me -- before I go through this one, introduce the theme we use for each of these lessons learned slides. So up at the top in blue we've got a topic. So this first one is on excitation mechanisms, and then each of the bullets on the top are the lessons that we learned or the observations that we have made, right.

So we've got three of them there, and then the arrows down below are the actions that we took, right, the modifications we made to the Reg Guide to address our lessons or observations made. So that's the procedure, if that makes sense. We have to go through a couple of them and that will become clear.

But first is just the important excitation mechanisms to consider, and in the old Reg Guide it was all FIV and it was I think okay writing, but it wasn't terribly well defined. So we wanted to address that. We also had a lot more operational experience with the resonances that we've observed on main steam line valves and elsewhere.

And the Susquehanna experience, that hey, there was an RRP, reactor recirculation pump, vein pass-through frequency, excitation, that may have contributed to some fatigue cracking. So each of the areas down below are the actions we took. So we started off by introducing the mechanisms more than a FIV.

We added acoustic resonances, AIV, MIV. We specifically called out to the flow excitation the oscillation modes, the sheer layer. Samir Ziada's on the line. He's our expert there. We also pointed out that you get to resonances in MISVs, which haven't -- had not been considered previously.

The last was just an example. It wasn't meant to be, you know, something you always have to look for. But one of the big problems that the steam dryer community has had in properly capturing the low frequency vibration and stresses in the skirt. We kind of looked at the ways they were modeling the excitation and one important one left out is when you take skirt, you dunk it in a big bucket of boiling water.

None of that's considered in the forcing functions, and I don't know how you consider it. But it has to be addressed somehow, and the way we address it is via this end-to-end benchmarking approach that I'll talk about later on. So that's just the example. It wasn't meant to be a forcing function. You always had to look forward, just an example of how we were confronted with a new internal or a dramatically modified internal.

We had to think outside the box and think about all the possible functions that might influence you. So any questions on that first slide or how we're doing it?

So now we've got three slides on structural modeling lessons learned, and the first one is just looking at modes of vibration, and this lesson is not a surprise. Anybody that's ever worked in structural modes and comparing measured mode shapes to modeled or analytic mode shapes knows that there are always differences.

The frequencies are different between a

measurement and a model. The shapes themselves can be a little bit different between the measurement and the model. That's just reality. Those differences really have to be used to establish an uncertainty in how you model resonance frequencies.

You build a model and you get a frequency. So you have to realize that that's got a plus or minus. So the action that we're taking there, and we've been doing this for over ten years now, is that any forcing function that's applied to an internal, to account for the fact that a modeled set of resonances has uncertainty in it, the forcing function has to be either compressed.

So if you think about a time series, you've got to make it shorter so the frequencies move it, or stretch it so that all the frequencies move down, and have several increments of stretching and compressing so that you're applying those forcing functions to your analytic or numerical model.

By stretching and compressing, you're making sure that you're coming up with worse case comminations of forcing functions and resonance response. So you're sort of aligning your peak forcing functions with your peak responses, and pulling out the worse case response as a conservative estimate.

We just threw in there plus or minus ten percent. It has been acceptable in past applications, but that is not a specific acceptance criterion. It is hey, this is what's worked in the past. You guys need to tell us that yes, plus or minus ten percent is okay for your application.

It may be that plus or minus 15 percent is required, depending on their particular structure. The second action we took is addressing essentially Peach Bottom, and that's force inference procedures. So I can try to speak to Peach Bottom without going proprietary but --

MEMBER CORRADINI: This is microphone analogy, if I remember. I don't want to say too much, but I'll probably get it wrong, so it can't be proprietary. But I seem to remember this is the approach that you explained to us when we were doing this comparison, in terms of the methodology. Am I --

DR. HAMBRIC: Let me talk it through, and we'll see if that matches up or not. So (name) is in the back, and he'll raise his hand if I'm getting proprietary and stop me. But he was the lead on -- or is still the lead on Peach Bottom, although I think we've tied it off.

In spite of all best intentions, analyses, measurements, when they turned Peach Bottom on with the replacement drive and all this nice instrumentation and measured the strains, they discovered that the strains were above the acceptance criteria.

After a lot of soul-searching and head scratching, they came back to us and said you know, we're not sure why. We think our methodology is overly conservative. We do not believe this tank of a drive we just built and installed is really going to fatigue fail. Let's suggest a different approach to it.

The approach was let's use all of our strain measurements on the dryer. These are measured strengths now, and combine them with numerically computed mode shapes for the model.

MEMBER BLEY: I'm sorry. Numerically computed what?

DR. HAMBRIC: Mode shapes.

MEMBER BLEY: Mode shapes.

DR. HAMBRIC: Right. So we've got a model. We've extracted the mode shapes. We know how this structure is vibrating. We know where all the peak strains are, we know where all the peak stresses are. But mode shape is just a mode shape. There's no amplitude associated with it. It's arbitrary. It's just here's how it vibrates.

Where do we use these strain measurements, and there's a lot of them? Attach them to the mode shape and then use those to tell us how strongly that mode is vibrating, and look at the peak stress locations and see if we're under or above the acceptance limit.

So they're inferring the stresses based on measured strains and a numerical model of the mode shapes, and that's fine, as long as you prove to us the model converged and the stresses are converged and all that good stuff. But where we went back and forth originally is they did not take into account the fact that the numerical model had uncertainty in where the resonance frequencies were.

There may be a strain at one resonance frequency in the real dryer, and a strain to a simulated resonance in a model dryer. But there's no guarantee that the frequencies are right. Does that make sense?

MEMBER BLEY: No. Say it again please?

DR. HAMBRIC: So I've got this bottle.

It has a resonance at 63 hertz. I go off and have somebody build a model of that bottle. They come back with that same resonance at 78 hertz, okay. I take a measured strain at 63 hertz and try to apply it to the response of the model alt 63 hertz and it's wrong, because it really should be at 78.

They have to account for that uncertainty. That's all that's saying. So we put that in a reg guide. You have to account for that in an inference procedure.

MEMBER REMPE: This is all Peach Bottom 2, and now where are they with respect to Peach Bottom 3 that only has instrumentation on the steam lines, because it was believed to be a limited prototype, and I again, when we recruit the EPU, it was all in the future. So I'm curious on what's happening? Have they started that, the EPU at Peach Bottom?

DR. HAMBRIC: Oh yeah. That's all been done. So what they had to do is they were going to instrument Peach Bottom, the second one. I always get them mixed up, which one came first. They were going to instrument the second one. It was too late.

MEMBER REMPE: It was 3.

DR. HAMBRIC: Three. It was already in there. So what we had to do was make a link between the measurements that we're going to make, which was the main steam line measurements, which is pretty typical, and what happened on the dryer in Unit 2, the first dryer.

So we had to go through a lot of statistical correlation studies, looking at sensors in the dryer versus what happened in the main steam lines and the first instrumented prototype, and then come up with a correlation analysis that we thought was conservative, that we could then apply to the limited prototype case.

MEMBER REMPE: And how is that going with the data?

DR. HAMBRIC: It worked. It was fine.

MEMBER REMPE: Okay.

DR. HAMBRIC: The other benefit we got out of that is that we could throw away a lot of the scale model testing and CFD and other procedures they use to estimate the SRV resonance amplitude because we had them measured in the prototype plant, and we could sort of track them in the second plant and show that yes indeed, they were following the same arc.

There wasn't a big surprise, no big amplification. Everything was okay. So because they're able to make that link between the measurements that we're going to make and the prototype measurements, we were allowed to -- we felt we were reasonably assured we could proceed with the limited prototype assessment on the second drive.

MEMBER BLEY: Let me sneak a question in. You said we could throw away the CFD and some other things.

DR. HAMBRIC: Yeah, because we had in-plant measurements at that point.

MEMBER BLEY: But did they -- had they actually done the CFD? When you say "throw away" --

DR. HAMBRIC: It was a very limited CFD just to -- and then I only get proprietary --

MEMBER BLEY: I was kind of hoping there was more ---

(Simultaneous speaking.)

MEMBER BLEY: --as to how it matched up.

DR. HAMBRIC: No. Most of what they used to estimate the SRV amplitudes was scale model testing, which is another big topic that we'll get to.

MEMBER BLEY: Okay yeah, thank you.

DR. HAMBRIC: CFD was more about what are the flow rates, what are the Struhold numbers, just basic screening stuff. But it was not rigorous by any means. Don't know if I fully answered your question or addressed your concern.

MEMBER REMPE: Maybe I missed it, because this is not my area. But when I was reading through the Reg Guide, I would not have gotten that there's a way around if you go the limited prototype methodology and things just didn't work out the way you planned, and there seems to be another path through it all is what I'm getting from this discussion.

I didn't get that from reading the Reg Guide, and I mean it's much easier in life than saying well, you've got to put some more sensors on, as I heard at the beginning of the discussion today. I'm just wondering did I miss it and it's really in this Reg Guide, or is there some additional --

And I know you're talking about proprietary stuff. But are there some additional clues you can give people in the future?

DR. HAMBRIC: We could. We added some vague discussion.

MEMBER REMPE: And it was vague enough I missed it, okay.

DR. HAMBRIC: But we didn't want to get too detailed about this particular application either. But we could go back and think about maybe beefing that up a little bit, trying to make a general guess.

MEMBER BLEY: I think that's fine. I've been interested in this. I'm learning a lot listening to you today for me too. It's not my area, although the analog over in electrical was once my area. But that's been a long time ago.

I know we've written letters that touched on many of the things that are in here in the past, and I was kind of hoping when this was done, one of the reasons I wanted us to review it is so we could make sure things were in here that we might ask about, that it's covered in the Reg Guide.

And as I read it, being a bit of a neophyte to the words, it seemed like it gave general coverage to everything that might be important, but it was pretty darn general. My question is, as a Reg Guide, is it too general? Now this is what you were just talking about.

Is it too general for an applicant, and for a reviewer, I think it's got the things a reviewer could start digging in and say did you do this? Did they face this enough.

But it's also a reg guide that the

applicants and licensees would use, and is it thorough enough to make sure they think of all the things they should be thinking about? I don't know the answer to that. I'm just wondering.

DR. HAMBRIC: Well, we tried but I'm sure we missed some things. But I can appreciate some generic guidance on, you know, a lessons learned for how we handled the Peach Bottom situation when despite best intentions, instrumentation didn't work out. It was too late to add more instrumentation. How did we make it work out anyway, in a fashion that gave us reasonable assurance that things were okay?

CHAIRMAN SKILLMAN: Steve, before you go on, let's go back to 16 just for a second. When I envision these gauges that are on the dryer, I see these small devices that are fixed, and in a past life I lived we had a very difficult time assuring that the strain gauge remained fixed and the effect that we were sensing on the strain gauge was truly the effect of the device that we were monitoring versus the effect of the physical phenomena, temperature, pressure, evaporation rate on the strain gauge itself.

So here is a particularly complicated welded structure that is seeing wetting and mount wetting and other oscillating modes, whether they are acoustic, whether they are mechanical, whether they are thermohydraulic. How does one discern the difference between the effect on the strain gauge and the effect upon the component to which the strain gauge is affixed?

DR. HAMBRIC: All right. So we have in the measurement section some discussion on strain gauges. It would not completely answer your question, but it might be a good point to poke it out a little bit further.

CHAIRMAN SKILLMAN: Okay.

DR. HAMBRIC: We can wait until we get to that.

CHAIRMAN SKILLMAN: I'll wait. Yes, I'll wait. Thank you.

DR. HAMBRIC: All right.

MR. HAMBRIC: So, this is Slide 2 out of 3 for structural modeling. The last one was modes, this one is damping. This has a lot of history to it, but a lot of applicants still use a time-domain analysis approach, instead of a frequency-domain approach. And, historically, that means something called Rayleigh damping. And for those of you who are not familiar with that, you pick a low frequency anchor point, a high frequency anchor point, and you set the damping at those frequencies.

The issue is what happens away from those frequencies. And what you get is almost like a parabola, not quite. But at the anchor frequencies, the damping is exactly what you specify. In between, it's lower, and that's conservative, it means more vibration response predicted, higher strains and stresses, so that's fine. But outside those anchor frequencies, the damping is too high and is not conservative. So, we have seen applicants set their anchor frequencies and have a really strong excitation below that anchor frequency, meaning that they've got a structural response that's non-conservatively too damped. Or the opposite, they've got a forcing function that's above the high frequency anchor point, meaning they're applying a load to the structure and they're putting too much damping on the structure.

So, we've spelled it out, hey guys, when you've got forcing functions, you need to look at those forcing functions and make sure your anchor frequencies bracket them. I think that's pretty obvious. We also are always getting push-back from industry, we've put in the guidances that one percent damping has been acceptable in the past. And that one percent encompasses pretty much everything, it's the structural damping, it's the damping you get when you mount a structure in a system and you've got interface damping, it's the fact that you're in a steam environment with radiation damping. It's meant to cover the as-installed damping conditions. We said one percent is a conservative number you can use.

Some applications have said, hey, we know in this particular structure, in this case a steam dryer, we have other components inside the dryer that have higher damping, and the one in particular is a perforated plate that the steam goes through. And as the plate vibrates and the steam pushes back and forth through the holes, you get viscous effects, that's higher damping. And they said, hey, let us claim an extra damping for that. We put that as an example in the Reg Guide that that's fine if you substantiate and validate it, and previous applicants have done that.

MEMBER RICCARDELLA: By test or by analysis?

MR. HAMBRIC: Both.

MEMBER RICCARDELLA: By test?

MR. HAMBRIC: They've done a simple test with a perforated plate, pushed it through air, measured the damping. Done an analytical study to show that they can calculate it. Made sure --

MEMBER RICCARDELLA: Okay.

MR. HAMBRIC: -- that the analytical study was conservative and applied a conservative added damping level to their structure. So that's kind of a success story that we put in there. Next. And final --

MEMBER RICCARDELLA: And percent, that's percent of critical damping, right?

MR. HAMBRIC: Yes, or -- yes. They always have to report it as percent as critical, but they can compute is as viscous or hysteretic, but it has to be converted back over to percent critical.

MEMBER RICCARDELLA: Okay.

MR. HAMBRIC: Okay. A couple of other things we've noticed is that some of the early applications we got were not terribly well documented, particularly regarding benchmarking, and that's very important. And also, we've had applicants come back to us after the fact, during power ascension, for example, and said, you know, we've designed this dryer and here's how we analyzed it and then when it was built, these wells were different and this structure was different and we replaced that and made it all better, so they say, but it was different. And so, we learned that sometimes there are differences between as-designed and as-built conditions. And so, the action is that we need a very formal, rigorous documentation of procedures and any differences between as-built versus as-designed structures.

This is a single slide on acoustic modeling. The acoustic models are typically built to propagate forcing functions from steam line valves, for instance, or to propagate forcing functions that come from flow within the RPV itself. If you think about what's happening to the flow in there, it's very messy, there's steam kind of being dumped out and reformulating and sucked into a nozzle, lots of pressure gradients, turbulence, pulsations that excite the acoustics inside the entire RPV.

And we noticed in a lot of those applications, the properties that got dumped into those models were questionable, to say the least. They have to put in a sound speed, a damping, a mass density, two phase flow sometimes. We've also looked at the acoustic models that were put together of the

RPVs in particular and you get to regions where they wouldn't have a whole lot of elements, so you're trying to model a wave that looks like that and it might have two elements over that distribution, that's inappropriate. Also, the flow gets sucked into nozzles eventually and we looked at some of those models and they were sort of pretty course and discretized and instead of a pure circle, you've got sort of an octagon or something like that, and the area was wrong and things like that.

So, we put in the guidelines, hey, your properties have to make sense. So you can adjust them a little bit for benchmarking, but they can't deviate excessively from reality. Just try to get a better answer. Any acoustic model has to have at least six elements per acoustic wavelength, that's well established in my field, so that's now in the Reg Guide. And any time you have circular nozzle areas, you have to make sure the area is correct, either by adjusting it or whatever you want to do, you have to make sure that the area is represented properly.

MEMBER SKILLMAN: Is this is the physical area? Or the adjusted area based on some correlation factor?

MR. HAMBRIC: No, no, it's the physical area. So, if you discretize something, you try to discretize a circle, you'll never get it right, it's always a little bit less than what it should be. So you just have to account for that and correct for it in their analysis so we have the correct area in there.

MEMBER SKILLMAN: Thank you.

MR. HAMBRIC: Next three blocks or slides are on forcing functions. And just to reiterate, we did the best we could to capture as many forcing functions as we could, but I think we tried to point out in the Reg Guide that any new design internal, external system, you have to consider what other forcing functions might be there and try to account for them. But hopefully we have enough examples in there to capture the flavor of what needs to be looked for so it's pretty rigorous. So, these are kind of broken into little pieces. So the dash is the lesson/observation, the arrow is the corrective action we took to modify the Reg Guide.

So the first is regarding pumps, there's more than one pump and in some cases, there are a whole bunch of pumps, and that can lead to pretty different flow distributions inside the Reactor

Pressure Vessel. And, obviously, you can't, I don't think you can analyze every possible pump operating condition. So we say, the guidance is, use the flow distribution that gives you the highest possible local flow velocity, and that presumably gives you the worst case possible forcing functions.

MEMBER SKILLMAN: Steve, let me ask this question. We have a design that we're now reviewing that has four reactor coolant pumps, it does not have isolation valves. So, like these big four loop machines, you can have one pump running forward, two running forward, three running forward, four running forward. With one running forward, you've got backwards in three. If you've got two running forward, you've got a heck of a lot of flow running backwards in those other two loops. Is it the vision of this Reg Guide to address that?

MR. HAMBRIC: We tried, yes. We talk about multiple pumps and not only flow issues, but mechanical issues, what happens when you got all --

MEMBER SKILLMAN: I didn't see reverse flow, every once in a while when I raise that --

MR. HAMBRIC: Oh, we didn't talk about that.

MEMBER SKILLMAN: Okay. Bingo. I will be

a witness of one that you get a big four loop plant and you run one reactor coolant pump at its highest density, at the coolant's highest density, you've got reactor coolant pump issues, motor current issues, and backward flow issues that really need to be addressed.

MR. HAMBRIC: So, in this Reg Guide, we could address that for what's happening inside the reactor, but --

MEMBER SKILLMAN: That's what I said.

MR. HAMBRIC: -- pumps are --

MEMBER SKILLMAN: This is -- it doesn't say -- the way you're addressing the replacement steam dryers, you are viewing them as they are affected by, clearly, the bells, lights, and whistles downstream. The location of your relief valves, the size of the stacks, the size of the standoffs, all of which are important. How about the Ps and their permutations and combinations?

MR. HAMBRIC: Right. This isn't necessarily aimed at steam dryers. This is recognizing that there are multiple pumps --

MEMBER SKILLMAN: Okay.

MR. HAMBRIC: -- and you're going to have multiple different potential flow conditions inside your reactor and then they take the most conservative one.

MEMBER SKILLMAN: I'm raising the issue of reverse flow.

MR. HAMBRIC: Right.

MEMBER SKILLMAN: I'm also raising the issue that I raised before, and that is, consideration for a broader description of what this Reg Guide is intended to address.

MR. HAMBRIC: Right.

MEMBER SKILLMAN: Okay.

MR. HAMBRIC: Good.

MEMBER SKILLMAN: Thank you.

MR. HAMBRIC: Yes, got that marked down.

MEMBER SKILLMAN: Reverse flow, I want that etched on your --

MR. HAMBRIC: We have that written down.

MEMBER SKILLMAN: -- pad here.

MR. HAMBRIC: That's a good point.

MEMBER SKILLMAN: Okay. Thank you.

MR. HAMBRIC: But the intent was, have the applicant come up with the most conservative combination of flows so that you had the highest possible local flow velocity.

MEMBER SKILLMAN: Well, I will tell you,

if you got one on a big P with four loops, four reactor coolant pumps, you run the one --

MR. HAMBRIC: Right.

MEMBER SKILLMAN: -- you've got some flow issues that probably haven't been looked at real closely unless the designers have been thinking of the run-out and the effect of that run-out on what's flowing forward and what's flowing backwards.

MR. HAMBRIC: Right. So, for our efforts, can we get the name of the application you're looking at? Is that all right or not?

MEMBER SKILLMAN: Later.

MR. HAMBRIC: Later, okay. All right. So, the next one -- oh, lord. We've got to do two more bullets, sorry. So, not only do we need to look at the local flow velocities, but the response also depends on the phase distribution. So if you look at forcing functions coming from different locations, they're coming in at different times, so there's different phase distributions. The forces, in some cases, are turbulent, and that means they have random correlation over space. So the effect of correlation lengths matter.

And we're not asking an applicant to run all possible conditions, that's unreasonable. So instead, we're asking them to consider conservative simplifications, perhaps all in phase, all out of phase, perhaps maximum correlation lengths, just to make sure the forcing functions are bounding. That's really what we're after, is worst case response. And then the final bullet down below, there's been a lot of work over the years trying to assess the forcing function amplitudes of SRV resonances. We'll get to some of that in the scale model testing discussion coming up, but we've had applicants measure data and then try to extrapolate what they think the forcing function is going to be at a higher power, such as EPU, using inappropriately averaged data.

So, we've instead nailed them down and said, if you have a total excitation and you're measuring how that progresses over power flow, you've got to look at just that tone and how it changes over time instead of averaging over a really wide frequency band which can kind of mask that tone a little bit. So, Slide 2 out of 3 on our forcing functions. This get back to the importance of small geometry changes can have big impacts on forcing functions, unfortunately, in plants like these. And we just throw out a few examples.

For example, you have the flow coming

over a standpipe opening, how sharp that corner is matters. Almost every plant now has sort of a smoothed corner to make sure that the strength of the resonance is mitigated. Just the physical dimensions, the length of an SRV, the diameter, all that matters, it changes the frequency where you get the peak. Clearances, structural supports, that can matter. The RPM of the reactor recirculation pump, if that aligns with the resonance or doesn't has a huge impact on the net response. So, we tried to give some guidance in the Reg Guide to address all that.

The first is looking at the different ways of assessing the forcing functions, either with CFD or scale model testing. And it may be obvious, but we've had applicants come with some pretty interesting proposals, but they've got to be accurate replicas, they've got to get the geometry right. Even if a smaller scale, it might be hard, but you have to get all those geometry details correct. If there are changes, this gets back to the limited prototype/non-prototype issue, the effects of the changes have to be addressed, both individually and cumulatively. So you can refer back to a previous successful design, but any deviation, you have to stack up those deltas and then tell us what they mean according to the forcing function.

A lot of times, we get one component that they consider a prototype that was big and then they wanted to scale it down into a smaller plant. That's okay to do, but you have to analyze the effects of those differences. And then finally, we've seen a lot of different reactor recirculation pumps in these different plants, they all have different drive frequencies, some are variable frequency drives, some are constant frequency drives. That has to be assessed, we have to look at what that means to the response of the internal. And numerical simulation.

So I think we're finally to the CFD and we can maybe answer that question you had earlier. Mostly where we see CFD being used is just to estimate flow velocities. And they'll take those velocities, hopefully worst case velocities, and go off to other empirical methods to estimate the forcing function amplitudes. We realize that computers are always getting better, tools are getting better, at some point, somebody is going to try to use CFD to assess the forcing function amplitude. So we realize that and we added some guidance to what to look for if that does happen.

But one of the big issues that comes in with that is the bounding conditions. It's often more straightforward to model an actual flow regime or structure than it is to model its boundaries. For a structure, for example, you say it's welded on to another structure, well, where did you weld it and how strong was the weld and what's the effect of stiffness and is there a joint effect there? If you've got a flow regime, you think you know what the inflow is, you think you know what the discharge flow is, but you have to model the pressure and the velocity and the density, there are differences.

There are always differences. Sometimes they're variable, right? The plant operating condition changes a little bit as you go from the beginning of the fuel cycle to the end of the fuel cycle. The flow speeds up so they can get more power out of it. That changes things. So, the message is, always conservative. What can you do to come up with a bounding response? So, for the CFD, we need to have the codes that are used validated, but they have to be validated on plant components that are similar to the components that are being designed. And that means the proper geometrical complexity, proper flow regime. So we need representative benchmarking before a simulation tool can be somewhat trusted.

And then, the boundary conditions have to be feasible and we have to look for conditions that give us a bounding response. This gets back to a little bit of the issue of CLDMs that might be inside containment. We've got these boundaries on the top and the bottom, it's moving up and down, what do you do? You can't model all of them, but try to look at the box that you're in and come up with the worst case boundary conditions for your assessment. So that's not necessarily a forcing function question, but it sort of got to be part of this and so, I figured I would point it out.

So, the question about when do we stop believing CFD and switch to SMT or other tests? That's a tough one. I think all we can do is review on a case-by-case basis -- I'm sorry, we're still back on the previous slide -- and look at the quality of the benchmarking, how good a job did they do with benchmarking a representative case? How rigorous were they with their conversion studies? How conservative are they? The latter is probably the most important, how conservative are they? Can they prove that they really chose conservative boundary conditions, conservative flow regimes, conservative

Reynolds numbers, and that they're guaranteed to be applying a higher forcing function than what they're going to get in reality? If they can't prove that to us, then our belief drops and we start thinking, well, maybe we need some extra testing there to back you up, maybe supplement part of the CFD simulation.

MEMBER CORRADINI: Are the CFD -- this is a little bit off topic, so the Chairman will stop me. Are the CFD simulations all single phase?

MR. HAMBRIC: We didn't go that far.

MEMBER CORRADINI: But, my point is, when I do the CFD simulations, you've only -- when you look at them, those that are presented to you are mainly single phase simulations?

MR. HAMBRIC: So far, yes.

MEMBER CORRADINI: Okay.

MR. HAMBRIC: All right.

MEMBER CORRADINI: Okay, fine. Thank you.

MR. HAMBRIC: Okay. So, scale model testing. These are used more often than the CFD simulations. And we've broken this down into several little pieces. The first is dynamic similitude. We need to ensure that the SMTs have dynamic similitude. What does that mean? That means the mach number has to be right, so the flow rate divided by the speed of sound. In a reactor, we have steam, we have water, sometimes the scale model testing using air are different, so you have to properly account for the mach number there. And then something called a fluid--elastic parameter, that's sort of the combination of the damping in the working fluid and the mass density in the working fluid.

So that has to be comparable, particularly in a scale model test, to what they're going to get in the real reactor. Or if not comparable, conservative. And that's what that second sub-bullet down there, only conservative distortions are acceptable. So you can use air, you can use other mach numbers, but you have to prove to us that you've done a conservative assessment, you're going to get a stronger forcing function than we would expect to see in reality. Second bullet is the effective Reynolds number. All scale model testing is invariably smaller, nobody ever builds a bigger scale model test. And those Reynolds numbers can be lower --

MEMBER BLEY: You're in an area I don't know real well with mechanical systems. When you do scaling, there must be things that affect resonant frequency and I'm not sure you can always define what's conservative if that sort of thing is happening. Can you talk at all about that?

MR. HAMBRIC: Right. That's sort of rolled into the mach number, the speed of sound you're assuming.

MEMBER BLEY: That kind of covers it?

MR. HAMBRIC: It partially does, but you have to look at your dimensions too.

MEMBER BLEY: Yes.

MR. HAMBRIC: So, you're trying to come up with a test that, at a given flow rate, has the right coupling to the acoustic response, which is similar to what you'd expect in a full scale plant.

MEMBER BLEY: But that's easy to say --

MR. HAMBRIC: It's easy to say --

MEMBER BLEY: -- but proving it is --

MR. HAMBRIC: -- and difficult to do.

MEMBER BLEY: Yes.

MR. HAMBRIC: That's right. That's absolutely right.

MEMBER BLEY: That's kind of tough.

MEMBER CORRADINI: But I guess, to Dennis's point, you're looking though to, I keep on coming back to what you said, you're looking to bound it. So if somebody is going to do a scale test, maybe two scale tests and then extrapolate from that, they might want to over, I don't want to say overdo, but go to an extreme relative to the fluid velocity so that I would excite the system more than I would expect it --

MR. HAMBRIC: Right. That's actually one of the ones, I think, in a future bullet.

MEMBER CORRADINI: Okay.

MEMBER BLEY: Okay.

MR. HAMBRIC: Yes. So there's a lot of steps you have to go through to prove that a scale model test and that your working fluid --

MEMBER BLEY: I guess, this is one place where like a page and a half in the Reg Guide seemed not to hint at the depth of what they have to do.

(Laughter.)

MR. HAMBRIC: Right. Yes. Samir is the expert on this, he's written long, long articles, we even cite a couple of them, I think, in the references, for further guidance, see these articles.

MEMBER BLEY: Well, we don't cite much in the way of references. I mean, there's only a handful of references in the whole thing.

MR. HAMBRIC: Right.

MEMBER BLEY: So there's -- mostly one

would have to, well, one hopes you know what you're doing if you're going to use this anyway, but you'd have to have a pretty thorough background in --

MR. HAMBRIC: Correct.

MEMBER BLEY: -- the literature to be able to pull this off.

MR. HAMBRIC: Yes. This is not a textbook, it's a Reg Guide. So, again, the Reynolds numbers, we know they're smaller. And this gets to a little bit of one of the comments you guys made, a good way to demonstrate that the results are not influenced by further increase in Reynolds numbers is to run a little bit faster and then see. A typical way a Reynolds number affects work is, you get a forcing function, as Reynolds number goes up, eventually you sort of hit an knee in the curve and converge. So, I want to make sure that you've shown that you're kind of beyond that knee in the curve and you've converged. Next.

The scale model tests that we typically see are transient. So, what they've done is they'll take a pressure vessel, attach a bunch of pipes to it, put models of the standpipes and the pipe, and in the very ends of the pipes, they'll put a bunch of valves. And they'll pump holding up as high as the pressure rating will let it go and then get their instrumentation ready, turn on the acquisition system, and open up the valves and then do a blow-down. And the hope is they have enough capacity so that this blow-down is fairly steady state for a while and then starts dying off, the pressure starts rolling off to the point where the velocities go down and it's no longer relevant. So, that's the reality.

There's actually a transient test condition, the pressure is going down as we proceed, the temperature is going down, the velocity is slowing down. But, the issue is, these sorts of forcing functions depend significantly on those kinds of variations. The resonance peaks, I can do a little peak with my hand here, as you slow down, it's going to start getting wider and smaller. And you want to make sure that you're capturing the worst case forcing functions. So one of the things we added to the Reg Guide is, you've got to run multiple runs at the same test conditions so that we can establish the uncertainties, because it is a transient test, and the sampling over which they're doing the calculations, one second, two seconds, five seconds, ten seconds, we need to make sure that those give us bounding estimates of the forcing functions, realizing that you do have a transient test.

The parameter that typically comes out of these sorts of tests is called a bump-up factor. And this comes out of an EPU application. So they'll have operating plant data at a current power level, they want to go to some higher power level. They're not allowed to go to that higher power level to see how much stronger the forcing function is going to be, that's the whole point of the review process, to make sure it's okay to go to that power. So instead of doing it in the plant, they'll do it in a scale model test. They'll run a current power condition, go to what they tell us is a conservative EPU power condition, measure what happens to the forcing function, take the ratio and call it a bump-up factor. Somebody coined it that years ago and it sort of stuck, and sort we've sort of maintained it. So, it's the ratio of the loading at higher power level divided by the loading at a lower power level.

What they'll do is they'll take the forcing function in the actual plant at current power, multiply it by the bump-up factor, and say, here's what we expect it to be at EPU. And we hope that estimate is conservative. We have found that those bump-up factors depend on frequency, if you have a valve that's singing at 110 hertz, you've got a different bump-up factor than a different valve singing at 160 hertz. It's just different. Take that same valve and move it ten feet further down the main steam line, different. Put it close to another valve, different. Everything depends on the actual as-installed application.

And of course, uncertainties in the transient test. If you're not quite sure exactly what your flow rate is or exactly what your Reynolds number is or exactly what your mach number is, that gives you uncertainties. So, the bottom line is, it's okay for estimating, as long as we think you're conservative, but during power ascension, when you get to the end, you've got to validate that your bump-up factor was right. And you essentially replace that bump--up factor with what happened in actual plant. Another thing we can do is, if we're uncertain about mach numbers and Reynolds numbers, is just extend the SMT to even farther beyond where you think the actual power plant condition is, so we have some margin, we're getting a true worst case.

And we have had applicants come back to us and say, well, away from this resonance, we did the ratio of EPU versus CLTP and we actually got lower forcing functions. That's a measurement error. So we established a long time ago that the absolute minimum bump-up factor that you can physically have is the square of the flow velocity ratio, that's just flow physics. So that's a bare minimum. Okay.

We talk about structural response, structural modeling, flow induced forcing functions, CFD to predict the forcing functions, scale model tests, you piece all that together and you come up with a final assessment of what we think the structure vibration is, the structure strain is, the structure stress is, and compare that against an allowable limit. We need benchmarking of that whole process. And we first started on this procedure back in the Quad Cities days.

What the applicants were doing is they would benchmark the forcing function part, they would benchmark the structural response part, they would benchmark the mapping of loads to a structural model. They'd benchmark all those pieces and then they would say, all of these components in the analysis procedure are unrelated to each other, they're not correlated, that means we can combine all the bias errors and uncertainties, using square root sum of the squares. And we accepted that for a while until we got to Susquehanna, and the end-to-end measurements of strains on an actual operating dryer were much higher than the predictions. Much higher than the predictions plus the SRSS bias correction. What's going on? Clearly some forcing functions were not accounted for or some structural response components were not properly accounted for.

And the lesson learned there was end-to-end benchmarking is the best way to go. Put either accelerometers or strain gauges, some sort of a final measurement on the reactor internal. By definition, it has to include everything, the actual structure is loaded by whatever it's loaded by, it's responding however it wants to respond. And in spite of everything you've done, if you don't properly capture that, you apply a bias correction to it based on the final measurement and you apply an uncertainty based on the statistical assessment of several measurements, and that does it, that captures any neglected issues in your procedure. So we think that's quite powerful and we highly recommend that approach be used. Okay

MEMBER SKILLMAN: But, Steve, what you are saying is, every design needs to be fully instrumented.

MR. HAMBRIC: No. No, we cover that earlier in the Reg Guide. It's only components that we are concerned about, that we think may have a flow-induced, acoustically-induced, mechanically-induced strong vibration. You don't want a margin --

MEMBER SKILLMAN: So we're back to the steam dryer at Susquehanna with some unresolved questions and your guidance is --

MR. HAMBRIC: We force them to apply a bias to it. And steam dryers have failed, that's why we're spending all that attention on it. But if you've got a component that's never failed and you can prove to us with a lot of margin for safety that there's no significant forcing functions to worry about, there's no reason to have to go off and instrument it.

MEMBER RICCARDELLA: But how would you do end-to-end on a non-prototype or limited prototype if you're not putting gauges on the one end?

MR. HAMBRIC: Again, only if we think we have reason to believe there's a strong forcing function response that gets you close to the acceptance limits.

MEMBER CORRADINI: But, maybe I misunderstood, end-to-end in your definition is not simply instrumenting the steam lines.

MR. HAMBRIC: No, that's --

MEMBER CORRADINI: That would be under the category of limited or non-prototype?

MR. HAMBRIC: Remote monitoring is what that is. But for a structure that's had all the problems the steam dryers have, we've said, hey, if you want to change the design or change the operating conditions or do something different, you need to go in there and prove to us things are okay so we don't have a Quad Cities on our hands again.

MEMBER RICCARDELLA: But then is that voiding out this concept of limited prototypes and non-prototypes for steam dryers?

MR. HAMBRIC: I don't think so.

MR. WONG: In the guidance, for limited prototype, we -- excuse me, for non-prototype, there's a statement saying for EWL steam dryer, the applicant need to provide significant justification in order to classify the steam dryer as a non-prototype. And in our EPU experience, all units need to monitor the main steam line at a minimum.

MEMBER RICCARDELLA: But that won't give you end-to-end?

MEMBER SKILLMAN: No. That's --

MR. HAMBRIC: No, but they've benchmarked their procedures on another dryer and proven that they're conservative, with bias correction.

MEMBER REMPE: Can we talk about another example, it's in your backup, Browns Ferry, that's coming to us?

MR. HAMBRIC: Okay.

MEMBER REMPE: Apparently, it tried to do an EPU with the existing dryers and it failed, and I don't know the details and I'm curious, and now they are going to have replacement steam dryers. Are they going to do what Peach Bottom did, one heavily instrumented, others not? Or what's the -- could you give us the real world story on that one?

MR. HAMBRIC: Yes. That's the plan. I'm sure we'll be in front of you again --

MEMBER REMPE: I'm sure you will too --

MR. HAMBRIC: -- in a year, but --

MEMBER REMPE: -- but I'm just curious about what happened as it relates to this Reg Guide and how the Reg Guide adequately covers that situation.

MR. HAMBRIC: They don't have to follow this Reg Guide, is my understanding, because it hasn't been issued yet.

MEMBER REMPE: Right, but --

MR. HAMBRIC: But they are making the attempt.

MEMBER REMPE: -- there will be another plant in the future, and it may not be a steam dryer, and I'm just wondering, can you talk a little bit what happened when they failed?

MR. HAMBRIC: Old application? Yes. The old application essentially comes down to poor quality plant measurements. There's a lot of noise in the measurements you saw earlier, electromagnetic noise, that they just could not remove in a fashion to convince us they weren't being non-conservative about it.

MEMBER REMPE: Okay.

MR. HAMBRIC: So they just did not have good quality plant data and could not prove to us that the existing dryers were going to meet the acceptance levels. Going forward, yes, the first dryer, I think I can say this, if anybody wants to stop me, you can, but they're going to instrument the first one and after that, it's going to be main steam line monitoring.

MEMBER REMPE: Okay.

MR. HAMBRIC: And if we have an issue like we had on Peach Bottom, we'll --

MEMBER REMPE: We'll be back.

MR. HAMBRIC: -- adapt and overcome.

(Laughter.)

MEMBER REMPE: Okay. Just curious. Thank you.

MEMBER RICCARDELLA: Since Quad Cities, that event, has anybody been able to implement an EPU without replacing their steam dryer?

MR. HAMBRIC: Yes. Hope Creek, and Vermont Yankee made modifications to their dryer, did not replace it, beefed up the outer banks of it. Nine Mile, but they beefed up their structure a little bit. So there have been modifications made to try to improve the strength. So, yes, there's been at least those three, VY, Hope Creek, and Nine Mile. I think on the backup, there should be a list of all the dryers. And I thought we put in there one of the columns that said replaced or retained. If not, we certainly have it.

MEMBER REMPE: It's not really a call-in, but there's a discussion about it in there.

MR. HAMBRIC: Right. And the next block, Yuken was going to cover, right?

MR. WONG: Yes. The next Lessons Learned

is the structural stress calculation. The structural analysis of reactor internal core support structures follow the guidance in ASME Boiling and Pressure Vessel Code Section III Subsection NG. The non-safety related reactor internal components, such as the steam dryer, also adopt the ASME Code Subsection NG to ensure structural integrity. The limits on the various stressors, including fatigue stress due to cyclical loading, need to be satisfied. This is to ensure high frequency excitation mechanisms will not cause high cycle fatigue.

To perform the stress analysis, it is necessary to have conservative estimates of local stress concentrations, such as at fillet welds. To address these issues, detailed guidance for structural analysis were included in the Reg Guide. The guidance include how to perform successive mesh refinement to achieve stress convergence. Next one, please.

MEMBER SKILLMAN: Why should an applicant or the ACRS be comfortable with this? The guidance for internals design has been available for years and highly qualified well intentioned men and women designed internals in accordance with Section III NG and we have internals that cracked. And so, we're saying, oh, by the way, we're going to do a couple of other things. Why should we be confident that a couple of other things are going to solve the problem? Where's our comfort going to come from? Is there something else going on that we aren't considering?

MR. SCARBROUGH: In the past, the steam dryer was not typically Subsection NG. If you -- there's been, like, stories of how these were just sort of made in the garage, right? They were -- the original steam dryers did not have the pedigree that they do now. But with the improvements, the applicants and licensees are saying, well, we're just going to design it to NG, except they take some liberties with regard to some non-structural parts, like the fillet welds, and they don't sort of follow all the quality requirements, all of those additional requirements that are in NG because they feel that they're non-load bearing welds and joints and they can use something a little less. It's that little less that gets us involved in terms of what they're going to do.

And there was a lot of discussion with the ESBWER, with GEH, in terms of how they were analyzing these fillet welds. And a lot of this discussion had to do with, like Yuken mentioned, was the convergence of the solutions in terms of what they were assuming. So, what the Reg Guide does, it lays out a couple of different approaches that were worked out between the NRC Staff and the analysts at GEH in terms of what would be a reasonable way to evaluate the sort of non-structure bearing joints, these fillet welds, in a steam dryer, so that they would maintain their structural integrity and not generate any loose parts. So, that's what we're doing in this section. We're trying to provide additional guidance to help the licensees so when they come in, they'll know what's a reasonable to way to try to deal with these portions of the dryer from a structural point of view.

MR. WONG: I would like to also add, the stream dryer failure example, they did not properly account for all the excitation mechanisms, such as the acoustic resonance. So in this Reg Guide, we try to explain all the different excitation mechanisms, make sure the applicant will consider each one.

MEMBER RICCARDELLA: I think it's fair to say that things didn't fail because the NG stress limits were inadequate, they failed because they didn't define the loads properly.

MR. SCARBROUGH: That's correct.

MEMBER RICCARDELLA: And if you defined the loads properly, they were higher than the NG stress limits.

MR. SCARBROUGH: We've also had issues with, I think, weld quality on Susquehanna, right? Which I think we've since addressed. And Quad Cities weld quality issues, the residual stress problems on some of the other dryers, they've since corrected their design to make sure that doesn't happen again.

MEMBER RICCARDELLA: I suspect those were built before NG was published, right?

MR. SCARBROUGH: Susquehanna was new, right? Yes.

MEMBER RICCARDELLA: Oh, that was a new steam dryer?

MR. SCARBROUGH: Yes.

MEMBER RICCARDELLA: Okay.

MR. SCARBROUGH: They just weren't following NG because they didn't feel that it was really needed. And it wasn't until -- licensees have done a tremendous job in terms of improving the pedigree and the quality of building the steam dryers. I give them credit for that. They really -- and they use NG for most of the situations, but there are some places where they feel that they can do something less and we work with them and come up with some reasonable guidance of what's acceptable.

MEMBER RICCARDELLA: Okay.

MR. WONG: Okay. Next slide.

MEMBER RICCARDELLA: Thank you. Okay.

MR. WONG: In the structural analysis, to capture the rapid time variation and spatial variation of the dynamic input, the input time step need to be short enough and the model mesh need to be fine enough. The structural model mesh and the surface loading mesh usually are different. To address the time input issue, for the time analysis, the time step should be no larger than one quarter of the shortest period of interest. As an example, for the frequency interest of 250 hertz, the solution time step should no larger than 0.0005 second. The input time increment may no larger than a quarter of the shortest period of interest. To address the mesh differences of the structural and the loading model, the generated load distribution and the applied load distribution should be checked. And this is particular in areas of high stress to ensure conservative load mapping has occurred. Next one.

MEMBER RICCARDELLA: Just to correct the record, I think for that first arrow, you said one quarter, I think you meant one eighth, right?

MR. WONG: One eighth, yes. Thank you for correction. Fillet welds are used to connect thin plates to heavy sections, such as a typical steam dryer. The fatigue evaluation procedures and acceptance criteria of the fillet welds typically follow ASME Subsection NG. The stress concentration factors, or known as fatigue strength reduction factors, are needed to ensure reasonable estimates of total stress for fatigue evaluation of fillet welds. The total stress includes the peak stress due to local discontinuities, such as a weld.

The Reg Guide describe two acceptable methods to calculate for the weld stresses. The first method, the fillet weld is included in the finite element global model without the fillet details. The nominal stress at the weld juncture is multiplied by a factor of four as specified in Subsection NG. And in the second method, the geometry of the fillet weld is modeled in the solid element model. The linearized stress on the throat of the fillet weld is multiplied by a factor of three. And the Staff found both methods provide a consistent level of conservatism.

MEMBER RICCARDELLA: Shouldn't there be a third method where you would allow an applicant to do some testing to develop his own fatigue strength reduction factor? Going from one to two seems like an awful lot of additional effort just to get from four to three, and these fatigue strength reduction factors are basically empirical developed by fatigue testing.

MR. SCARBROUGH: We could add something there where an applicant could propose a separate program. I mean, this was just examples.

MEMBER RICCARDELLA: Okay, well --

MR. SCARBROUGH: Yes, we could do that. We could add that.

MEMBER RICCARDELLA: Well, they're kind of not written as examples, they're --

MR. SCARBROUGH: As the two methods, yes.

MEMBER RICCARDELLA: -- written as two acceptable methods.

MR. SCARBROUGH: Yes, we'll look at the wording and the applicant always --

MR. MORANTE: Tom, can I say something on that?

MR. SCARBROUGH: Yes, please do, Rich.

MR. MORANTE: I think it would be pretty difficult for an applicant to do a sufficient amount of testing to demonstrate that the peak strength reduction factor is appropriate. Now, it can be added here, but I don't think, number one, that many applicants would take that route and, number two, it may be difficult for them to do a sufficient amount of testing to adequately demonstrate a different fatigue strength reduction factor than what the code currently specifies.

MEMBER RICCARDELLA: The factor of three and the second step, that's a code value or is that one that you --

MR. MORANTE: No.

MEMBER RICCARDELLA: -- came up with?

MR. MORANTE: No, that is not a code value, but what we looked at was, if you made a local model which included a nominal representation of the fillet, that if you multiplied the stress at the root on the throat --

MEMBER RICCARDELLA: Yes.

MR. MORANTE: -- the linearized stress at the root on the throat and you multiplied it by three, you would get comparable conservatism to the first approach, which is just more like the traditional way where you calculate a moment and a force at the juncture and you apply your factor of four, which is in the code. So, we accepted the second method only on the basis of a comparison through a parametric study that conservative predictions would be arrived at, that were comparable to using the first method. But, no, the second method is not in the code.

MEMBER SKILLMAN: Let me ask this, theoretical question, but it's one that I've dealt with in the past, where the effort has been focused so greatly on making the structure strong in terms of the size of the weld, the gussets, the internals, that are just much like a Sherman tank, that under changing thermal conditions or changing flow conditions, the strong device has almost become brittle to where it's not able to respond and the only way it does is by failing a section of the metal. In other words, it's so strong it is no longer sufficiently flexible for the environment in which it dwells. Can we be in the situation here where we have virtually over designed, to our detriment?

MR. WONG: One thing I would comment, the steam dryer, I think, sits on top of the reactor internal components, so usually it's free to expand. So thermal stress may not be a critical issue.

MEMBER SKILLMAN: Well, normally thermal stresses are self-relieving, unless the rate of change is so great that it can't relieve itself the way it wants to and so, what it does is it fails. It just goes, clink, and you end up with a split weld.

MR. SCARBROUGH: Right. And I think it's important for the licensees or applicants to look at their steam lines and what would be their driving functions. I agree with you that just making a bigger, bigger brick may not be the right answer. If you look at what your forcing functions are, you design your dryer so that it's fully sufficient for that, but you don't need to make a brick if they can show that their forcing functions are something that's reasonable for that dryer.

MR. MORANTE: Let's start off on the premise that they're using ASME code materials. Now, typically ASME code materials are selected because they exhibit a significant amount of ductility. These are not materials that are ultra high strength. And typically, they would exhibit a significant ductility or the code wouldn't have them in there, unless for certain applications. One of the problems here with the fatigue is that these are high cycle fatigue issues, which means the allowable maximum stress is quite low compared to a yield strength. I don't know much about the issue of rapidly changing thermals on producing brittle behavior. If that's a real issue, then it ought to be addressed.

MEMBER SKILLMAN: Thank you.

MEMBER RICCARDELLA: The only thing that might lead to brittle behavior is if you have some components that are in a very highly irradiated zone. I mean, it's stainless steel, it's pretty ductile stuff, but --

MR. MORANTE: It's very ductile.

MEMBER RICCARDELLA: -- if you had, like we're dealing with baffle bolts, for example, and very highly irradiated, there is some embrittlement going on there.

MR. SCARBROUGH: Oh, okay. Great, thank you.

MR. HAMBRIC: So, the next couple of blocks of slides are on measurements. The first couple are on instrumentation and then the next few are just on measurement procedures in general. For instrumentation, the first section is actually on where you measure. And you can't just slap sensors anywhere, whatever internal you're looking at, whether it's a dryer or something else, the measurement locations have to correlate to high vibration and hopefully fairly close to high stress regions, so that they're actually relevant to a structure's condition during power ascension.

So we added to the Reg Guide was that accelerometers had to be near peak or near-peak response locations. You get those out of the simulations, so they'll simulate the response and then use those to guide the accelerometer locations. Strain gauge is a little bit different, you want to put those in locations where you have minimum gradients in strain. The reason for that is you want to minimize your measurement uncertainty. So if you put yourself in a location where there's a really strong gradient, that means you've got a plus or minus of quite a bit on your measurement and that becomes problematic when you want to do your benchmarking against the simulation.

And typically we ask the applicants to show that the sensor locations, the response to the sensor locations is highly coherent with the critical response locations. So, an issue we have is you can't put strain gauges on locations of high stress, those are usually right at welds or other joints. And so, the gauges have to go kind of close to them, but not exactly. So, where is that kind of close? And to prove they're close enough, they'll do a coherence assessment between the peak stress location and where they put the sensor and show that there's a good strong coherence there, so that it's relevant to the high stress location.

MEMBER SKILLMAN: Let's go back. Perhaps this is where you can answer my question relative to the sensor being affected versus the sensor displaying or revealing what the structure that it is attached to is displaying.

MR. HAMBRIC: So are you concerned about the accuracy of the gauge itself or are you concerned that the installation of the gauge is affecting the stiffness of the structure?

MEMBER SKILLMAN: Not so much about the accuracy of the gauge itself, more concerned about being deceived because the gauge is responding to the stimulus, but not displaying the reaction of the structure to which it is attached.

MR. HAMBRIC: Yes, I think that's the next three slides that we talk a bit --

MEMBER SKILLMAN: Okay.

MR. HAMBRIC: -- about that and we can continue the discussion. Sorry to put you off yet again, but --

MEMBER SKILLMAN: That's okay. Thank you.

MR. HAMBRIC: So, this next one is

specific to main steam lines. The standard operating procedure has become the use of circumferentially oriented strain measurements, which when summed are directly proportional to the internal pressure. The observations we have made is it sounds easy, but for whatever reason, we've had a lot of problems from several applicants. Repeatability issues, they'll measure it one year and they'll measure it the next, big differences. Sensors have failed. Background noise is way too high, that was the issue we had in the initial Browns Ferry application. Or just QA problems, operator error, have led to some pretty, in some cases small errors, in some cases really egregious errors.

So the guidance we've given is that you have to have at least four working gauges around the circumference. Most applicants go with double that just to give them some margin in case some of the sensors fail, and they do. We're also recommending a standard operating procedure that a static pressurization calibration be done, where you know what the internal plant pressure is, you measure your hoop pressure, make sure that you're getting the same thing. And we've had problems with that too. There have been calibration errors that we've had to live with because they did not go through that test, so we're recommending that in the future.

And there's always a pretty good gap, a couple years at least, between the submission of an application, for an existing plant anyway, and when power ascension starts. And so, we're requiring that updated measurements be made right before they start power ascension, just to make sure that they're still relevant and reasonably close to what they got during the application process. All right.

So in-plant measurements. These overlap a little bit, but again, we've had some measurements that have been absolutely unacceptable, the channels were wrong, they took one channel, plugged it into one number, another channel plugged in another number, didn't update what happened in the data acquisition system. Humorously incorrect calibrations were applied, orders of magnitude differences and they've tried to convince the results were okay. And we set them straight on that. High EMI interference, we've had people that run instrumentation wires next to power lines, not a good thing to do.

So, to correct for that hopefully in the future, we added some general in-plant measurement guidance. Number one, all instrumentation has to properly function in the plant, high temperatures, high pressures, high moisture content. And here, I think, is maybe your question, the as-welded strain gauge calibrations are required. So, when you buy these strain gauges, they'll tell you how to weld them, but sometimes they'll weld them a little bit differently in a plant and the base structure is a little bit different from what the calibration spec says.

So it's that kind of thing that we've asked the applicants to get a little more rigorous about, that they come up with a calibration that is based on a representative application or installation. Take a plate that has about the same thickness, use the same welds, go through the calibration process and use corrective calibrations for in-plant applications. The other thing you can do with strain gauges is they're almost self-calibrating. If you calibrate them once, you can calibrate them again by just applying a voltage to it. It's called shunt calibration. So, we recommend that and a lot of people have been doing that, which is good. So I don't know if that addresses your question or not. They prove to us that the calibration is correct on a representative installation.

MEMBER SKILLMAN: It goes part of the way towards my question. And I guess as I think of how these tests are done in the field, there is some discipline to ensure that the location of the stress gauge, strain gauge is, if you will, protected and that it is in fact giving an indication representative of the base to which it is attached, as opposed to being wedded or blanketed by or somehow affected by an external environment that would cause that gauge to not reflect the underlying surface that it is intended to monitor.

MR. HAMBRIC: Well, they're all qualified for in-plant pressure, temperature, moisture conditions. So that should be taken care of. And then, to make sure the cal is correct, we just make sure they've applied it to a representative structure. I think that's about as much as we can do.

MEMBER SKILLMAN: It sounds like you had a bad experience --

MR. HAMBRIC: A couple of years worth.

MEMBER SKILLMAN: -- trying to get to here. It took a couple of years to finally figure out how do to exactly what Steve's talking about.

MR. HAMBRIC: So they've mounted these strain gauges, at least one applicant has, to flat plates, done them again to curved pipes, and then the final, at least for main steam line measurements, the proof in the pudding was a calibration against the known internal pressure. Now, you can't do that with every internal structure, but at least we could do it there, so that gave us some confidence.

MEMBER CORRADINI: And that is one of the, if I remember correctly, a couple slides back, that's what's now you're recommending.

MR. HAMBRIC: Yes, we put that in the Reg Guide that it's highly recommended. I don't know if we're allowed to use the word highly, but we recommended it. And then, finally, the last couple are, don't run instrumentation and don't put the instrumentations near high EMI regions. You're measuring voltage, so don't corrupt the voltage. And even data acquisition systems have their own calibrations that need to be done periodically. They have noise floors that need to be addressed. Okay.

MEMBER SKILLMAN: Okay. Thank you.

MR. HAMBRIC: And I think this is my last slide. We've had -- because it's a nuclear power plant, because there's a lot of EMI, there are real life issues that can corrupt data. We've had to address dealing with various proposed noise reduction methods that applicants have thrown at us. The obvious ones to get rid of are electrical tones, you've got 60 hertz multiples, that's fine, they need to go away. RRP drive frequencies, not vane passing frequencies, but the drive frequencies, those are electrical, so those are non-relevant, they don't drive structures or anything like that, and they can be removed.

And then, all measurement systems, whether it's from the sensors, the cabling, the data acquisition computer itself, have a broadband noise floor. That's just life. So, what we put in the guidance is that you can use noise reduction methods, provided they do not remove excessive signal. We've had some pretty egregious attempts to remove signal back in the old days, which are not allowed, but we've come through. So we don't allow excessive signal reduction.

To get rid of electrical tones, something called notch filtering is typically used. You can set this up in a signal processing software pretty easily. But what you get in your signal is you get this huge dip where there's almost no signal at 60 hertz, there's no signal at 120 hertz, and so we've recommended that sort of some random noise be put back in to backfill so you don't get a big dip in your signal, because we know there's at least some excitation there.

We've had different approaches for broadband noise reduction suggested. One is something called coherence processing, where you'll use a nearby sensor that you think is associated with your background noise and remove all signals associated with that from the signals that you care about. So without getting into huge detail, we've said that's okay as long as you substantiate it, usually with an example problem or a demonstration and, once again, prove to us you've not removed excessive signal.

A more clever way of doing it lately has been suggested, it's called wavelet noise reduction. This is used quite a bit in image processing, so if you've got Photoshop, chances are you've got a wavelet based noise reduction there to get rid of little pops in your images. You can do the same thing in a one--dimensional time series. But, again, we require that it be demonstrated and proven to be not excessive noise reduction and substantiated with an example problem. And a big one is a while ago we had somebody try to use one noise reduction method to qualify a design and a different noise reduction method during power ascension. That was unacceptable, consistency is required. So we put that in the Reg Guide as well. And I think you're taking over.

MR. SCARBROUGH: Okay. I'll take over.

MR. HAMBRIC: So I'm going to hang around for another 15 minutes and then probably duck out.

MR. SCARBROUGH: Okay.

MR. HAMBRIC: Now, what I may do is call into the number while I'm driving out to the airport, so if you have a question during --

MR. SCARBROUGH: Great, thank you. The next set of slides, what I wanted to do was just let you know that we've taken the Lessons Learned from all the power ascension and license conditions that we've developed over the years for all the EPUs, where we have a slow and deliberate power ascension process that we have where we review the plan and there's a 75 percent power sort of baseline and there's five percent increments as they go up and then they hold for 72 hours at 75, 85, and 95 percent and send us the information and make sure our consultants get a chance to take a look at it. Then when they get up to 100 percent, they give us the data within 72 hours and then 90 days later, they give us the full analysis and then they do two refueling outages inspections in a row and then they develop a long-term plan based on what they see.

So, we've sort of taken that sort of generic Lesson Learned and applied it into the guidance in the Reg Guide. So here these slides basically are saying that the sensors and wiring and data acquisition systems may change slightly over time due to aging. And so, all this has to be done. Grand Gulf, they had their sensor on, then they were running for a while and they started losing some sensors, and so, that's all something to be concerned about. And how you develop your limits, your power ascension limits, there's root mean square, there's frequency dependent limits, which is what we typically, I call, limit curves, where they look at the differences between and they anticipate making sure that by the time they get to the next level, they haven't exceeded one of those limits.

In terms of the peak and RMS, you have to make sure you have the proper number of sensors and that you don't have -- all your important resonances and forcing function frequencies are bounded. But if you get to what we call limit violations, when we talk about limit curves, there's Level 1, Level 2, you have a hold at one point, you reduce power at another, you analyze and determine if you have anything that's happening there that's significant. A lot of times, what you'll see is you'll see a sharp resonance pop up and they'll jump up and hit a limit curve or get close to a limit curve and then they have to analyze, okay, why is that?

And they do things that Steve was just talking about in terms of, okay, it's not significant, it's just a peak and it's not going to cause a problem in terms of the overall structural integrity of the dryer. So they give you that. They analyze, the make sure that, like we say, these sensors have finite lives, so you want to move things along. They reanalyze, reanalysis you perform using the methods to anticipate where you're going. And then you do a final structural analysis using your full procedures. Next, we have -- the next slide.

In terms of the limits themselves, you update them at every power ascension, because things change and you have small peaks come and go as you go up in power. Your responses are projected up to a full power level, you don't want to end up hitting a limit if you know you're going to get there before the next power level, so you look at that. And then you look at coupled resonances where you might end up having a combination of the flow-induced vibration or acoustics or something adding up so you might end up hitting a peak.

But the bottom line during all that is the Staff monitors that power ascension, basically on a 24 hour basis. I think all of us have been on 24 hour call when they're going up, over the EPU, that week time period when they're going up and they're sending us data and taking a look at it. And the licensees are very, very good about making sure we get the data, we look at it, we get it to our consultants, they look at it. They want to make sure that nothing untoward is happening, just like we do. So, there's a very interactive effort there, in my experience with working with the licensees as they go up in power.

MEMBER SKILLMAN: So, Tom, for these three slides, what you're really referring to is the response of replacement steam dryer for a power ascension?

MR. SCARBROUGH: Right. That's what this is talking about, right.

MEMBER SKILLMAN: Making sure we're clear. This is all about an RSD?

MR. SCARBROUGH: Right, exactly.

MEMBER SKILLMAN: Okay.

MR. SCARBROUGH: Okay. And that's -- just kinda I wanted to give an overview of that and then you can talk about public comments.

MEMBER SKILLMAN: Let me ask my colleagues, is this a good time to take a ten minute break? We've been at it for two hours and 40 minutes. Let's take a ten minute break, please. We are in recess until 20 minutes after on that clock.

(Whereupon, the above-entitled matter went off the record at 3:06 p.m. and resumed at 3:20 p.m.)

MEMBER SKILLMAN: Ladies and gentlemen, we're back in session, and let us proceed. We were at the slide addressing public comments. Tom, back to you, please.

MR. SCARBROUGH: Thank you. Are you guys going to walk us through the public comment slides?

MEMBER SKILLMAN: Okay. You can, please. Go ahead.

MR. WONG: The NRC received 53 comments from Westinghouse, GE Electric, Hitachi, and then private individuals. All comments were addressed; the comments led to several clarifications of the reg guide. The comments were consistent with the intent of the revision in that they improved and clarified the guidance. The significant comments that led to revisions are summarized in the following slides, and a full list of the comments and the NRC responses were sent to the ACRS. Next slide. The first comment was asking to clarify what is background information and what is regulatory guidance. The reg guide was revised to better distinguish what's background information and what's regulatory guidance. The reg guide referred to the steam dryer for lessons learned, and although these examples are specific to the steam dryer, the guidance can be applicable to other reactor internal components as well.

The second comment asked to define what is high marginal safety, and the revised reg guide provides an example of high marginal safety; it says a factor of 2.0 for the steam dryer alternating stress.

MEMBER RICCARDELLA: Is that a factor of 2 relative to the code limit, or the fact that the code limit has a factor of 2 built into that?

MR. WONG: Relative to the code limit. Yes.

MEMBER RICCARDELLA: That's the requirement?

MR. WONG: That's a guidance for using the main steam line monitoring method.

MEMBER RICCARDELLA: I see. Okay.

MR. WONG: This comment asks to provide guidance to determine the hydro-dynamic loading on a steam dryer due to water boiling rumbling. The reg guide was modified to clarify the boiling water sources and include other internal dynamic forces which are difficult to quantify. The reg guide discusses that MPN bench marking can account for any unaccounted sources. The next comment deals with the ill-defined boundary conditions. The reg guide was modified to call for assessment of boundary conditions variability when that variability leads to non-negligible response differences. The next comment deals with CFD validation; the reg guide was revised to be a little more flexible by replacing the smallest flow areas with small sole passages. This comment also deals with CFD validation; similarly, the reg guide was revised to be less rigid, replacing maximum passable flow velocity with high local flow velocity. Next one.

This comment requests that low measurement prediction comparisons should be made supplemental and not necessary, and the guidance was revised to clarify that supplemental measurements are helpful but not always necessary when end to end bench marking is used. Next one. This guidance asked for the chemical basis for reducing this fatigue strength reduction factor from four to three. As discussed in the structural analysis lessons learned, the method two provides a level of conservatism consistent with the ASME codes of section NG guidance, and the NRC reviewed the parametric studies of the different cases using method one and two, and found both methods acceptable.

MEMBER RICCARDELLA: So the parametric studies, they did the model in the conventional way and used four, and then they modeled the fillet weld and used three and got the same answer or higher?

MR. WONG: The answers are similar.

MEMBER RICCARDELLA: Why would anybody go through all the effort to do the local model then if you're going to get the same result?

MR. WONG: They may have other complex

geometries this kind of alternative method.

MEMBER RICCARDELLA: Okay.

MR. MORANTE: But I would just like to add that hopefully people will just go with method one. We follow the traditional way of handling fillet welds, because you're right, the extra complication and complexity of the model seems to be hardly worth it.

MR. WONG: Okay, thanks Rich. The comment deals with the pre-operational testing at allowance for specification for no instrumentation for any new components. The reg guide was revised to add flexibility to allow for no instrumentation for new components that have no operating experience. But the reg guide basically said consider instrumentation for new components that have no operating experience, and try to allow flexibility for the applicant to apply instrumentation. The next comment, the reg guide discussed the disposition of fuel samplings during pre-operational testing, and the comment suggests that the reg guide should address test configuration and condition as well, and the reg guide was revised to add the guidance. Next one. The comment brought up in a situation where one or two components were replaced, and the FIV effect on these two components are significant; however, the effect on the rest of the reactor internal components are insignificant, and how do we address the classification and instrumentation of the reacting internal components? So the reg guide was revised to add a section to address this specific situation. Next one.

In this comment, it was stating to perform rigorous statistical analysis for the theoretically derived forcing function, and the finite element analysis uncertainties, and the provocation of the variable uncertainties can be very difficult, and does not add value to the program. Most of the uncertainties during the analysis are addressed by using conservative assumptions, and the reg guide already mentioned if using end-to-end bench marking, it can eliminate the need for component-level bench marking, and to further clarify--to further address the comment, the section was revised to mention the acceptable use of conservative assumption, and not to do the component level bench marking. This comment point out in the reg guide, in certain places it used the term peak stress to refer to total stress, and the reg guide was revised to use terminology consistent with ASME Subsection NG. The next one, it mentioned that during pre-operational testing, the testing results may not always be conservative without a fuel, and the reg guide was revised to allow testing without the fuel assemblies if the test results will yield reasonable results.

MEMBER SKILLMAN: How would one know--how would you know that?

MR. WONG: The way the current wording of the reg guide says, only if the tests results are conservative bounding the actual plant operation with the fuel assemblies; otherwise, you cannot run the pre-operational tests without fuel assemblies. So it is the wording conservative that may cause problem for the applicant. So we revised the word to say reasonable result. If the results are consistent with the actual plant operation, then the pre-operational test can be run without the real or dummy fuel assemblies.

MEMBER SKILLMAN: Is that commonly done?

MR. WONG: Yes, for pre-operating casts, if there are no real or dummy fuel assemblies put in the reactor core to simulate the pressure drop or the weight, typically people will place flow restricters in the core to simulate the flow and pressure drop.

MEMBER SKILLMAN: Thank you.

MR. SCARBROUGH: Okay.

MR. WONG: In the reg guide, it mentioned an example of a steam dryer failure caused by a reactor pump ring passing frequency; the comment pointed out that the root cause for the failure did not point out the reactor pumping passing frequency as the sole cause, so the NRC revised the statement saying the reactor coolant pump passing frequency may have contributed to the fatigued area. And in conclusion, the reg guide 120 was revised to simplify the prototype classifications from eight to three, address as many lessons learned from EPU and new reactor applications, ensures a reasonable applicability to SMRs. The revised reg guide provides improved guidance to the different high-frequency excitation mechanisms. The public comments were addressed and led to several clarifications. And finally, the reg guide is ready for final production. That's the conclusion of the presentation.

MEMBER SKILLMAN: Okay, I would like to ask a couple of questions if I can from my review, and perhaps my colleagues will have questions from their review. So let's take some time and go through these. It would help if you have a copy of the reg guide.

MR. SCARBROUGH: I've got it right here.

MEMBER SKILLMAN: If you would look at the top of page 13.

MR. SCARBROUGH: Okay.

MEMBER SKILLMAN: The sentence that I'm going to refer to is the sentence at the top of the page, and I'll quote that sentence so my comment is in context. "These mechanisms include vibration induced by flow turbulence, turbulent buffeting, acoustic resonance, exitation by separated flow instabilities, vibration induced by vortex shedding exitation, and fluid elastic instability. FIV occurs not only in the lift or normal to the flow direction, but also in the drag or stream wise direction." Would you explain lift and stream wise, please?

MR. WONG: The lift is the cross flow, and stream wise is--

MEMBER SKILLMAN: In the direction of the stream? Are those terms thoroughly understood by users of this reg guide?

MR. ZIADA: Hello, Samir Ziada; can I add?

MEMBER SKILLMAN: Please, yes sir. Go ahead.

MR. ZIADA: Yes, somebody who is doing flow induced vibrations, they should be familiar with this, thoroughly understood, and this was added because of the mentioning about SONGS because the two vibrated in plane which can be -- refers to the stream wise, and also because of a problem of thermal couples in Japan, in a nuclear power plant in Japan, which has failed due to -- vibration in the steam wise direction. So it is quite known in the field of flow induced vibration what is stream wise and cross stream or the lift. If you think it is not so clear, we can add clarification for this.

MEMBER SKILLMAN: As an experienced nuke and user of many documents like this, I would be surprised that others like me might at least pause to understand what that means. So a footnote or clarification I think would be valuable.

MR. SCARBROUGH: Okay, we can do that.

MEMBER SKILLMAN: But this is a subcommittee, and that's one man's opinion.

MR. SCARBROUGH: We can do that, thank you.

MEMBER SKILLMAN: Okay, next comment is on for document page 16, it's under modes of vibration, and at 2.1.1.1, the sentence that is my target for comment is about the third under 2.1.1.1. "The differences between measured and simulated natural frequencies are used to establish uncertainty ranges for FRS and final response calculations. For example, if bench marking reveals that the simulated natural frequencies are within plus or minus 10 percent of those measured, FRS and final responses are computed over that range of uncertainly." My question is, what sets, or how do you know that range of uncertainty? I think you may have touched on this very gently earlier in the presentation, but this gets to uncertainties. How do you know? Why pick that number?

MR. HAMBRIC: This is Steve Hambric; I'm on the phone now. Typically they have a measured mode shape, a simulated mode shape, and your dasher, and then you see what the residence frequencies are and look at the difference. If you do that for many modes, you can usually come up with a bracketing percentage, and your model is plus or minus--accurate plus five or 10 percent accurate. We just put 10 percent in there as a typical value that if you do the math -- not necessarily one that has to be used for all applications.

MEMBER SKILLMAN: And I see that the

wording allows for that interpretation, Steve, so I get it. Thank you. Next comment is on page 17, third paragraph from the top, and that sentence is "Some structures might have variable or ill-defined boundary conditions during normal reactor operating conditions. When boundary conditions have a more than minimal effect on component response, their variability needs to be addressed." Question, how would one know what is more than minimal? That almost sounds like enforcement language that we dealt with out in the field, where more than minimal is someone's opinion versus if you will a measurement based on a baseline that we could agree on before we begin our discussion.

MR. SCARBROUGH: Yes, we'll go back and look at that and come up with some better words, better than "more than minimal" and try to come up with some sort of example that would give you more clarity there. I can understand how that--that's really open to interpretation. We'll see if we can add--

MEMBER SKILLMAN: One could say substantial, or what's substantial? More than minimal? Well, is it less than significant? Those words are really complex for the implementer.

MR. SCARBROUGH: Right, right.

MEMBER SKILLMAN: Thank you. One or two more comments if I could.

MEMBER BLEY: Let me say something on that one.

MEMBER Skillman: Please.

MEMBER BLEY: Because the way I interpreted the discussion I heard from Steve when he was here was that this is a thing that really needs to be laid out, looked at and discussed between staff and the applicant, so whatever your language is, I don't think we're looking for a bright line, we're looking for a description of the process.

MEMBER SKILLMAN: Bingo.

MR. SCARBROUGH: Yes, because that's exactly true. This is a give and take a lot of times in terms of what's--

MEMBER SKILLMAN: I recognize this is a negotiation, but it needs to be one of precision where both sides are able to come to agreement objectively.

MR. SCARBROUGH: I agree.

MEMBER SKILLMAN: My only point. The next comment is on page 19, and this has to do with the topic of lock-on, and Steve mentioned this earlier. I just simply wanted to suggest the context of the words on page 19 generally apply to the replacement steam dryer; in reality, this lock-on concept can be anywhere. It can be in a P, it can be in a B, it can be in an SMR, and it kind of raises the question how do you get out of the lock-on? Once that lock has occurred, what do you have to do to get out of it, because they are strong couplings, and for some reason at least I can't explain, when you try to back away from the lock-on, it stays locked. It doesn't want to let go. So I think this concept of lock-on is important, and there needs to be a recognition. It isn't just replacement steam dryer connected. It--lock-on is what happened at Palo Verde. It locked on, and no matter what they did, that EKE line, residual E line kept on vibrating and swaying.

MR. SCARBROUGH: Right, and we--you know, one example is the locking that occurred at Quad Cities where they ended up changing the stand pipes for the relief valves drastically, so that you would get away from that lock-in. And whereas at Dresden, when they went up in power, they hit the lock-in, but they still were increasing power, so they still increased the flow right on through it, so it dropped back off on them. Whereas Quad Cities, they locked in, they were sitting right at 116 percent power. And so yes, we'll go back and look at this and add more discussion of this concept that applies to more concurrence.

MEMBER SKILLMAN: Thank you. On page 32, you have a section that is dedicated to guidance for BWR steam dryers, specific guidance for BWR steam dryers. Are you inviting the need for special guidance for pressurized water reactor internals? It just seems to me that here is this rather overarching draft regulatory guide; it seems to be somewhat surgically focused on te steam dryers when in reality, perhaps there should be specific guidance for SMRs, there should be specific guidance for PWR internals, and special guidance for steam dryers, and I would just observe from my years in the industry each of those may have a unique set of considerations. Not problems, considerations, things you might want to address differently for the differences between those.

MR. SCARBROUGH: You know when we were looking at this, there was a lot of discussion of maybe taking the BWR steam dryer discussion and moving it to an appendix. If we did something like that, that would make it more possible to have a different appendix for PWR internals or appendix for SMRs. I know we've done that with other, like inspection procedures where we want the focus on MOBs in one appendix, and air operated valves in another appendix where we could spend that whole appendix just talking about that one topic, and not having to jump back and forth so much. So we could go back and take a look at this and see if that would be something where we could, if we have some guidance that we could put in for PWRs and SMRs, maybe not as detailed for steam dryers, but to kind of give--start the process where with the next revision of this a few years from now, we might have even more guidance for PWRs.

MR. LUPOLD: That's a key statement he just said right there--

MEMBER SKILLMAN: I got it.

MR. LUPOLD: --is if we have that additional experience. Right now, this red was based on the experience we've had since Quad Cities, et cetera, and the vast majority of it has been steam dryers. So as we--if we accumulate additional experience or issues with PWRs, small modular reactors, learn things about that, and we can add that in there at that point.

MEMBER RICCARDELLA: You know, the lead

in to that paragraph discusses SSEs with no prior history of adverse effects.

MEMBER SKILLMAN: One or two more comments. I'm on page 33, and this is explaining the locating of the strain gauges on the main steam lines, and the sentence is "At least four strain gauges, evenly spaced around the pipe circumference, are necessary to filter non-breathing signals." And I got stumped at non-breathing; is this jargon, or is this a term that is commonly recognized in the industry?

MR. SCARBROUGH: It's--from the discussions with Steve Hambric, yes, this is a very common type of discussion; he's used that terminology many times in terms of explaining this to me in terms of--we'll go back and talk to him about if we can add more language to make it even more clear. But it is sort of a jargon that his folks use in terms of how--

MEMBER SKILLMAN: A footnote or a lexicon or the description of terms of what is it?

MR. HAMBRIC: This is Steve, we can spend a --

MEMBER BLEY: Steve, what is it physically?

MR. HAMBRIC: Oh, it's a hoop motion, the entire internal --

(Simultaneous speaking.)

MR. HAMBRIC: -- that's pushing the tie valve.

MEMBER BLEY: Okay I get it. So this is a circumferential oscillation just simply due to the internal pressure?

MR. HAMBRIC: Yes, the hoop strain. That's the breathing that we care about; everything else we don't care about. The steam motion, the overring, all that gets filtered out.

MEMBER SKILLMAN: Thank you. The final comment that I would make is the comment on the use of the term internals important to safety; you've already heard me --

(Simultaneous speaking.)

MEMBER SKILLMAN: -- and you can find those very easily on a word search, because they pop up. And I want to also repeat my comment about a prototype, becoming a valid prototype to a limited prototype to a non prototype. I find those confusing; I would have started with a first of the kind and then an identical to first of the kind, but my colleagues and perhaps our consultants might have a comment or two that any of them may wish to make, so with that I'm going to halt and allow my colleagues here to offer any comments they may have before we go to the public. So colleagues, might any of you have comments, please?

MEMBER BLEY: I'd only add one thing to what you said. Those early pages that describe prototype, reference to prototype and not a prototype, the words didn't bother me, but the details as we've talked in our discussion is where I think the problem exists.

MR. SCARBROUGH: Yes, we're going to go back and try to add examples and guidance to help clarify when you'd be pushed from one to the other, or what would drive you to be one of those ask opposed to another one. We're going to go back and look at that and get our consultants together and come up with a better language for that, and do a redline strikeout of that area.

MR. MARCH-LEUBA: As invited experts, are we members of the public, or can we talk?

MEMBER SKILLMAN: You are a consultant at this point, and so we welcome your comments, Dr. Leuba.

MEMBER BLEY: Invited expert.

MEMBER SKILLMAN: Invited expert, I'm sorry.

MR. MARCH-LEUBA: Yes, I'm a paid consultant, right? Yes, I'm Jose March-Leuba, I'm an invited expert. I wanted to have--two thoughts. Number one, I didn't see any discussion on the steam dryer about steam or liquid carryover on the calculations, which has a big impact depending on the conditions, how much leak will you carry over to the steam line. You always have one, two percent droplets, which one will imagine will have a big impact if, I mean--

MR. SCARBROUGH: Okay, I will go back and see if that's covered, and if it's not covered, we'll add something to talk about that. Thank you. Carryover effects, okay.

MEMBER CORRADINI: Is Steve on the phone?

MR. SCARBROUGH: Steve, are you still there?

MR. HAMBRIC: Yes, I'm here.

MEMBER CORRADINI: So I think Jose's point is well taken; I'm wondering does that drive you to a more conservative calculation or gives you margin? That's what I was wondering.

MR. HAMBRIC: You're talking about like

the water volume fractions?

MR. MARCH-LEUBA: Yes, liquid droplets carried over by the steam that are moving back along the wall, and they have a lot of mass.

MR. HAMBRIC: Oh, on the dryer structure itself?

MR. MARCH-LEUBA: Yes.

MR. HAMBRIC: Right, right, right. No, that would be taken care of with the end to end bias correction. So they don't model that typically now, at least I'm not aware that they do, but for some reason the as-measured stream differed significantly from the simulated stream that would be carried--would be taken care of by a bias drill.

MR. MARCH-LEUBA: One would expect water droplets hitting the walls to have a big impact. Of course, it's only one percent.

MR. HAMBRIC: What sort of impact are you thinking about? Like a damping incident or a--

MR. MARCH-LEUBA: When you're raising my window, the window makes noise.

MR. HAMBRIC: Right.

MR. MARCH-LEUBA: So, I mean I always take it to be important.

MR. HAMBRIC: So you're talking about a

force of exitation.

MR. MARCH-LEUBA: Additional exitation, correct.

MR. HAMBRIC: Right, okay. Yes, that would be, again, taken care of by the end to end bias correction, the same way that--the fact that nobody tries to calculate the boiling water loading, that's a fluctuating loading of the -- so we can add that to the sample, along with flowed water that can also be rain on the roof kind of excitations for water droplets. Tom, you can take a little note of that, we can throw that in as part of our discussion.

MR. SCARBROUGH: Yes, I got it. Thanks, Steve.

MR. MARCH-LEUBA: And also keep in mind that the efficiency of the steam separators is extremely dependent on the flow, so for example if we were to -- lower flows, there is higher carryover. So depending on the flow where you operate to, you will have--instead of one percent, you have two percent carryover, and you may double the mass of liquid.

MR. SCARBROUGH: Right, so as they go up in the power ascension, these are factors they would need to consider, because carry-over would have changed.

MR. MARCH-LEUBA: Because the steam separators are steam, if you have rubber floors they don't skid as much, and then they will separate the steam from the liquid as well. Just the lessons he has to consider.

MR. SCARBROUGH: Right, right. Thank you. We'll add that.

MR. MARCH-LEUBA: And now that you guys are used to my accent, I'm going to throw a really-- I wasn't going to insult him, but it's something of a revolutionary concept.

MR. SCARBROUGH: Provocative.

MR. MARCH-LEUBA: What is the value added for the staff to review this calculation? Let me repeat that.

MR. SCARBROUGH: Okay.

MR. MARCH-LEUBA: This is an extremely difficult calculation, which frankly, not even Steve believes the answer to, and then he is going to require a measurement to confirm that everything works. What we're doing--the staff is tasked to protect the safety of the public. The safety of the public is protected by the experiment, not by the calculation. By reviewing the calculation, what you are doing is protecting the investment of the licensee. The licensee is investing the money and at risk and saying if I don't pass those tests, I will have to stop my reactor and do it again. So by reviewing the calculation, we're not protecting the safety of the staff or the public. Okay, so I've been involved in many, many reviews on the NRR side, but I can see the poor guys from the licensee, they really don't like those reviews because it has uncertainty, it has the bring me a rock syndrome, and a lot of cost and time. One option would be to have the licensee run it at their own risk. You run the calculation; I'm not saying don't run the calculations. You run them, we'll look at them, we'll look at the results.

MR. SCARBROUGH: Okay, I can answer that question. When we started--when the Quad Cities event started, we had sort of had that philosophy. They had their first failure after 90 days, they broke it apart, they welded it back together, made it thicker. A few months later, they broke it again, you know. A few months later, it broke again --- they kept welding it back together, and kept saying we'll just weld it back together, right? And eventually, you know, they decided they were going to replace the dryer, right, and they did some more calculations and said we're good to go, right? We're going to be fine forever, right? And then they shook their relief valves, so they almost had a double blow down of Quad Cities, right, on New Year's Eve, right? Remember that? Where they would have blown down this rack and probably would have--might have sympathetically blown down the other rack, right, on New Year's Eve. So there's a lot of consequences of looking at the analysis, and when we finally got to the point our office director NR said that's enough, that's enough, we're not going to keep relying on--we've lost confidence in the ability of the licensee to analyze this problem and ensure their plant is going to operate safely.

And so when we started looking in this analysis, we brought in Steve and Dr. Ziada and Mr. Morante to look at all this, and other consultants we've had from Argonne, Dr. Shaw. We've looked at the analysis and as we've looked at it, we've found some significant problems in how they did it. And so as we went along and when we met again with the NRR office director, and we told him what was happening and our concerns, his answer to me was these are not test reactors. We're not going to start this plant up and find out what happens. You need to be confident that their analysis is credible, so when they get up and power,, they don't want to have the steam dryer fly apart and go in pieces all down the steam line, or they're not going to shake their safety valves apart and blow down their reactor. So that was a direction that we got, that our job is to have confidence in the ability of the licensee to analyze its reactor so it can be operated safely, and the problem is, it's as you said, it's so complicated that there's a lot of interaction that needs to take place to make sure that we're comfortable with what the licensee is doing, and over the years, we found a number of places where their analysis was unacceptable and they had to make corrections.

MEMBER CORRADINI: But I think you're missing his question. His question is the experimental power ascension is showing adequate protection; the analysis is investment protection. That's what I think his point it.

MR. MARCH-LEUBA: That is my point.

MR. SCARBROUGH: But my marching orders from my office director at the time was we just can't run this plant up in power and see if the dryer breaks; we have to be comfortable before it goes up, or Scarbrough you're in trouble, right? And so that was the marching orders that we've had ever since I've been involved. And so I think what we're doing here is we're putting down guidance that puts in all of those years of lessons learned so that when a new applicant comes in, a new licensee comes in, they can okay, these are all the things I need to think about. And one of the things we talked about was for--we want this reg guide to be sufficiently informative so that if they follow this reg guide, we won't need to do all the detailed analysis that you're talking about that we're doing; that they're going to have it all here, and they're going to follow through on this, what it is we've talked about with the new reactors with tier 2 star.

Tier 2 star as you know with ESBWR, that whole analysis of the steam dryer is tier 2 star, it's an encyclopedia worth of documents in terms of how they had to do it. One of the thins we talked about is if they put this reg guide in their ITAAC, and it's a commitment that they follow this, we won't make all that encyclopedia tier 2 star. This is what they have to make sure they follow in the ITAAC. And so then we would verify that they're following this as opposed to doing all the detailed analysis that we've done in the past, that we verify that they're following the guidance in the reg guide. So that's some of the things we're thinking about, but I understand your point, but we need to make sure that we're comfortable before they start up the power ascension, to make sure--

MEMBER REMPE: But the pull the string a little further, you said your office director said to do this; that's not how we usually change things is it at the NRC? I mean, is that enough that the director says we will do this, and the staff does this?

MR. SCARBROUGH: If there's a safety problem, it's yes.

MEMBER BLEY: One thing we've seen on numerous occasions is things that were envisioned as investment protection; once they happened and we thought harder about them, they turned into safety issues, and especially anything that might be parts of a reactor coolant system.

MEMBER STETKAR: And it's certainly true in the public's perception.

MEMBER REMPE: I just am wondering--

MEMBER STETKAR: Trying to convince the public that there's a nuance between something breaking inside a reactor vessel that is not important to safety is really difficult, regardless of what you might think about that. That's why the public has been so concerned about the steam dryer issues.

MR. MARCH-LEUBA: Yes, but during the essential testing, you must load methodically and you stop when your steam gauges tell you you are at 20 percent of limits; you don't break anything.

MR. SCARBROUGH: Yes, and we've been fortunate now the--now Quad Cities, you know, they got up and were running for 90 days and they blew it apart, right, and then they tried it again, and this time they made it six months and then blew it apart. So they make it up for a while, but they didn't--and that was the philosophy we had back then.

MEMBER RICCARDELLA: They had the analysis and the strain gauges and all of that when they were doing this?

MR. SCARBROUGH: No. No because it was completely--

MEMBER RICCARDELLA: That's exactly Jose's point.

MR. MARCH-LEUBA: I know a few licensees that will put 10 times more instrumentation for your ascension testing, rather than do it on a license that has to be reviewed.

MEMBER CORRADINI: I think that's--just to repeat the point. The point is if you have an approved testing program, doesn't that trump the need to have a detailed analysis? Because when all is said and done, for safety demonstration, if they have to do the analysis anyway as part of the testing program, but yet the experiments or the power ascension testing with instrumentation is really the proof of the pudding.

MR. ZIADA: Tom, can I add something here please?

MR. SCARBROUGH: Yes, go ahead Samir.

MR. ZIADA: If we take the example of SONGS again. If SONGS had been built according to a reg guide like this reg guide at one point, most likely the problem would have been caught during the design time. First of all, it would have been classified as a prototype, the largest Mitsubishi have designed. Second of all, the codes would have been--must have been validated, which has not happened, and thirdly, the difference between Unit 1 and Unit 2 with the clearances between the two. They should have looked at it and it should have shown that it has no effect. So these three issues are addressed clearly in reg guide 120, and where they can put it and test it, but it still is--we can do anything with it.

MEMBER RICCARDELLA: I think the point is though that the proof of the design isn't just the testing, it's that the testing validates the analysis.

MR. ZIADA: Correct.

MEMBER RICCARDELLA: But still, I think Jose's point is that well, if the staff were just to review how well that testing did at validating the analysis, it probably wouldn't be necessary to completely also review the details of the analysis. The real proof is the validation of the analysis by the testing or by the measurements.

MR. MARCH-LEUBA: And now that I have a little break, let me emphasize that I'm not saying don't do the analysis; I'm saying don't review the analysis.

MR. SCARBROUGH: Right, and that was sort of our philosophy after about the third or--up until the third or fourth Quad Cities failure, and that's when my direction changed.

MEMBER RICCARDELLA: But that's long

behind us now.

MR. SCARBROUGH: I know, and we're getting--that's why we're putting this in here, we're writing this reg guide, because if they follow this reg guide, we don't need to do th detailed analysis anymore, right, because this tells them what's a reasonable approach and what's acceptable. So that's why this reg guide is so important to us, is we're trying to pull in all this lessons learned.

MEMBER CORRADINI: So let me say it back to you; so maybe we misunderstood you. So if they follow the reg guide, you won't review the analysis, you'll simply do as suggested, you'll look at the testing compared to the analysis, but not review the analysis unless there's some deviation?

MR. SCARBROUGH: I don't know who's going to be in charge of that, but following this is intended to be acceptable, right, and I don't know that the staff would just say we never look at anything that you do, because that's not our job. Our job is to look at what the licensee presents, but if they come in and they present that they're following this and they're following this approach, I think it's more of a confirming--for confirming that they're following the reg guide; as opposed to breaking new ground, we'd be confirming that they're following the reg guide. So it would be different. It would be a different type of review, it would be a confirmatory review as opposed to what we do now, which is basically making sure every step of the way is credible.

MR. LUPOLD: We would still review the application and make sure that the licensee is following the guidance which is in the reg guide, and if they are using something different than the guidance, evaluate that. I mean you wouldn't just say --you wouldn't just accept a statement that says well, we followed reg guide 1.20, and we said oh okay, if you did that, then you're fine to go, here's your--here's the safety evaluation. We would not do that.

MEMBER SKILLMAN: Good. Jose, do you have any further comments? Dr. Kirchner, do you have any comment, sir?

MR. KIRCHNER: Yes, thank you Chairman. My concern echoes some of the earlier questioning about your definitions for prototype and non-prototype limited, et cetera. What is the implication across the Commission for use of that terminology going forward? Is this something that will be adopted in other reg guides, and I'm thinking ahead to multiple module plants like the AP-1000 or the new SMRs coming before you. Is this a new set of definitions for what is a prototype and a validated prototype, et cetera?

MR. WONG: These different type of definition have been used in previous revisions of the reg guide. In revision 4, we simply reduced the number of different classifications to make it simpler--

MR. KIRCHNER: My question is beyond just this reg guide, and in terms of using that terminology elsewhere as the Commission takes up new reactor designs, et cetera.

MR. LUPOLD: Right now there is no direction to use this in any other application at this point. We haven't looked at that at this point.

MR. SCARBROUGH: Right, this is just for reactor kernels, just in this application. We're not trying to define prototype or limited type beyond just this discussion that we have here.

MR. WONG: You mentioned about AP-1000; AP-1000 uses prototype/non-prototype classification for their B plan and subsequent plan for the reactor internals.

MR. KIRCHNER: Now secondly, I think Mr.

Lupold already suggested this as a possibility. It seems to me that there's a lot of good information here obviously in lessons learned that--I'll use the word generic; that may not be clinically correct for PWRs as well as BWRs. Would it not make sense to pull out the steam dryer issue and put that in an appendix as you suggested, and then I have a question, and perhaps this is of ignorance. It seems to me you're doing a lot of what I would call detailed design criteria for BWRs based on your lessons learned. Is this the appropriate place to capture that, or should it find its way into other guidance? Specifically, things like not just the dryer, but based on your experience with these standpipe issues, is there some generic guidance that you could provide that says based on experience--I'm not familiar with the exact dimensions--these stand pipes should be no more than two feet or half a wavelength or whatever criteria you want to use to take out this amplifying, whether it's acoustic or other in the plants.

MR. SCARBROUGH: Yes, now we do in the standard review plan 3.9.2, which is the staff's sort of generic guidance for this general area, we do reference back to reg guide 1.20, so we do sort of pull in this guidance there, and then for the ITAAC for the new ESBWR, we do have an ITAAC that relates to the flow through the steam lines to ensure they do not get these resonances, and they're going to do an analysis and GH has already been doing that analysis to show that for their--the steam lines for the ESBWR, they will not see these resonances. So, but we haven't looked into putting that guidance in a different vehicle; that's more design oriented. But that would be an interesting thing to see--

MR. KIRCHNER: That was my feeling. This is a reg guide for operational testing, not for designing of the plants.

MR. SCARBROUGH: Right.

MR. KIRCHNER: But yet you delve into a lot of detail on the BWR issue, particularly the dryers and inferred that the driving functions are coming from X vessel causes. So it strikes me that that's design criteria, not red guidance for operational testing.

MR. SCARBROUGH: Exactly. That's a good point. We'll go back and look at that and see if there is somewhere else also that we can include this. I'd have to talk to maybe the systems branches and see what guidance they have in terms of their system review for steam lines and such, and maybe there's a way to try to copy this guidance into those documents to make sure that the new plants are addressing this for the new reactors and also for maybe SMRs as well. Thank you.

MR. WONG: Yes, the Reg Guide 1.20, the comprehensive vibration assessment program, it consists analysis, the stop testing, and later the assessment of testing results. So this comprehensive assessment program does include the analysis part.

MR. KIRCHNER: No, I understand that. So it seems to be you're dealing with--yes, I agree, but it seems to me you're dealing with fundamental design issues that shouldn't wait for the operational testing phase.

MR. SCARBROUGH: I agree. Thank you. That's a good suggestion. I'll go back and talk to the systems branches and see what documents, design documents they have where we might be able to incorporate this guidance. Thank you.

MEMBER SKILLMAN: I want to thank Jose and Walter for their comments; I want to ask the other members if they might have comments. Pete, any comments to the ?

MEMBER RICCARDELLA: Just a philosophical comment, and I've been working in this industry for close to 50 years now, and I haven't worked specifically on BWR steam drivers, but I've worked on a lot of similar failure problems, operational failure problems, and it seems like when we have a problem like that, we focus in on it like a laser. And we not only solve the problem, we solve it in spades, you know, and we make sure--and I just wonder if it would be better served with a somewhat more balanced approach where we assess the problem, but then we looked at other areas and brought all these other things up partially to speed, rather than just bringing this thing up so much so. And I kind of see that in here; I don't know how to solve it, but it's just kind of an observation that I've made through the years. I don't know if it has any implications at all on this reg guide, but it's just an observation.

MR. SCARBROUGH: And I understand that, and actually if you look back at what happened with the Quad Cities, they kept beefing up the dryer, beefing up the dryer and making it into a brick, right you know, it weighs 100,000 pounds, right? It ended up they put in the acoustics side branches, removed the resonance at all. That old dryer probably was fine just the way it was, you know, but they went through it by beefing up the dryer first rather than looking at hey what's causing that, and it was the resonance. And when they put in the side branches, resonance went away, it flatlined, right? And so they probably didn't need to replace the dryer.

MEMBER BLEY: And it wasn't the resonance in the dryer, it was the resonance--

MR. SCARBROUGH: Yes, it was system. It was the resonance in the steam line.

MEMBER BLEY: It was the system, not the dryer.

MR. SCARBROUGH: Yes, right? And so that's--and so I agree--

MEMBER RICCARDELLA: But yet as we said, we've put in requirements that are so rigorous that in effect, every plant that wants to do an EPU ends up buying and spending the money to buy a new steam dryer, and is that really necessary?

MR. SCARBROUGH: Right, and so if they went the other way and started looking at their steam lines, and if they found resonance, they'd be putting in the acoustic side branches and get the resonance to go away, maybe their current dryer might be--

MEMBER RICCARDELLA: Well aren't there a lot of EPU plants out there that are operating with their old dryers? The ones that were approved before Quad Cities?

MR. SCARBROUGH: I guess there are some, but then I think going up to 16 percent, you know, the Quad Cities was going up quite high. There were a lot of lower ones, like five percent or so that everybody thinks is fine. But yes, there's definitely ways to look at this and I agree, we're guilty sometimes of jumping on something and really piling on when we have a problem. You know, it's just the way we are.

MEMBER SKILLMAN: Well Tom, will the revised Reg Guide 1.20, which is Rev. 4, give access to the line of thinking that Pete just described? Is there an exit route in this revision that would suggest if the applicant or the owner can demonstrate that by use of side pipes or standing pipes or other means, such that the resonances are defeated, that the dryer might be just fine?

MR. SCARBROUGH: Yes.

MEMBER SKILLMAN: Is that in there now?

MR. SCARBROUGH: There is a discussion of side branches, things like that, but--

MR. HAMBRIC: This is Steve. Let's not--that's overly simplifying it. Susquehanna didn't have that kind of resonance, and it cracked, so there's other things, too. There's a lot of low frequency stuff we've been messing with lately, the reactor recirculation pump down, it's not always the valve resonance. There's other stuff that hits the dryers, too, so.

MEMBER SKILLMAN: Fair enough. Thank you, Steve.

MR. HAMBRIC: Complicated structures, so I don't think we can just write everything off because if we took care of the side branch, everything should be okay.

MEMBER SKILLMAN: Thank you. Good response. Thank you. Pete, anything else?

MEMBER RICCARDELLA: No.

MEMBER SKILLMAN: Thank you, Pete. Mike, anything?

MEMBER CORRADINI: Just I had mentioned before, about some sort of screening suggestions in the reg guide, but I think you've caught that and you mentioned it, so--

MR. SCARBROUGH: I wrote that down, thank you.

MEMBER SKILLMAN: Thank you. Joy?

MEMBER REMPE: Well, to kind of go back

to Pete's comment a little more, and what we briefly discussed with Browns Ferry, they said the data were bad, was--and they gave up, and I guess their application has a replacement steam dryer in it, but I mean how long was the discussion about well your data are bad, and what triggered the licensee to decide oh, they'll just go buy some new steam dryers for three units?

MR. SCARBROUGH: Yes, well I was involved with Browns Ferry years ago, and they were just talking, started talking about a replacement or the power upright. And so it spanned five or six years of -- so what triggered--can you just answer--do you know what triggered Browns Ferry to go for a replacement steam dryer?

MEMBER REMPE: Steve did say they had poor data that they -- lots of noise and things like that, but why not try and do something else?

MEMBER SKILLMAN: Please identify yourself.

PARTICIPANT: The reason why Browns Ferry withdrew the first application was because the data was not consistent, and also they did not use consistent methods in bench marking their methodology. And then they kept modifying the dryer, and they were not able to show that it met the allowable limits. So because it was an existing dryer, and they couldn't qualify, they finally withdrew that application. So there were a multiple number of issues associated with the submittal of the Browns Ferry application. So then they decided that they will replace the dryer, and then also change their contractors. And then they just came back about a year ago, not quite a year ago, about nine months ago with the new application, and with new dryers.

MEMBER REMPE: Thank you. And I don't have any other comments.

MEMBER SKILLMAN: Thank you. John, any comments please?

MEMBER STETKAR: No sir, nothing.

MEMBER SKILLMAN: Thank you, John. Dennis, comments please.

MEMBER BLEY: Nothing additional; I really got a lot out of today's presentation, thanks. I think it's a really solid reg guide.

MR. SCARBROUGH: Thank you.

MEMBER SKILLMAN: Derek, would you make sure the line is open, please? For the record, there's no one in the room to make a public comment; we'll check the phone line for a second here.

Members, please don't scoot, we've got a bit of business when we close the microphone here, so please don't leave.

DEREK: It's open.

MEMBER SKILLMAN: Good afternoon, this is the ACRS, by chance is anybody from the public on the line please? If someone is there, would you simply say hello? Hearing none, thank you. Let's close the line. Members, the question at hand is are we satisfied with the reg guide in its current configuration such that we could write a letter to NRR saying we do not wish to have further action on this, or do you think we should bring it to the full committee for the full committee's consideration, and then for a full committee letter?

MEMBER CORRADINI: I have a question for the staff. So I need to hear what Tom--his plans are. Are your plans to make modest, clerical changes to the reg guide, or substantial changes? You get to define substantial; I don't want to audit it.

MR. SCARBROUGH: What my plan is, we're going to sit down with the consultants and go over everything we've heard; we're going to prepare a redline markup of this and incorporate what we've heard of your suggestions, and then what we've talked about was sending it back to Derek, and let you all take a look at it and see if we've captured everything. We thought we'd also look at the transcript and improve it, and then send it back to you and let you all decide if we've captured your issues, or if there's additional changes that you all might want to relay through Derek back to us, and we'd be happy to incorporate those. Because we're trying to make it the best possible document, so we have no problem doing that, and I think that would be great to improve it that way. So that's my plan.

MEMBER BLEY: Point of process. The full committee could write a letter if we take it to full committee. We don't do anything, although at a PNP in the future, we could recommend that the Executive Director send a memo back, but we don't usually do that, but we could.

MEMBER SKILLMAN: Yes, that's my failure in being clear with the admin. What I'm really trying to get to is where do we want to go from here? It sounds to me like the best thing we should do is to allow you to amend Rev. 4, do an adjusted Rev 4 and to allow those of us who did this review to review it again, and to then make a recommendation to our colleagues.

MR. SCARBROUGH: Right, that would be great.

MEMBER SKILLMAN: Does that make sense?

MEMBER BLEY: Are you saying to have another subcommittee, or just to read it?

MEMBER SKILLMAN: No, just to read it and caucus among ourselves, and then make a decision what to do. So I'm clear for the record, here's what I believe is going to happen. Tom, you and your team are going to take what you've heard today, and you're going to spend some time considering what we've offered, what our consultants have offered. You'll look at the transcript, and you will amend the present revision 4. And then you'll send it back to Derek, and Derek will send it to those of us who have been involved and ask us members what do you think, what do we do with it from here? And at that point, we as the combined subcommittee will make an answer back or give an answer back to Derek where to go from here.

MR. SCARBROUGH: Very good, yes.

MEMBER SKILLMAN: Is that what we agreed to? Does that work? Everybody? We've got a plan. Tom, thank you very much.

MR. SCARBROUGH: Thank you.

MEMBER SKILLMAN: Any other comments? We

are adjourned.

(Whereupon, the proceedings were concluded at 4:24 p.m.)

Regulatory Guide 1.20 “Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Startup Testing”

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ACRS Subcommittee Briefing
May 17, 2016

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

Agenda

- Overview of Regulatory Guide (RG)
- Reasons for Revision
- Summary of Revisions
- Specific Lessons Learned
- Public Comments Received and NRC Responses
- Summary and Conclusions

Overview of RG 1.20

General Information

- Applicable Regulations
  - 10 CFR 50
    - Appendix A, GDC 1
    - Appendix A, GDC 4
    - Appendix B
- RG 1.20 provides guidance on acceptable methods for developing and implementing a Comprehensive Vibration Assessment Program (CVAP) for reactor internals at nuclear power plants
  - Particular attention is given to avoidance of adverse effects from Flow-Induced Vibration (FIV), Acoustically Induced Vibration (AIV), and Mechanically Induced Vibration (MIV)
- Related Guidance: SRP 3.9.2, “Dynamic Testing and Analysis of Systems, Structures, and Components”

Overview of the RG

Technical Issues

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- Guidance on classification of reactor internals as prototypes, limited prototypes, or non-prototypes
  - Considers multi-unit plants/applications
  - Considers individual component replacement
- Analysis procedures
  - Forcing functions (FIV, AIV, MIV)
  - Response modeling, including convergence of stress calculations
  - End-to-end benchmarking
- Measurement procedures
  - In-plant measurement issues

Reasons for Revision of RG 1.20

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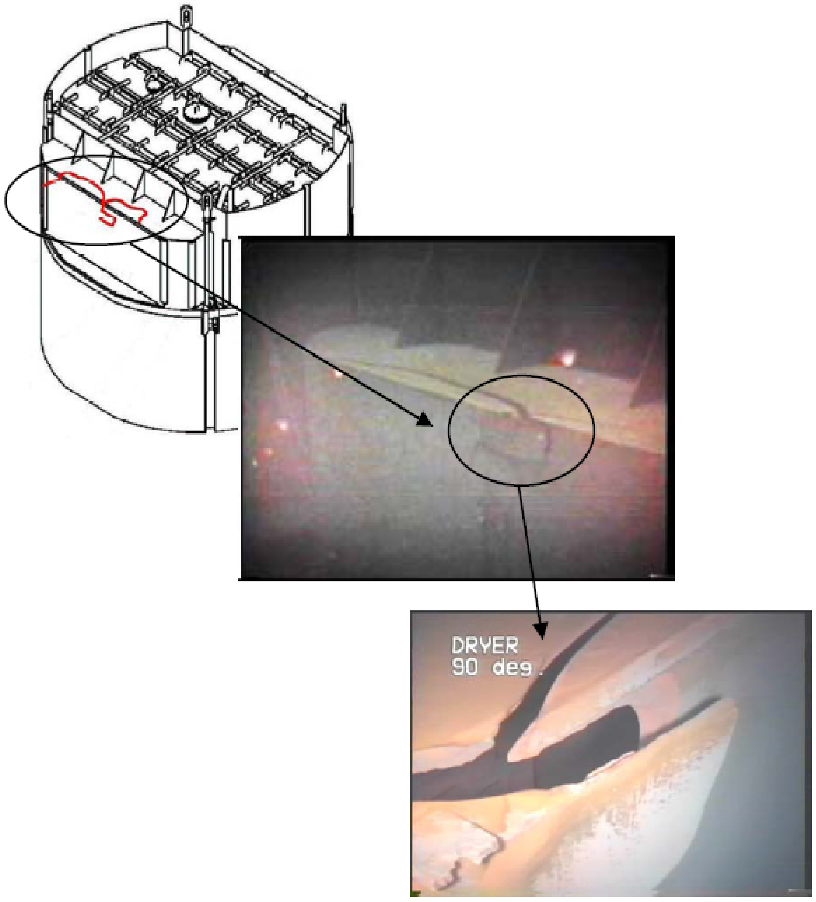
- Update prototype definitions
  - Rev. 4 includes only 3 classifications (reduced from 8)
- Reorganize into more concise and useful sections
  - Ensured consistency with organization of revised SRP 3.9.2
- Add numerous lessons learned for analysis and measurement procedures
  - BWR extended power uprate (EPU) applications (steam dryer FIV and AIV)
  - ESBWR Design Certification application (steam dryer)
  - South Texas ABWR Combined License application (steam dryer, and reactor internals
- Applicability to small modular reactor (SMR) applications
  - Control rod drive mechanisms (CRDMs) might be inside reactor pressure vessel (RPV) module
  - Close proximity of reactor internals and potential interactions

BWR Steam Dryer Lessons

- Many RG 1.20 improvements are based on lessons learned from BWR EPU and new plant applications involving steam dryer structural integrity
  - Used as examples throughout revised RG
  - Lessons are applicable to other reactor internals



- Minor adjustments to geometry, structural properties, and/or operating conditions can lead to significant changes in structural vibration and alternating stress

Technical Revision Summary

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- Prototype definitions
- Analysis procedures
- Measurement procedures

Technical Revision

Prototype Definitions

- Prototype
  - First-of-a-kind or unique design for which no previous "valid prototype" can be referenced
  - Becomes valid prototype after completion of CVAP with no adverse inservice vibration phenomena
- Limited prototype
  - Demonstrate by test or analysis that differences from valid prototype have no significant impact
- Non-prototype
  - Substantially the same arrangement, design, size, and operating conditions as a valid prototype

Technical Revision

Key Excitation Mechanisms

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- FIV and acoustic resonances produced by fluid flow across or parallel to structural components
- AIV caused by reactor pump pressure pulsation or pressure waves emanating from acoustic resonators such as the standpipes of safety relief valves (SRVs) in main steam lines (MSLs)
- MIV of reactor internals and other structural components caused by structure-borne vibration transmission from reactor recirculation pumps (RRPs) and other machinery

Technical Revision

Analysis Procedures

- Structural, Hydraulic, and Acoustic Modeling
  - Modes of Vibration
  - Structural Damping
  - Frequency Response Functions
- Forcing Functions
  - Flow Excitation with Feedback and Lock-In Mechanisms
  - Scale Model Testing (SMT)
  - Computational Fluid Dynamics (CFD) Modeling
  - Force Inference Approaches
  - Mechanical and Acoustic Forces from RRPs

Technical Revision

Analysis Procedures (continued)

- Computing and Benchmarking Structural and Acoustic Operational Response
  - Benchmarking of Overall (End-to-End) Computed Response
  - Stress Convergence and High-Cycle Fatigue Evaluation
  - Operational Vibration and Stress Acceptance Criteria
- Preoperational and Testing Analysis

Technical Revision

Measurement Procedures

- Specific guidance for BWR steam dryers
- In-plant measurement issues
- Vibration measurement program documentation
  - Instrumentation and data acquisition
  - Preoperational and power ascension test plans
  - Acceptance criteria
  - Test duration and conditions
- Inspection criteria

Technical Revision

Limited and non-Prototype

- Simplified analysis and measurement sections
- Applicants reminded that seemingly minor changes in geometry or operating conditions can lead to significant increases in FIV, MIV or AIV
  - Testing and analyses needed, but reduced in scope
  - Case by case evaluations by staff

Technical Revision

Specific Lessons Learned

- Excitation mechanisms
- Structural modeling
- Acoustic modeling
- Forcing functions
- SMT
- End-to-end benchmarking
- Structural stress modeling
- Instrumentation
- In-plant measurements
- Power ascension

Technical Revision

Specific Lessons Learned: Excitation Mechanisms

- <u>Relevant Excitation Mechanisms for Dynamic Analysis</u>

  - Not well defined in Revision 3 of RG 1.20
  - Operational experience with acoustic resonances of valves on main steam lines
  - Operational experience of structural failure that may have been due to RRP excitation at the vane passing frequency

  ➡ *Brief introduction of mechanisms (FIV, AR, AIV and MIV)*

  ➡ *Flow excitation by various oscillation modes of shear layers*

  ➡ *Resonance of the acoustic trapped modes inside main steam isolation valves (MSIVs)*

  ➡ *Boiling water excitation of the immersed lower portion (skirt) of BWR steam dryer (included in end-to-end benchmarking)*

Technical Revision

Specific Lessons Learned: Structural modeling (1/3)

- <u>Structural Modes</u>
  - Previous application materials show differences between as-modeled and as-measured modal frequencies and mode shapes
  - Used to establish uncertainty in structural modeling resonance frequencies
  - ➡ *Forcing functions should be compressed and expanded in frequency to span uncertainty (+/-10% has been acceptable in past applications)*
  - ➡ *Force inference procedures which combine measured response and modes from models need to properly account for uncertainty in resonance frequencies*

Technical Revision

Specific Lessons Learned: Structural modeling (2/3)

- Structural Damping
  - Rayleigh damping is commonly used for time-domain structural analysis. Some applications chose anchor frequencies either:
    - Above a strong low frequency forcing function
    - Below a strong high frequency forcing function

  ➡ *Anchor frequencies must be chosen to ensure conservative response are calculated at peak loading frequencies*

  - Some applications have applied additional damping due to hydrodynamic viscous effects (perforated plates, for example)

  ➡ *Acceptable when substantiated and validated*

Technical Revision

Specific Lessons Learned: Structural modeling (3/3)

- Documentation and Justification
  - Previous steam dryer EPU applications initially provided incomplete or inadequate documentation and benchmarking of vibration and stress calculation methodologies
  - Also, previous applications showed sometimes significant differences between as-designed and final as-built conditions and final alternating stresses
  - ➡ *A more formalized and rigorous documentation and justification of procedures is therefore warranted*

Technical Revision

Specific Lessons Learned: Acoustic modeling

- <u>Acoustic models are often used to calculate structural loading distributions</u>
  - Previous applications have initially provided inaccurate modelling of acoustic properties, sound wave spatial discretization, and nozzle areas
  - ➡ *Acoustic properties (sound speed, mass density, damping) may be adjusted during benchmarking, but must not deviate excessively from physically justified values*
  - ➡ *Spatial discretization must be at least 6 elements/acoustic wavelength*
  - ➡ *Circular nozzle areas must be properly represented in discretized meshes*

Technical Revision

Specific Lessons Learned: Forcing Functions (1/3)

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- <u>Bounding Expressions of Forcing Functions</u>

  - Number and arrangement of operating pumps can vary resulting in biased flow distribution inside RPV
  ➡ *Use the reactor flow distribution which results in the highest possible local flow velocities*

  - Dynamic response of reactor internals depends on the phase distribution and the correlation length of fluid forces
  ➡ *Use conservative simplifications and approximations to ensure that forcing functions are bounding*

  - Some initial applications extrapolated resonance amplitude from response over an excessively wide frequency range
  ➡ *Use a narrow frequency band centered around the resonance peak to estimate the growth rate of resonances*

Technical Revision

Specific Lessons Learned: Forcing Functions (2/3)

- <u>Effect of Geometry Details</u>
  - Some self-excitation mechanisms can be affected strongly by small changes in geometry:
    - sharpness of a corner at flow separation
    - length or diameter of the standpipe of a SRV
    - clearances at structure supports
    - revolution per minute (RPM) of RRP

➡ *CFD and SMT models must be accurate replicas*

➡ *Analyze the effects of individual changes and the cumulative effects of all deviations from previous successful design*

➡ *Analyze components which are similar in design but larger in size than a previous successful design*

➡ *Analyze effect of changes in the RPM of RRP*

Technical Revision

Specific Lessons Learned: Forcing Functions (3/3)

- <u>Numerical Simulations</u>

  - CFD codes are often used to estimate flow velocities which are used to estimate forcing functions
  - Although presently not common, CFD techniques may in the future assist in developing forcing functions
  - Boundary conditions in numerical simulations (acoustic, hydrodynamic or structural) are often variable or ill-defined. This needs conservative assumptions to produce bounding response

  ➡ *All simulation codes must be validated on systems which are similar to the plant components in both geometrical complexity and flow regime*

  ➡ *Use feasible boundary conditions which result in bounding dynamic response*

Technical Revision

Specific Lessons Learned: Scale Model Testing (1/3)

- <u>Dynamic Similitude</u>
  - Previous applications used SMTs to estimate forcing functions

  ➡ *Ensure dynamic similitude of the SMTs:*
    - *Mach number for flow-acoustic coupling, and fluid-elastic parameter for fluid-structure interaction*
    - ***Only conservative** distortions of model parameters are acceptable*
- <u>Effect of Reynolds Number (Re)</u>
  - The Reynolds number is much lower in SMT than in plants
  - Previous SMT showed results dependence on Re

  ➡ *Demonstrate that the SMT results are not influenced by further increases in the Reynolds number*

Technical Revision

Specific Lessons Learned: Scale Model Testing (2/3)

- <u>Effect of Transient Test Conditions</u>
  - SMTs are often performed at transient test conditions (variable pressure, temperature, and velocity)
  - SMT results are very sensitive to variations in test conditions
  - Measured resonance peaks become wide and weaker
  - ➡ *Perform multiple test runs at the same test conditions to obtain reliable SMT results with reasonable uncertainties*
  - ➡ *Perform sample size sensitivity analyses to ensure bounding estimate of the forcing functions*

Technical Revision

Specific Lessons Learned: Scale Model Testing (3/3)

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- Bump-Up Factor (BUF)
  - The **ratio** between the dynamic loading at a power level to that measured at a lower power level
  - Obtained from SMT and used to estimate in-plant forcing functions from in-plant measurements at lower power levels
  - Found to be frequency and location dependent
  - Uncertainties in transient tests can cause BUF underestimates

➡ *BUFs must be validated with plant test data*

➡ *Increase range of SMT to provide margin against uncertainties in test conditions*

➡ *BUF cannot be less than the square of flow velocity ratio*

Technical Revision

Specific Lessons Learned: End-to-end benchmarking

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- Benchmarking: previous applications have benchmarked individual component of the analysis procedure, and combined their bias error corrections and uncertainties (B/U) using square root sum of the squares (SRSS)
  - Such an approach assumes that all forcing function and response mechanisms are included in the analysis procedure
    - Not always true (as learned from steam dryer experiences)

  ➡ *End-to-end benchmarking is preferable*
    - *On-structure vibration and strain measurements include all sources and response mechanisms*
    - *Single B/U captures any neglected sources or erroneous response modeling*

Technical Revision

Specific Lessons Learned: Structural Stress Calculations (1/3)

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- Structural Stress Procedures

  ASME BP&V Code Section III, Subsection NG

  – Provides stress and fatigue limits for core support structures; adopted for nonsafety-related BWR steam dryers to preclude loose parts generation

  – Limits on primary stress, primary + secondary stress, and fatigue due to cyclic loading all need to be satisfied

  – Due to high frequency excitation mechanisms, the potential for high cycle fatigue must be evaluated, requiring conservative estimates of local stress concentrations, such as at fillet welds

  ➡ *Detailed guidelines for structural analysis included in RG; ensure convergence of stress solution through successive mesh refinement*

Technical Revision

Specific Lessons Learned: Structural Stress Calculations (2/3)

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- <u>Analysis Procedures</u>
  - The input time step and model mesh refinement for the structural analysis must be short enough and fine enough, respectively, to capture both rapid time variations and spatial variations of the dynamic input
  - Structural model meshes and surface loading model meshes are nearly always different

➡ *Solution time step should be no larger than 0.125 times the shortest period of interest (e.g., 0.0005 sec. for 250 Hz)*

➡ *The input time increment may be no larger than 0.25 times the shortest period of interest, with 0.125 times preferred*

➡ *Checks on the load mapping of localized loading distributions, particularly in areas of expected high stress, need to be conducted*

Technical Revision

Specific Lessons Learned: Structural Stress Calculations (3/3)

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- Weld Stress Concentrations
  - Follow the fatigue evaluation procedures and acceptance criteria of ASME B&PV Code, Section III, Subsection NG, for fillet welds
  - Stress concentration factors needed to ensure reasonable estimates of total stress (primary+secondary+peak) for fatigue evaluation of fillet welds

➡ *Two acceptable methods described*

  ➡ *1. Four times the nominal stress at the juncture in a global model without fillet details*

  ➡ *2. Three times the linearized stress on the throat of the fillet in a submodel analysis with nominal fillet geometry included*

Technical Revision

Specific Lessons Learned: Instrumentation (1/2)

- Measurement locations
  - Selection of measurement locations which are well correlated to peak vibration and stress regions ensures rigorous monitoring of a structure's actual condition during power ascension

  ➡ *Accelerometers need to be placed at or near predicted peak response locations*

  ➡ *Strain gages need to be placed at or near locations with predicted minimum gradients in strain*

  ➡ *Coherence needs to be maximized between sensor and critical response locations*

Technical Revision

Specific Lessons Learned: Instrumentation (2/2)

- <u>MSL Strain Gage Arrays</u>
  - Internal pressures inferred from hoop strain measurements
  - Past applicants have reported difficulties measuring repeatable MSL hoop strains within the same plant, or between plants
    - Sensor failures, background noise problems, and operator error have all led to erroneous loading estimates
  - ➡ *At least four working gages around circumference needed (more preferred for risk mitigation if some sensors fail)*
  - ➡ *Static pressurization calibration recommended*
  - ➡ *Updated measurements needed before power ascension*

Technical Revision

Specific Lessons Learned: In-plant measurements (1/2)

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- Previously submitted measurements have been unacceptable
  - Q/A issues (wrong sensor channels, improper calibrations)
  - Poor data quality (high Electromagnetic Interference [EMI], unexplained data corruption)

➡ *General in-plant measurement guidance provided*

➡ *Instrumentation need to function properly in plant*

➡ *As-welded strain gage calibrations needed, periodic shunt recalibration recommended*

➡ *Instruments/cabling should be far from high EMI regions*

➡ *Data acquisition systems should be calibrated*

Technical Revision

Specific Lessons Learned:
In-plant measurements (2/2)

- <u>Noise reduction methods</u>
  - Electrical tones (60 Hz multiples, RRP drive frequencies) often add noise to measured data
  - All measurement systems have a broad-band noise floor
  - ➡ *Noise reduction techniques acceptable provided they do not lead to excessive signal reduction and unreasonable data*
  - ➡ *Notch filtering to remove electrical tones should be used with care, perhaps with ‘backfilling’ of averaged signal*
  - ➡ *Coherence processing and wavelet noise reduction acceptable but must be substantiated*
  - ➡ *Use same noise reduction method in benchmarking and during power ascension measurements*

Technical Revision

Specific Lessons Learned: Power Ascension (1/3)

- <u>Power ascension limits</u>
  - Sensors, instrumentation wiring, data acquisition systems, and reactor response may change slightly over time due to aging and other effects
  - Root mean square (RMS) and/or frequency-dependent limits may be used

➡ *Since limits are based on relative differences between a base state and future condition, they should be updated prior to power ascension*

➡ *If peak or RMS limits are used:*

(a) Use sufficient number and type of sensors and locations

(b) Ensure all important resonance and forcing function frequency peaks are bounded

Technical Revision

Specific Lessons Learned: Power Ascension (2/3)

- <u>Limit violations and reanalyses</u>
  - Full structural reanalyses are time consuming, and often impractical during power ascension
    - Monitoring sensors have finite lives
  - ➡ *Reanalysis may be performed using approximate methods that have been shown to be reasonable and conservative in previous benchmarking*
  - ➡ *Final structural analysis after completion of power ascension should be conducted using full analysis procedures*

Technical Revision

Specific Lessons Learned: Power Ascension (3/3)

- <u>Acceptance limit updating and trending</u>
  - Acceptance limits are updated at each power ascension level
  - Responses are projected to full power level using trending analysis and compared to acceptance limits

  ➡ *Trending must be based on data at several lower power levels*

  ➡ *For coupled resonance behavior, trending needs to apply conservative functions to ensure worst-case response at higher power levels is adequately bounded*

Addressing Public Comments

and NRC Responses

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- 53 Comments received from:
  - Westinghouse
  - General Electric – Hitachi
  - Private individual
- All comments addressed
  - Comments led to several clarifications of draft RG revision
  - Comments consistent with intent of revisions: improve and clarify guidance for reactor internal CVAP
- Significant comments (those that led to revisions) summarized on following slides with NRC responses
  - All public comments and NRC responses provided prior to meeting

Public Comments & NRC Response (1/10)

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	Public Comment	NRC Response
Guidance vs background	It is often unclear what text is background information vs. expectations for a predictive analysis, measurement program, or inspection program. Rework the document to clearly define the regulatory expectations for a CVAP separately from background or lessons- learned information.	The RG was revised to better distinguish background information from regulatory guidance. "Reason for Revision" section of RG includes statement to clarify that much of the revised guidance uses steam dryer lessons learned as examples. Although these examples are specific to dryers, the guidance is applicable to all nuclear power plant internals.
Safety Margin	In Section C.1.4, define "high margin of safety."	An example of what the staff considers to be a high margin of safety was included (e.g., a margin of safety of 2.0 in the steam dryer alternating stresses).

Public Comments & NRC Response (2/10)

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	Public Comment	NRC Response
Excitation by boiling water	In Section C.2.a, provide guidance on the approach to be utilized to determine the hydrodynamic loading on the steam dryer due to "boiling water rumbling."	The sentence was modified to clarify the boiling water sources, and include other internal dynamic forces which are difficult to quantify. Additional guidance for difficult-to-quantify internal forces is provided in Section C.2.1.3 which advocates using end-to-end benchmarking of on-structure measurements so that bias errors can be used to account for any unaccounted sources.
Boundary conditions	Section C.2.1.1, last paragraph should be reworded to indicate that "ill-defined boundary conditions" should be evaluated where they have a significant impact on the response of the component. In some case, test data shows that installation/assembly does not affect the frequency response of the component.	The sentence was modified to call for assessment of boundary condition variability when that variability leads to non-negligible response differences, not only "significant" response differences.

Public Comments & NRC Response (3/10)

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	Public Comment	NRC Response
CFD validation	In Section C.2.1.2, Subheading “CFD Modeling,” Paragraph “b,” reword to replace “including proper definitions and representations of the smallest flow areas” with more general guidance to appropriately consider the effect of small flow passages. Rephrase the statement to provide general guidance to use sound judgment and provide validation where necessary in CFD modeling.	This section was revised to replace “the smallest flow areas” with “small flow passages.” No changes, however, were made regarding CFD validation because this issue is addressed in Paragraph “a.”
CFD validation	In Section C.2.1.2, Subheading “CFD Modeling,” Paragraph “c”: The term “local velocity” is ambiguous, and could be misinterpreted. Further, depending on circumstances, higher local velocities may not result in more limiting flow-induced loads. Recommend rewording the guidance to ensure effects such as high local velocities are appropriately considered.	This section was revised to replace “the maximum possible flow velocity” with “high local velocities.” No other changes however were made since Paragraph “c” does not state that more limiting flow-induced loads result from higher local velocities. Instead, it states that high local flow velocities need to be taken into account.

Public Comments & NRC Response (4/10)

	Public Comment	NRC Response
End-to-end Benchmarking	In Section C.2.1.3, Subheading, “Benchmarking of Overall (End-to-End) Computed Response,” first paragraph, modify the guidance to “validate the simulation of intermediate quantities, such as loads….” to reflect that the <u>load measurement/prediction comparisons are supplemental and are not necessary</u>.	<u>The sentence was modified to clarify that the supplemental measurements are helpful, but not always necessary</u> when end-to-end benchmarking is used.

Public Comments & NRC Response (5/10)

	Public Comment	NRC Response
Stress Analysis of Filet Welds	Section C.2.1.3, Subheading “Stress Convergence and High-Cycle Fatigue Evaluation,” paragraph “c”: Method 2 – Is there justification (e.g., publication or test data) that supports reducing the weld fatigue strength reduction factor (FSRF) from 4 to 3? This is not consistent with ASME Code, Section III, subsection NG.	Method 2 provides a level of conservatism consistent with the guidance in ASME BPV Code Section III, Subsection NG, and is acceptable to NRC for calculating the alternating stress for two-sided fillet welds. In Method 2, the nominal geometry of the fillet weld is explicitly modeled using solid elements. The value of the linearized, converged stress on the throat, taken at the root, and multiplied by 3, provides alternating stress predictions for fatigue analysis that are consistent with Method 1. This was determined by parametric study of both Method 1 and Method 2.

Public Comments & NRC Response (6/10)

	Public Comment	NRC Response
Component Instrumentation	In Section C.2.2, first paragraph, revise “Instrumentation will be needed for new components that have no operating experience” to add allowance for justification for no instrumentation for this new component.	The statement was revised to enable flexibility for the instrumentation of new components that have no operating experience.
Test Configuration and Condition	Section C.2.2.3, paragraph “e” only discusses fuel assemblies, but should be generalized to address all significant differences between the CVAP test configuration and conditions and normal operating configuration and conditions.	The paragraph was expanded to address test configuration and conditions.

Public Comments & NRC Response (7/10)

	Public Comment	NRC Response
Component Modification	The paragraph on page 9 of Section C.1.2 did not address the situation where only one or two components change and the rest of the components remain the same as the prototype. The changes may have significant effect on these one or two components but not on the others. Will the entire reactor internal assembly be classified as prototype because it cannot be demonstrated that there is no effect on all components?	The introduction to Section C.1 was expanded to clarify the differences between the full reactor internals and individual components. Additionally, a new Subsection 1.5, "Special Considerations for Replacement / Modification of Individual Reactor Internal Components" was added to address individual component replacement / modification.

Public Comments & NRC Response (8/10)

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	Public Comment	NRC Response
Bias and Uncertainties	Using Section C.2.1.3, fourth paragraph as an example. At many places, addressing bias and uncertainty is required. Even though determining the uncertainty of the experimentally collected data can be done, performing rigorous statistical analysis for the theoretically derived forcing function and the finite element analysis uncertainties and the propagation of the variable uncertainties can be very difficult and does not add value to the program. Most of the uncertainties during the analysis are addressed by using conservative assumptions.	Paragraph 5 of the Background section in Section B, "Discussion" already provides a general summary of acceptable methods for determining bias errors and uncertainties, along with the benefits of end-to-end benchmarking which can eliminate the need for cumbersome component-level benchmarking. To further clarify the discussion, this section was revised to mention the acceptable use of conservative assumptions (provided they are substantiated).

Public Comments & NRC Response (9/10)

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	Public Comment	NRC Response
Stress Terminology	Using Section 2.1.3, Subheading "Stress Convergence and High-Cycle Fatigue Evaluation," paragraph "c" as an example. Throughout the RG, the term "peak stress" has been misused to refer to "total stress." Refer to NG-3213.10 and NG-3213.13 for the definitions of peak stress and total stress.	The stress terminologies were revised as necessary to be consistent with the ASME BPV Code Subsection NG terminologies.
Fuel Assembly Disposition	Section C.2.2.3, paragraph "e" does allow conducting the test without the dummy fuel if it is justified that such condition will yield conservative results. However, the conservative results may not always be achieved without the fuel due to many factors that affect the final response such as the flow rate, structural frequency and temperature. Higher flow rate or lower temperature may not lead to conservative stresses due to the structural frequency aspect of the analysis.	This section was revised to allow testing without real or dummy fuel assemblies if it is justified by analytical or experimental means such that the test condition will yield reasonable results.

Public Comments & NRC Response (10/10)

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	Public Comment	NRC Response
Reactor Pump Vibration	In Section B and Section C.2(c) the statement about studies of past failures have determined that the steam dryer in a BWR plant experienced fatigue failure caused by vibration transmission from the reactor pumps at the vane pass frequency (VPF) is misleading because <u>it was not conclusive that the reactor pump VPF vibrations were the sole cause of the failure</u>.	The RG sections were modified to state that <u>the reactor recirculation pump VPF tones may have contributed to the fatigue failure.</u>

Summary and Conclusions

- RG 1.20 revised
  - Simplifies prototype classifications
  - Addresses many lessons learned from EPU and new reactor applications
  - Ensures reasonable applicability to SMR applications
- Revised RG provides improved guidance to ensure structural integrity of reactor internals subjected to FIV, AIV, and MIV
- Public comments received and addressed
  - Westinghouse, GEH, and private individual provided comments
  - Several clarifications made to the draft RG revision based on public comments
- RG 1.20 Rev. 4 ready for final publication

Backup Slides

RG 1.20

ACRS Subcommittee Briefing

May 17, 2016

Overview of NRC RGs

- RGs identify one or more method(s) that the NRC has determined to be acceptable (but not required)
- RGs do not impose requirements
- Applicants are free to use an alternative method, provided that they demonstrate to the NRC that the selected method satisfies applicable regulations
- Use of RGs by applicants conserves staff resources and simplifies licensing because the guides identify methods that the staff has already determined to be an acceptable approach to meeting the regulations

RG Revision Process/Timeline

Draft RG Issued for Public Comment in Federal Register	July 2, 2015
Initial Comment Period Response Date	August 31, 2015
Total 53 Comments Received	
Westinghouse Comments Received	August 26, 2015
GEH Comments Received	August 31, 2015
Jianfeng Yang Comments Received	August 31, 2015
Public Comments Addressed and RG finalized	December 25, 2015
RG Issued to NRO/NRR for Concurrence Review	March 21, 2016
OGC Preliminary Review	April 7, 2016
ACRS Subcommittee Review	May 17, 2016
Incorporate Any ACRS Recommendations (TLs)	
OGC Review for NLO (Usually 2-weeks)	
Publish on the FR (Approximately 1- week)	

Technical Revision Details

Prototype Definitions - continued

- Multi-unit plants
  - Prototypes, limited prototypes, and non-prototypes for multi-unit plants on a single site or for a standard design at multiple sites
- Individual component replacement
  - Same definitions apply for individual components
  - Show that component replacement will not significantly affect other components

Technical Revision Details

Examples of Internals - BWRs

- Chimney and partitions
- Chimney head and steam separator assembly
- Steam dryer assembly
- Feedwater spargers
- Standby liquid control header, spargers, and piping
- RPV vent assembly
- Core plate
- Top guide
- Control rod drive housing and guide tube
- Orificed fuel support
- Jet pump and support
- Shroud and shroud support
- Core plate and reactor pump differential pressure lines
- in-core monitoring housing system/in-core guide tubes and stabilizers

Technical Revision Details

Examples of Internals - PWRs

- Core barrel
- Upper core support assembly
- Lower core support assembly
- Control rod guide assembly
- In-core instrumentation guide tubes
- Flow distribution device
- Heavy reflector
- Irradiation specimen baskets

Although this regulatory guide applies to reactor internals, it provides guidance that could be helpful for the evaluation of potential adverse flow effects on steam generator (SG) internals and tubes in PWRs

Technical Revision Details

Examples of Internals - SMRs

For SMRs, reactor internals might include the following additional components because of their location inside the integral RPV module, even though some components might not be traditionally classified as reactor internals:

- Reactor Recirculation Pumps (RRPs)
- Riser
- SGs
- Pressurizer
- CRDMs and supports
- Feedwater lines

BWR Steam Dryer FIV and AIV

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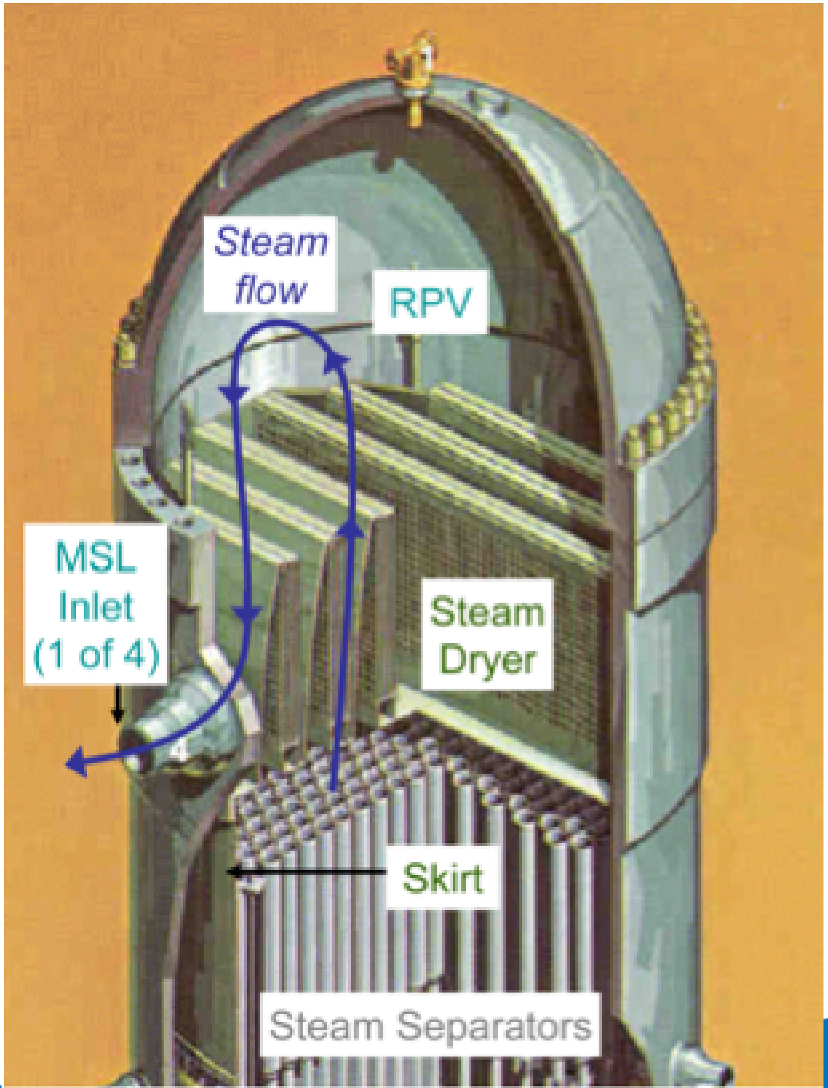
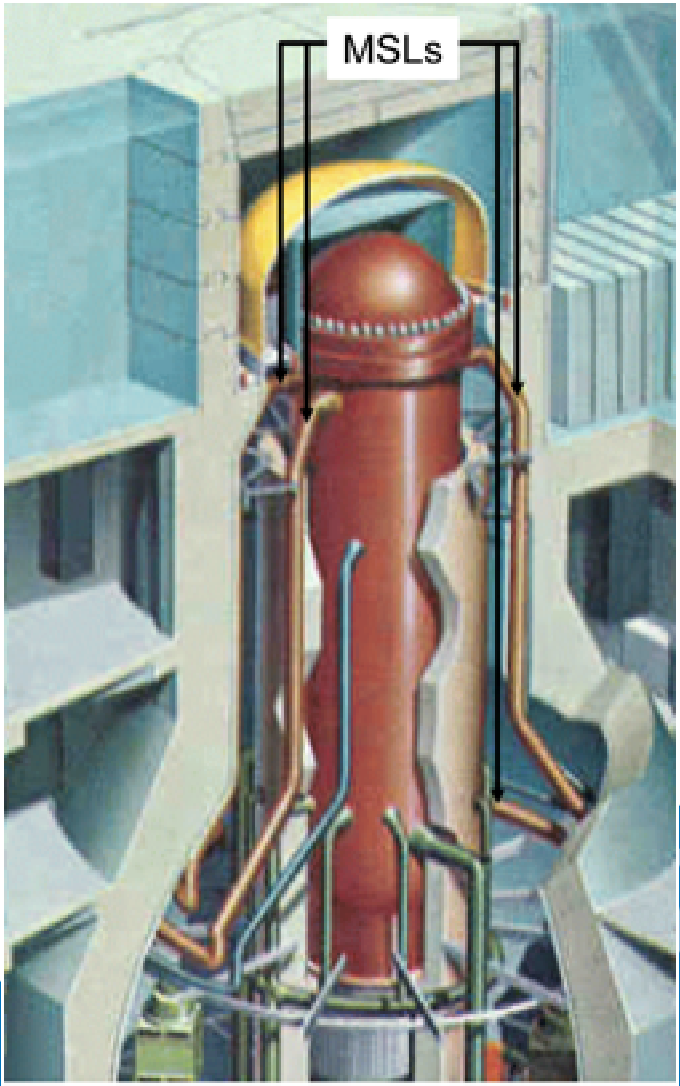
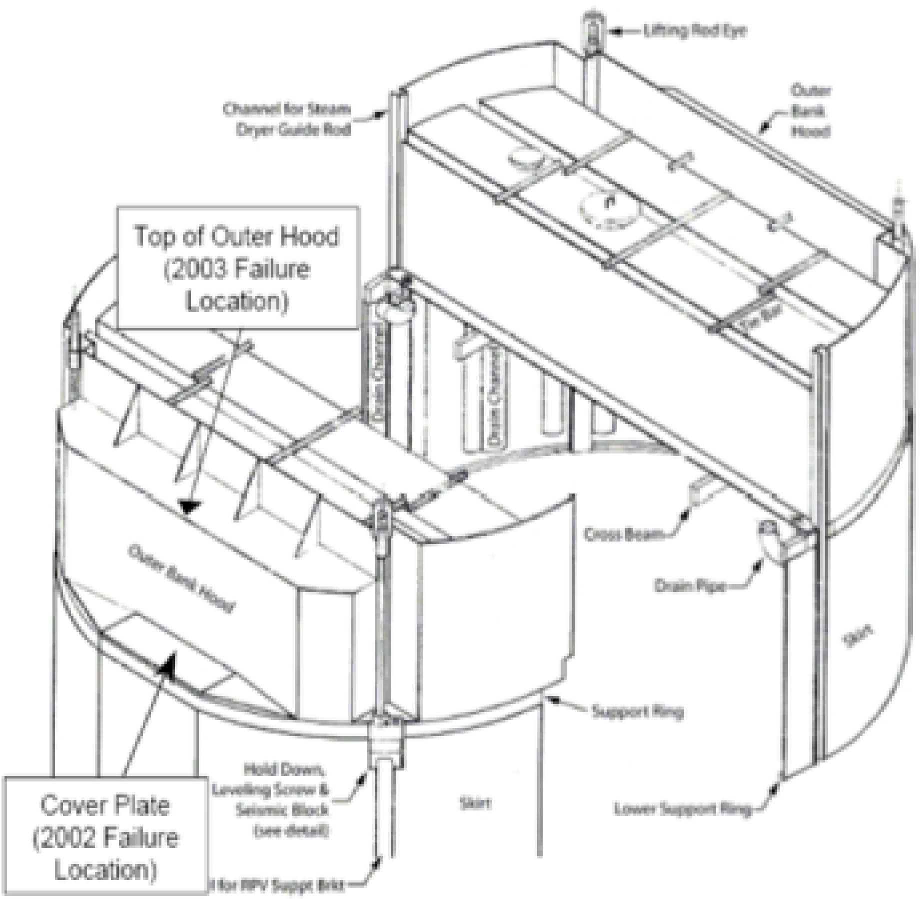
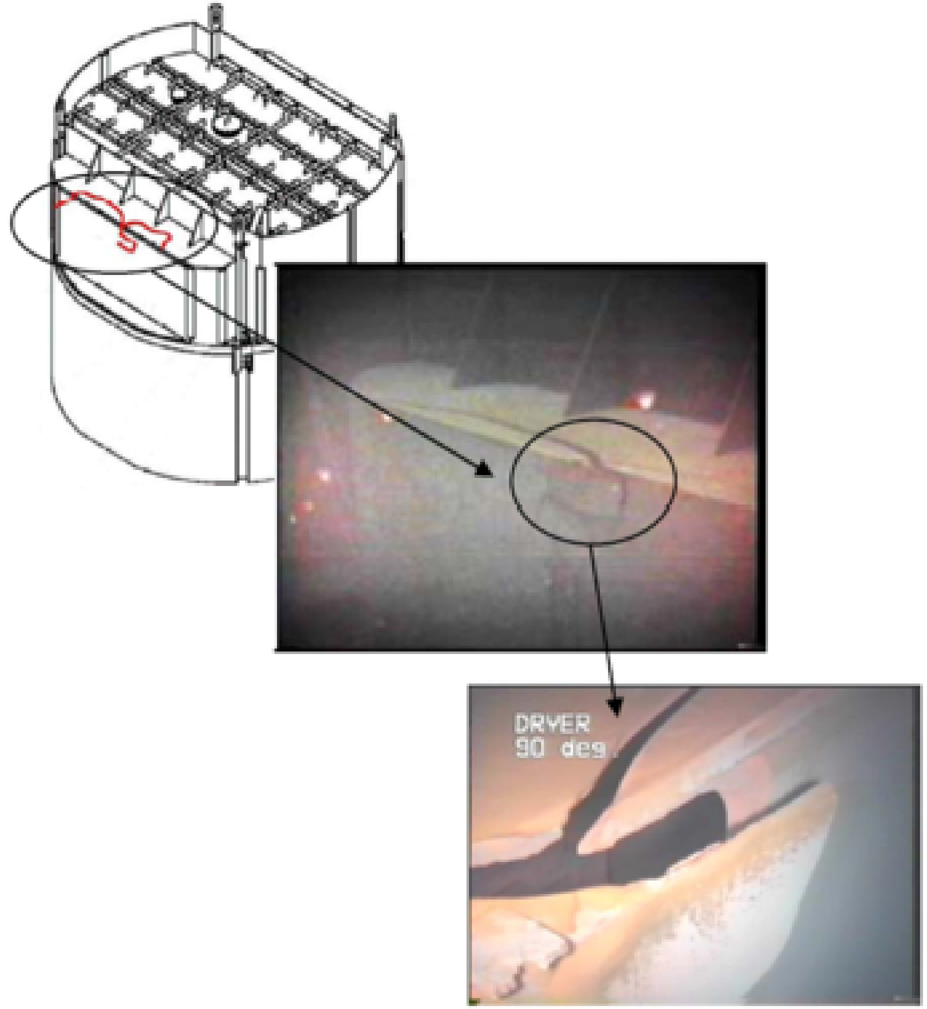




BWR Steam Dryer FIV and AIV

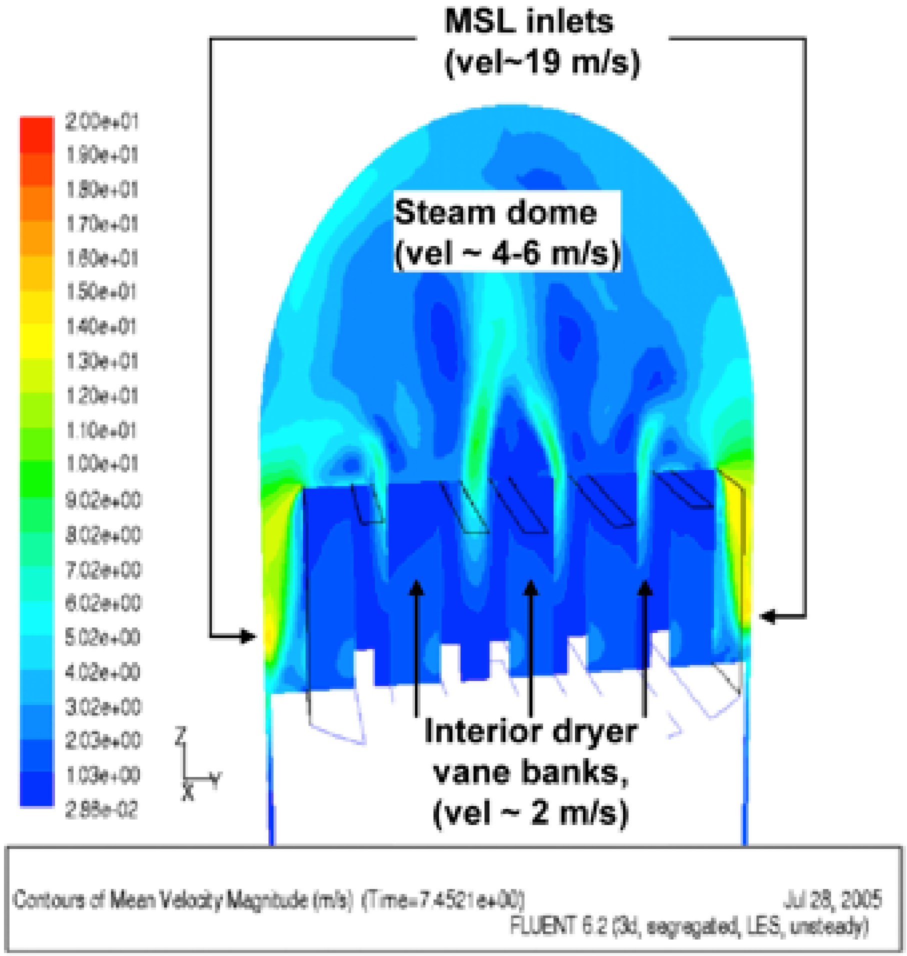
Quad Cities Dryer Cracking

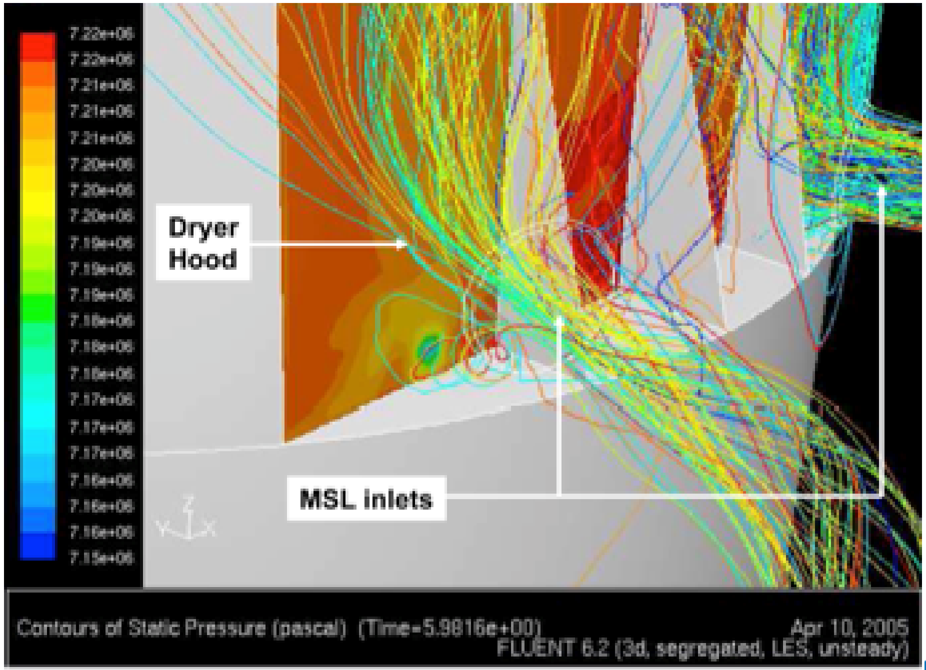




BWR Steam Dryer FIV and AIV

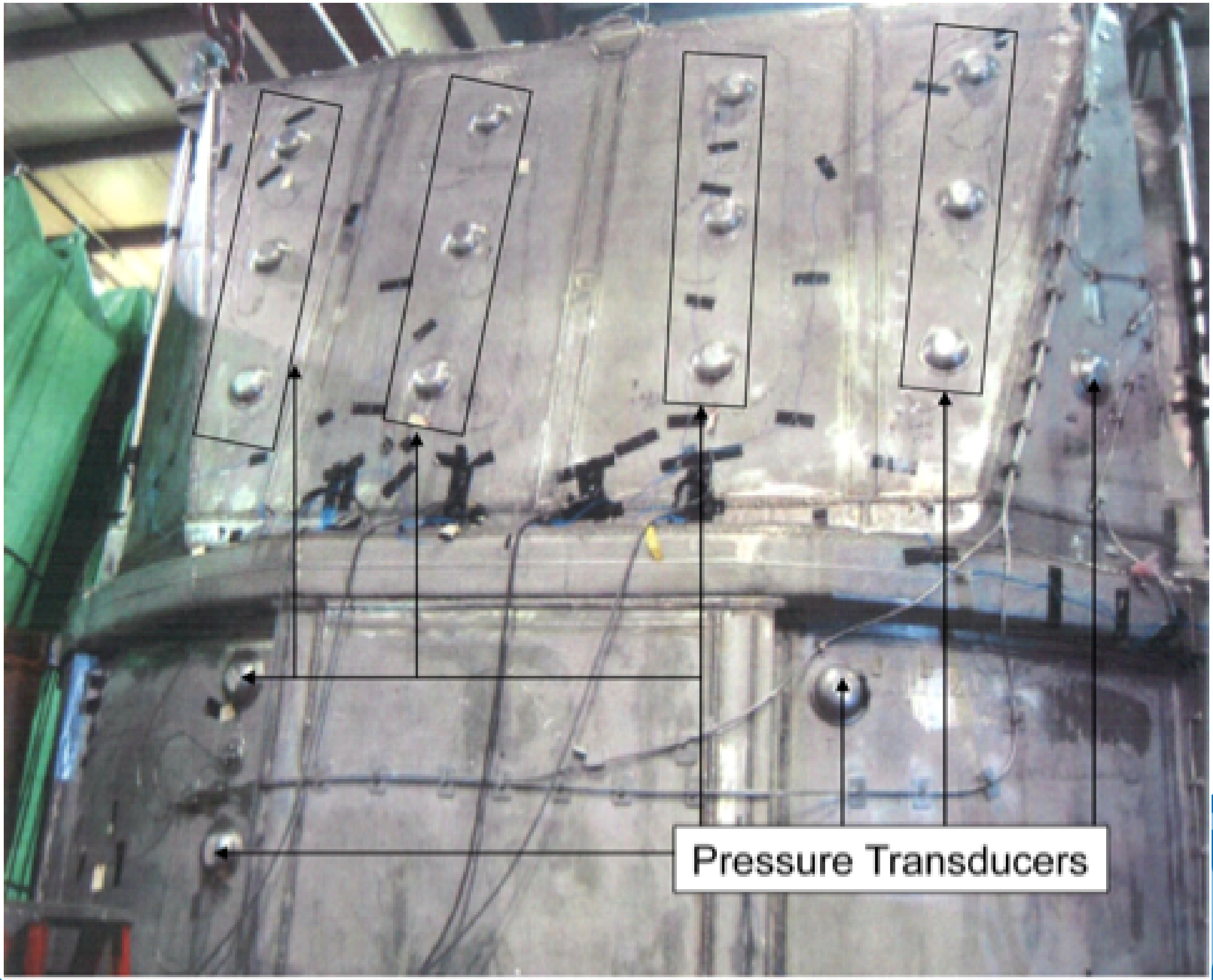
CFD Simulations – slow steam flow, no obvious strong sources





BWR Steam Dryer FIV and AIV

QC2 Surface Pressure Measurements



Hood

Skirt

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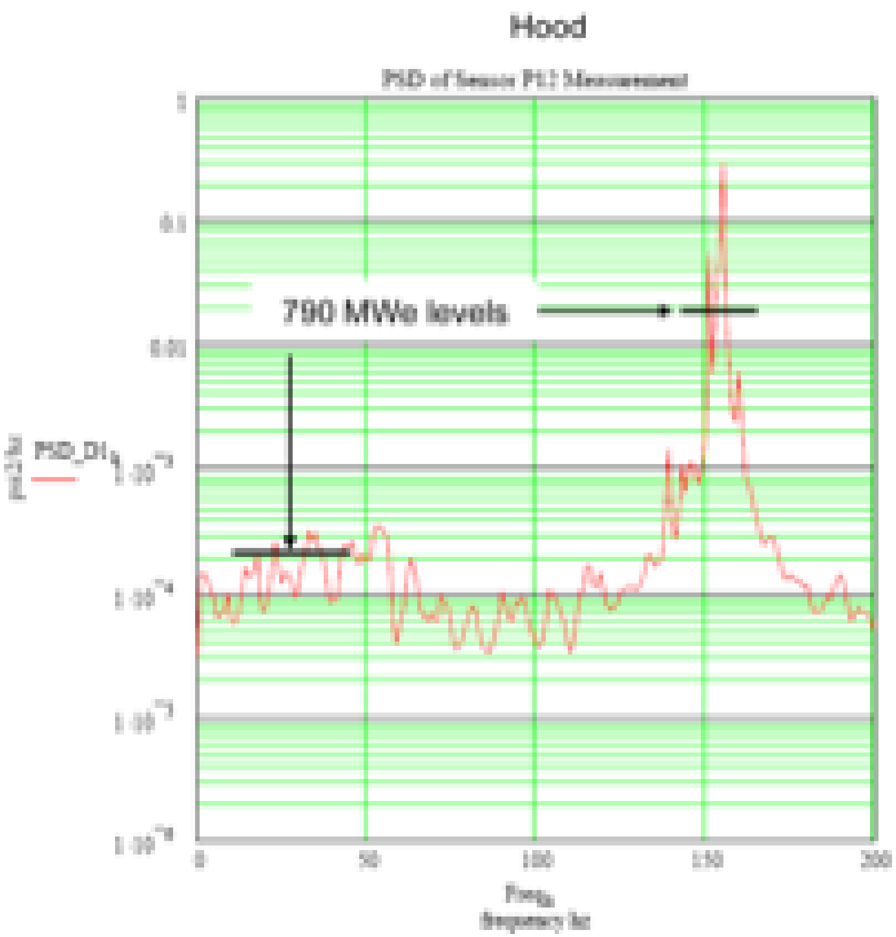
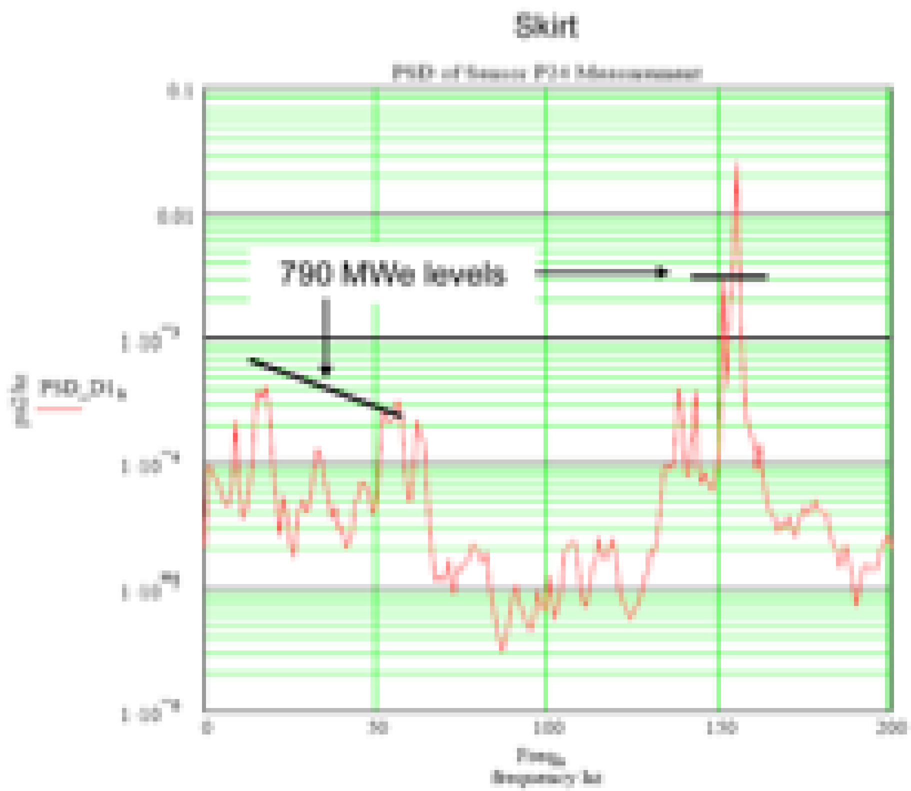
SRV Side Branch Resonance Loading





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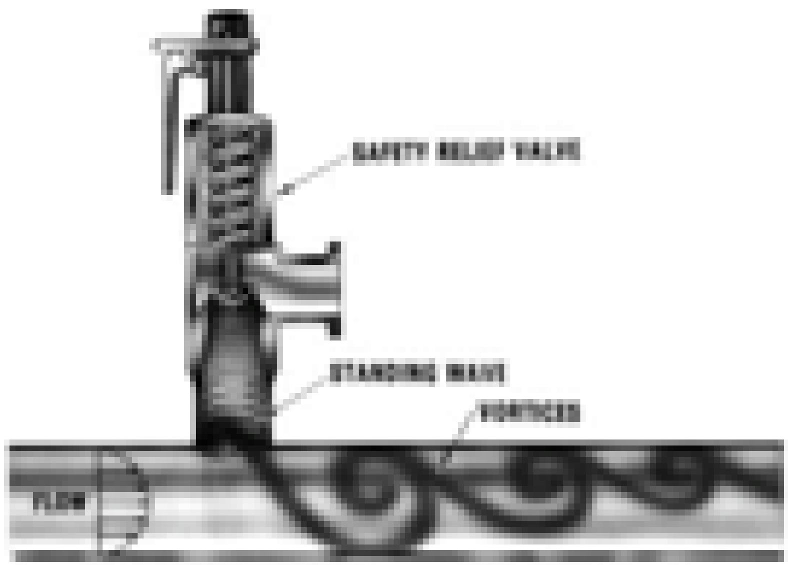
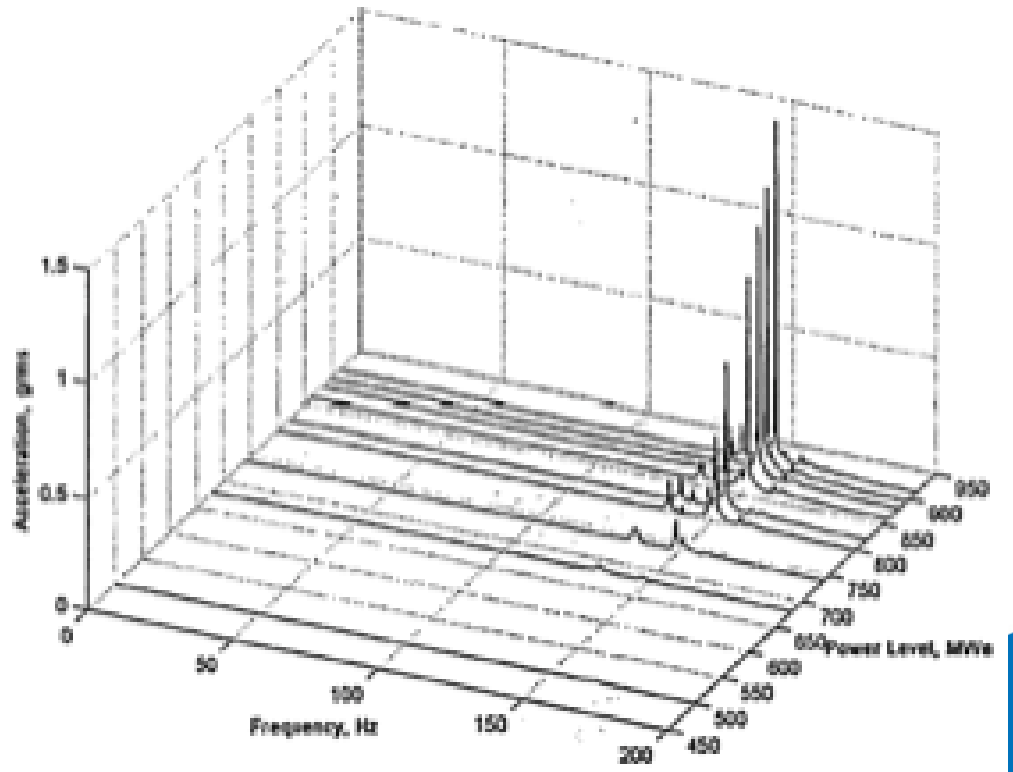
SRV Side Branch Resonances





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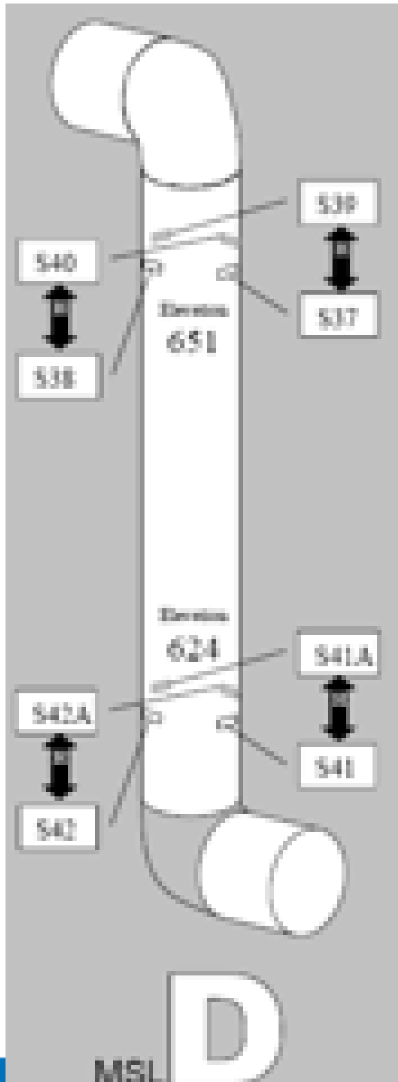
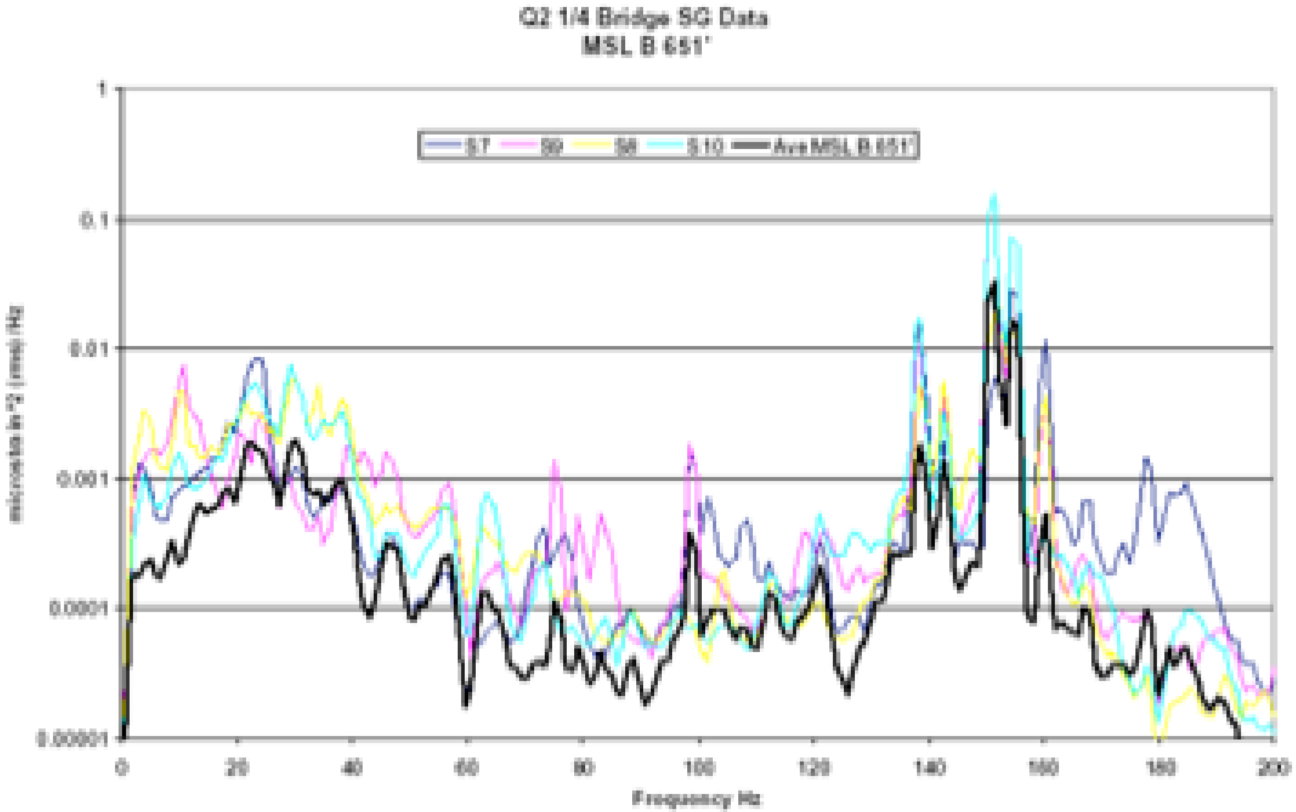
MSL Strain Gage Arrays



Hoop strain measures internal pressure



BWR Steam Dryer FIV and AIV

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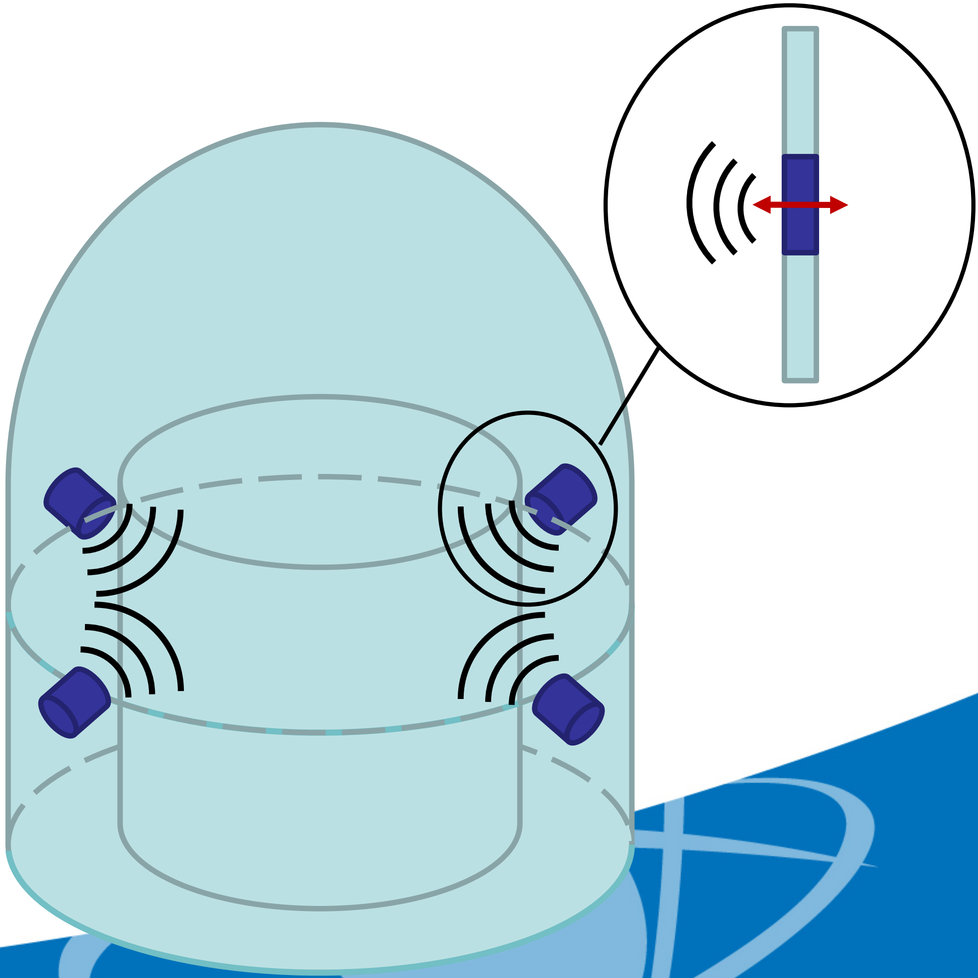
GEH PBLE01 Dryer Load Modeling



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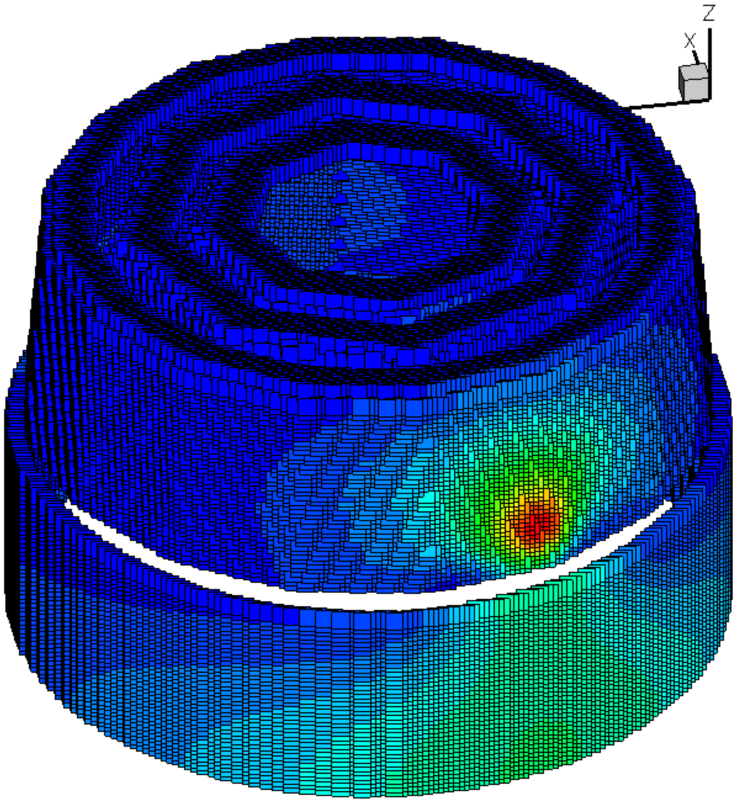
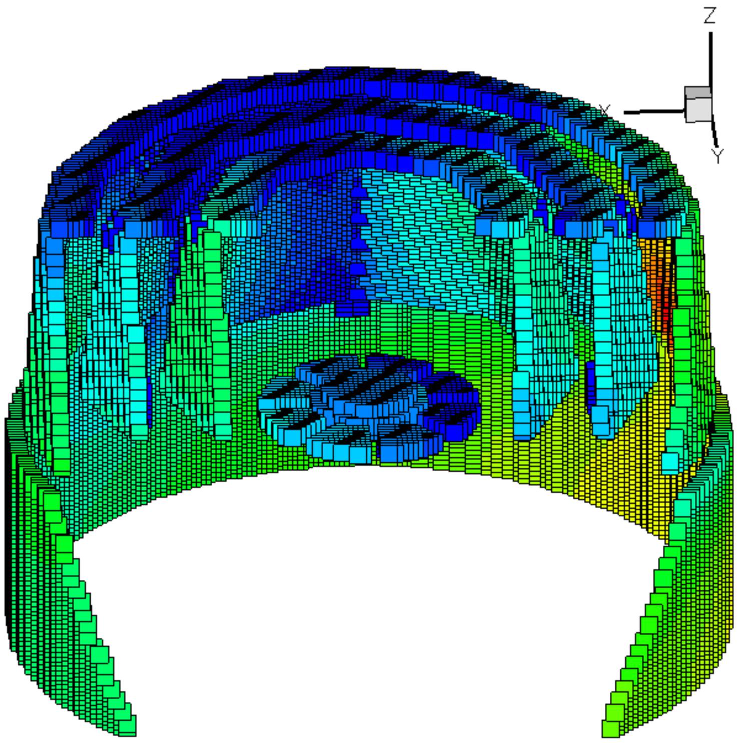
Westinghouse Approach: ACE (based on ACM)





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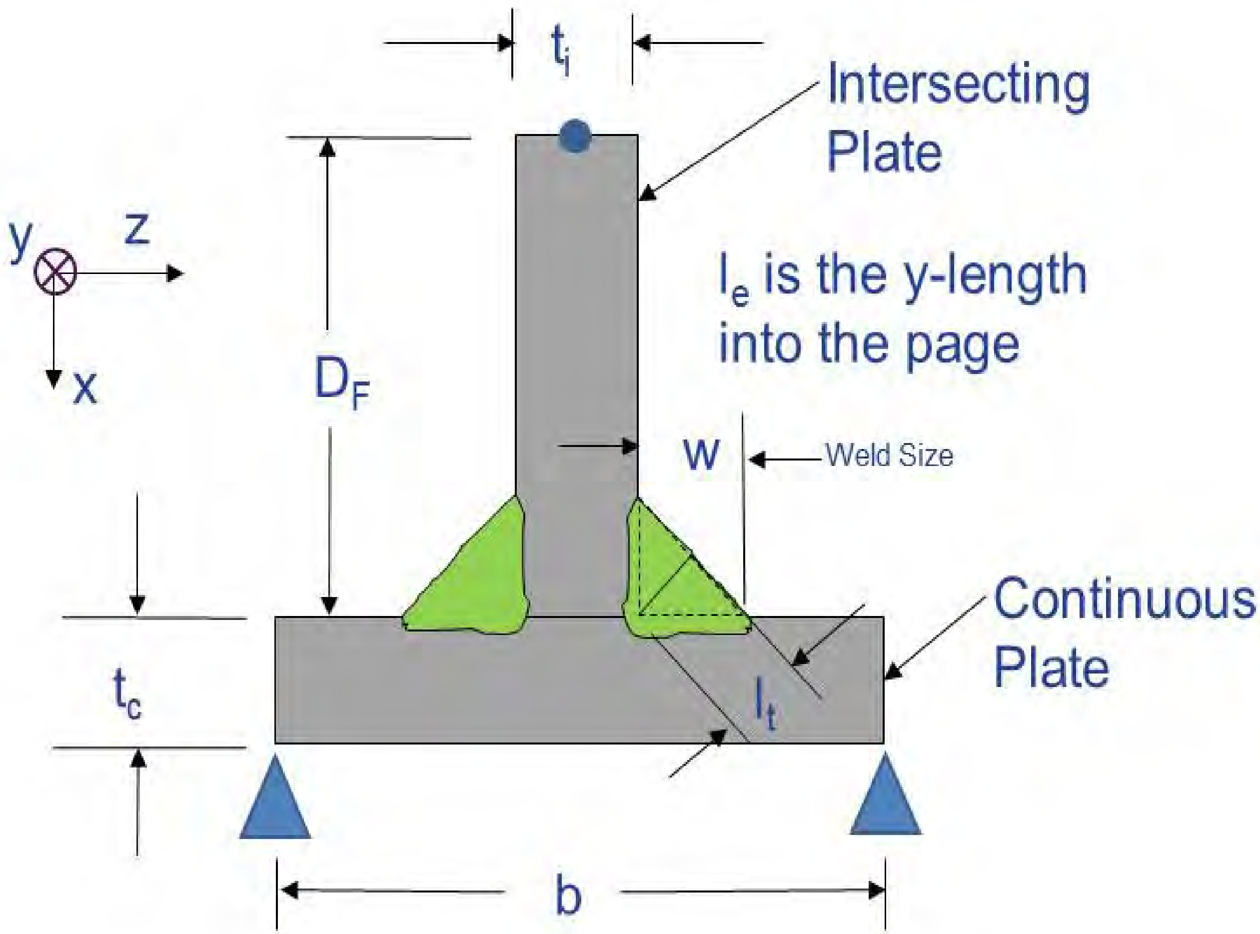
Weld Stress Calculations



BWR Steam Dryer FIV and AIV

Lessons Learned History

- Quad Cities (QC) – Replacement Dryers (RSD)
  - Discovered SRV side branch resonance issue
  - Evaluated GEH and Exelon measurement (MSL strain gage arrays) and modeling (ACM and structural analysis) methods
  - Evaluated benchmarking approaches, primarily of dryer pressure loading
- Vermont Yankee (VY) – Original Dryer
  - Evaluated GEH approximate modeling methods for more efficient power ascension
- Susquehanna (SSES) – RSD
  - Evaluation of RRP VPF mechanical excitation tones
  - End to end benchmarking data (on-dryer strain gages) acquired
    - Learned that industry has difficulty modeling low frequency dryer skirt loading and response

BWR Steam Dryer FIV and AIV

Lessons Learned History

- Hope Creek and Nine Mile Point (HC, NMP) - Original dryers
  - Assessed with ACM (CDI), apparent low loading
  - No end-to-end benchmarking
- Grand Gulf (GGNS) - RSD
  - Assessed with PBLE (GEH)
  - End-to-end benchmarking of full replacement dryer
  - Discovered core flow variability has stronger than expected impact on dryer stresses
- Monticello (MNGP) - RSD
  - Assessed with ACE (revision of ACM by Westinghouse)
  - End-to-end benchmarking of upper dryer only
  - Delays and Q/A issues with MSL measurements

BWR Steam Dryer FIV and AIV

Lessons Learned History

- GEH ESBWR
  - Designed with PBLE
  - Multi-plant prototype and non-prototype procedures established
- Peach Bottom (PB) - RSDs
  - Assessed with ACE
  - End-to-end benchmarking led to on-dryer stress estimates which exceeded allowable fatigue limits
    - Inference method developed based on FE mode shapes and on-dryer strain measurements
- Nine Mile Point and Hope Creek redux
  - ACM errors discovered by Westinghouse while evaluating MNGP and PB (skirt loads much too low, leading to non-conservative lower dryer stress estimates)
  - NMP2 assessment of impact of errors ongoing

BWR Steam Dryer FIV and AIV

Lessons Learned History

- Browns Ferry (BFN) – RSDs
  - Original EPU application attempted to qualify existing dryers
  - Electrical and other background noise corrupted MSL measurements
  - Could not establish existing dryer safety with reasonable assurance
  - New 2015/16 application provides improved MSL measurements
  - RSDs will be used with end-to-end benchmarking

BWR Steam Dryer FIV and AIV

Lessons Learned History

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Plant	Plant Design/ Containment	Original License	EPU granted	RPV I.D. (in)	OLTP Power (MWt)	EPU Power (MWt)	OLTP MSL Steam Velocity (ft/sec)	EPU MSL Steam Velocity (ft/sec)
Monticello (MNGP)	BWR3/Mark I	1971	2014	205	1670	1870	149	179
Quad Cities 1/2 (QC)	BWR3/Mark I	1972	2004	251	2511	2957	168	202
Dresden 2/3	BWR3/Mark I	1970	2004	251	2527	2957	168	202
Vermont Yankee (VY)	BWR4/Mark I	1972	2006	205	1593	1912	140	168
Browns Ferry 1,2,3 (BFN)	BWR4/Mark I	1973	Pending	251	3293	3952	128	161
Susquehanna 1,2 (SSES)	BWR4/Mark II	1983/1985	2009	251	3293	3952	128	158
Hope Creek (HCGS)	BWR4/Mark I	1986	2008?	251	3293	3840	143	167
Peach Bottom 2,3 (PBAPS)	BWR4/Mark I	1973	2014	251	3293	3951	129	155
Laguna Verde 1,2 (LV)	BWR5/Mark II	1990/1995	2014/2015	205	1939	2327		
Nine Mile Point (NMP2)	BWR5/Mark II	1987	2011	251	3233	3988	143	177
Grand Gulf (GGNS)	BWR6/Mark III	1984	2012	251	3833	4408	139	163

BWR Steam Dryer FIV and AIV

Lessons Learned History

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Plant	Original Steam Dryer type	FIV MSL tones	MSL ASBs installed	Dryer loading tool	Dryer structural analysis tool	Modifications/ Replacement
Monticello (MNGP)	GE Square hood	Yes, ...	No	ACE	Westinghouse frequency domain	Replaced with Westinghouse 3 ring octagonal 'Nordic' dryer
Quad Cities 1/2 (QC)	GE Square hood	Yes, primary shear layer	Yes	ACM	GE time-domain	Replaced with GE stiffened slanted hood (QC2 dryer instrumented), ASBs installed
Dresden 2/3	GE Square hood	Yes, primary shear layer	Yes	ACM	GE time-domain	Replaced with GE stiffened slanted hood, ASBs installed
Vermont Yankee (VY)	GE Square hood	No	No	ACM	GE time-domain	Modified original dryer
Browns Ferry 1,2,3 (BFN)	GE Slanted hood	Yes, primary shear layer, and deadleg low frequency	No	PBLE	GE time-domain	Replaced with GE stiffened curved hood, BFN? Instrumented
Susquehanna 1,2 (SSES)	GE Curved hood	Yes, secondary shear layer, and deadleg low frequency	No	ACM	GE time-domain	Replaced with GE stiffened curved hood, instrumented
Hope Creek (HCGS)	GE Curved hood	No	No	ACM	CDI frequency domain	Modified original dryer, in-air damping measured on spare HC original dryer
Peach Bottom 2,3 (PBAPS)	GE Curved hood	Yes, primary and secondary shear layer	No	ACE	Westinghouse frequency domain	Replaced with Westinghouse 3 ring octagonal 'Nordic' dryer
Laguna Verde 1,2 (LV)	GE Curved hood	Yes, primary shear layer	Yes	ACE	Westinghouse frequency domain	Modified original dryers
Nine Mile Point (NMP2)	GE Curved hood	No	No	ACM	CDI frequency domain	Modified original dryer following discovery of nonconservative dryer loading errors
Grand Gulf (GGNS)	GE Curved hood	Yes, secondary shear layer	No	PBLE	GE time-domain	Replaced with GE stiffened curved hood, instrumented