Official Transcript of Proceedings ACRST-3407

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguards
546th Meeting

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

SUNSI REVIEW COMPLETE

Docket Number: (n/a)

Location: Rockville, Maryland

Date: Thursday, October 4, 2007

Work Order No.: NRC-1797

Pages 1-245

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

October 4, 2007

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

546th MEETING

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THURSDAY,

OCTOBER 4, 2007

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ROCKVILLE, MARYLAND

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The Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., William J. Shack, Chairman, presiding.

MEMBERS PRESENT:

WILLIAM J. SHACK	Chairman
MARIO V. BONACA	Vice Chairman
SAID ABDEL-KHALIK	Member-At-Large
GEORGE E. APOSTOLAKIS	Member
J. SAM ARMIJO	Member
SANJOY BANERJEE	Member
DENNIS BLEY	Member
MICHAEL CORRADINI	Member
OTTO L. MAYNARD	Member

MEMBERS PRESENT: (cont'd)

DANA A. POWERS Member

JOHN D. SIEBER Member

JOHN STETKAR Member

NRC STAFF PRESENT:

TANNY SANTOS, Designated Federal Official

STEVE ARNDT

BELKYS SOSA

GURIJA SHUKLA

JACK GROBE

MIKE WATERMAN

DAVID BEAULIEU

WARREN LYON

AL CSONTOS

TED SULLIVAN

TIM LUPHOLD

DAVE RUDLAND

GARY HAMMER

ALSO PRESENT:

KIMBERLEY KEITHLINE

GORDON CLEFTON

JIM RILEY

GLENN WHITE

DAVID STEININGER

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

(8:31 a.m.)

CHAIRMAN SHACK: The meeting will now come to order.

This is the first day of the 546th meeting of the Advisory Committee on Reactor Safeguards. During today's meeting, the Committee will consider the following: digital instrumentation and controls project plan and interim staff guidance; a draft generic letter on managing gas intrusion in ECCS, decay heat removal, and containment spray systems; dissimilar metal weld issue; draft ACRS report on the NRC Safety Research Program; and the preparation of ACRS reports.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mr. Tanny Santos is the Designated Federal Official for the initial portion of the meeting.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's session. A transcript of portions of the meeting is being kept, and it is requested that speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume, so they can be readily heard.

I will begin with some items of current interest. We have a new member of the ACRS with us today, Dennis Bley. Welcome aboard, Dennis.

MEMBER BLEY: Thank you.

CHAIRMAN SHACK: We also have a returnee. Jack Sieber is back with the Committee after an absence, so welcome back, Jack.

MEMBER SIEBER: Okay. Thank you.

(Applause.)

MEMBER APOSTOLAKIS: That was for both, right?

CHAIRMAN SHACK: Mr. Dave Fischer, who has been with the NRC for 26 years, of which about two years have been with the ACRS staff, is retiring at the end of October. For the past two years, he has provided outstanding technical support to the ACRS in reviewing numerous technical issues, including the technology-neutral framework for future plant licensing, proposed revisions to 10 CFR Part 52, proposed regulatory guide and combined license applications, risk-informed and performance-based revisions to 10 CFR 50, early site permit applications, and revisions to regulatory guides applicable to future plans. And probably the hardest job of all is he had to read Tom Kress' handwriting all that time.

(Laughter.)

His hard work, dedication, attention to details, professionalism, and outstanding technical support to the Committee are very much appreciated. Good luck in your future endeavors.

(Applause.)

I should also note that our distinguished colleague, Dr. Apostolakis, was inducted this week into the National Academy of Engineering. Members of the Academy are elected by their peers, and election to the Academy is one of the highest professional honors accorded to an engineer. So congratulations.

(Applause.)

Denny Ross, who had a long and distinguished career in the nuclear industry, passed away suddenly a little while ago. There's a good writeup on Denny in the items of interest, though, that I commend to everybody.

There is also some speeches in the item of interest by Chairman Klein -- one, comments on some items that we have been considering with GNEP, the multi-national design evaluation program and its possible relation to the technology-neutral framework, and he has another speech on digital I&C. There are also some interesting SRMs related to the technology-neutral framework and 50.46.

One other item -- Mr. Sam Duraiswamy is being recognized for 30 years of government service. Sam has been an extremely valuable member of the ACRS technical staff, and is a walking Wikipedia of ACRS experience and history in nuclear reactor regulation.

I, and all the members, are greatly appreciative of his dedication and long service to the mission of the ACRS.

(Applause.)

Sam gets a certificate and a pen in lieu of a raise.

(Laughter.)

Our first item of business this morning is digital instrumentation and controls project plan and interim staff guidance, and our distinguished member of the National Academy, Dr. Apostolakis, will lead us through the discussion.

MEMBER APOSTOLAKIS: I had no --

(Laughter.)

Thank you, Mr. Chairman. We will hear today from the industry, NEI representatives, and they will give us their perspective on the work that is being done on digital I&C. And then, of course, we will also hear from the staff on overall activities of the Steering Committee, and, in particular, the three interim guidance reports that they have issued on diversity and defense in depth, highly integrated control rooms, the communications issues, and the human factors issues in highly integrated control rooms.

Our I&C Subcommittee met with NEI and the staff on the 13th of September, and again we covered these issues. The members of the Subcommittee were, in general, pleased with the progress that is being made. There was only one issue that we discussed in detail, and perhaps the Committee today also should pay extra attention to it.

In the guidance on defense in depth and diversity, the staff states that for 30 minutes after the incident there should be no reliance on human -- on manual actions. Therefore, there should be a backup system, if necessary, if appropriate.

The issue of the -- not in particular the numerical value of 30 minutes -- I mean, people felt that if you are to have a number, 30 minutes is as good as any, and the staff has some rationale for it. But the question was whether we needed a number at all, and whether there should be a process in place.

And in each case there should be an evaluation of how things are progressing and whether the operators in fact could intervene, say even before 30 minutes, and the analysis -- the analysis showed that if they could do so reliably, then of course that would be an acceptable -- an acceptable measure of defense in depth.

And I would remind the Committee that similar considerations were reviewed when we reviewed the regulatory guide on manual actions in the case of fire, where there was extensive discussion of manual actions, the context within which they might occur, and so on.

The staff came back and said, "Well, we would expect to have a lot of give and take if the licensee argued that the operators could intervene reliably in a period less than 30 minutes." And we are offering -- the 30-minute limit -- is a way out of it. In other words, instead of spending time arguing back and forth, we are telling the licensees that, you know, if you do this by 30 minutes, then that would be an acceptable way to proceed.

But the staff said that they would be open to other approaches that would consider manual actions, even in less than 30 minutes. And they in fact added a couple of sentences to the guide, which I expect we will read later today, to make sure that we all agree with what is being said there.

But in general, as I say, the Subcommittee members were very pleased with the progress, and there is also progress on that other recommendation that we made to the staff some time ago to develop a classification of the digital systems that will be used in -- are being used or will be used in the future in reactors, and also to collect failure data, so that future activities will be informed by the operating experience.

And with that, I would call upon NEI to start the presentations. In fact, I believe this is the last time we see Ms. Keithline. She is going back to naval reactors.

MS. KEITHLINE: Yes, yes. Just the last time you'll see me representing the commercial industry.

(Laughter.)

Oh, we see you all from time to time at naval reactors, and I'm going back to the Reactor Safety Division, so --

MEMBER APOSTOLAKIS: Okay. That's

something we are dealing with.

MS. KEITHLINE: But today it's still digital I&C.

MEMBER APOSTOLAKIS: Okay.

MS. KEITHLINE: Okay.

MR. RILEY: Since you brought it up, if I could make a quick comment. This is Jim Riley. I'm Director of Engineering. Gordon Clefton, who is sitting back here with a blue sportcoat on, is taking over from Kimberley in --

MEMBER APOSTOLAKIS: Why don't you come --

MR. RILEY: -- the future.

MEMBER APOSTOLAKIS: -- up front?

MR. CLEFTON: She can handle it fine today.

(Laughter.)

I'll be up there later this morning.

MEMBER APOSTOLAKIS: Okay.

MS. KEITHLINE: All right. Well, we appreciate the opportunity to meet with you today to share our perspective on what has happened on digital I&C, and on what we think still should happen in the future as we go forward.

The creation of NRC's I&C Steering Committee and the task working groups has been very helpful in focusing the effort and driving some of these issues towards resolution. We're encouraged by the interactions we've had with the staff during the past several months. They have listened to our concerns, and in some cases have incorporated or otherwise addressed our comments, and we appreciate that.

The open dialogue we've had with the staff has given us the opportunity to better understand what is important to the reviewers, and why they are concerned about specific things. Hopefully, with that knowledge we'll be able to address those issues earlier in the design and review processes.

Now, it would be nice at this point to declare victory and announce that we're done and that I don't really need to turn everything over to Gordon Clefton. However, there is still really a lot left to do in the digital I&C area. The interim guidance that has been generated needs to be tested. You know, we've really got to apply it and use it, and in some cases we may need to further refine that guidance.

And there are other areas where we haven't yet developed the guidance for where we still need to do that to ensure that we have a predictable, cost effective, timely, and safe implementation of digital technology.

As you'll see in the initial interim staff guidance documents, the staff intends to continue interacting with stakeholders to refine the digital I&C ISGs, as we call them -- interim staff guidance documents -- and to update associate guidance and generate new guidance where appropriate.

Okay. So we've set up that basis for continued interaction in this area, and industry believes that that's very important to the success of digital I&C and nuclear power applications.

Okay. So we're just going to jump right in and start with one of the most challenging areas and one where there really remains quite a bit to be done. Task Working Group Number 2, the Diversity and Defense in Depth, or D^3 group, or D-cubed group as we call it sometimes, they took on quite a challenge last winter.

And this group has been working on seven problem statements that really are all aimed at answering two basic questions: When is diversity needed? And what constitutes adequate diversity? As many of us heard at the IAEA meeting in June, there isn't a silver bullet or magic solution to dealing with the possibility of common cause failures in digital systems.

Last week NRC issued interim staff guidance to address these questions. Based on what's in the ISG, we can probably check off a couple of our problem statements as being completed. So there is good progress that has been made.

There are a couple more problem statements that will need to have some additional discussion I think to make sure that we understand exactly what the intent of some of the words is and how exactly it will be implemented. But that's a -- we'll work through that.

There are three problem statements that we probably -- I'm pretty confident there will need to be additional work, and those three are related to taking credit for manual operator actions, the applicability of common cause failures, and adequate diversity. I'll discuss those in a little bit more detail.

And the use of risk insights in D^3 applications, that's currently not a specific problem statement for the D^3 Task Working Group. It does fall within the Risk-Informing Task Working Group, and we think it relates in a very important way to diversity and defense in depth.

So I'll say a little bit more about manual operator actions. This is the 30 minutes. The D^3 interim staff guidance includes a 30-minute criteria for determining whether an automatic diverse actuation function is necessary, and the ISG says specifically, "Manual operator actions may be credited for responding to events in which the protective action subject to a common cause failure is not required for at least 30 minutes."

Industry is concerned that this guidance could in some cases result in the need for automation and complexity that might not really enhance reactor safety. Our fundamental belief is that credited manual actions taken to initiate protective functions must be demonstrated. We've got to show that it's feasible to take those actions in the times assumed.

Industry is recommending --

CHAIRMAN SHACK: Feasible and reliable, right?

MS. KEITHLINE: Feasible and reliable. Now, having said "reliable," I've read through the NUREG for the fire protection --

MEMBER APOSTOLAKIS: 1852.

MS. KEITHLINE: -- NUREG-1852, and I personally am not sure that I would go as far as that draft went in terms of the reliability discussion, but feasible and reliable. Details to be worked out.

MEMBER APOSTOLAKIS: Don't throw that bomb out and say --

(Laughter.)

-- let's go on. But there will be another time for this I guess, so --

MS. KEITHLINE: Yes. The next thing -- I was actually going to mention that at our Subcommittee meeting Dr. Apostolakis did point out that that NUREG -- NUREG-1852 -- discussed manual actions in response to fires. And the basic approach is very similar to what we've been talking about doing for digital I&C.

For I&C, the scenario is that a common cause failure prevents the safety system from responding when you need it -- for example, during a loss of cooling accident. If we want to rely on operators to back up the digital system, we need to enable the operator to determine what actions are needed, and then successfully execute those actions.

Okay. So that means the operator needs to have a sufficient set of diverse indications so that he will know he needs to take action. He also needs to have good procedures to tell him what actions to take, and he needs to be trained to recognize the indications and properly execute the correct procedures.

Then, we need a way to validate our assumptions. And in general concept, that's very similar to what was done I believe for the fire scenario.

And we'd like to continue working with both the D^3 -- the Diversity and Defense in Depth Task Working Group and the Human Factors Task Working Group to develop -- further develop an agreed-upon methodology for making these assumptions about operator response times.

The second bullet under --

MEMBER APOSTOLAKIS: Let me understand what your position is. You are not -- you are not really -- you didn't really state a definitive position. You are just saying that you are uncomfortable with the 30-minute limit, but you really don't know what to do about it. Is that --

MS. KEITHLINE: Well, we would like to have a process or a methodology similar in concept to what's in fire, and we've got a white paper that we submitted to the staff over the summer that describes a similar process that could be used for digital I&C. But because of the timing and the resource limitations and the need to get interim staff guidance out, we haven't had a chance to work through that white paper and that concept with the staff yet.

MEMBER APOSTOLAKIS: Do we have that paper?

PARTICIPANT: Yes.

MEMBER APOSTOLAKIS: We do. I remember reading --

MEMBER CORRADINI: We haven't seen it. Have we seen it?

MEMBER APOSTOLAKIS: Yes.

MR. SHUKLA: I'll make sure that you get it.

MEMBER APOSTOLAKIS: Okay. So right now you're saying it would be nice to have a process. you have made the first proposal.

MS. KEITHLINE: Yes.

MEMBER APOSTOLAKIS: And at some point in the future we'll have to actually review it and see how we can proceed.

MS. KEITHLINE: Right, yes.

MEMBER APOSTOLAKIS: Okay. Okay.

MS. KEITHLINE: On the second bullet under remaining challenges, use of risk insights, industry is concerned that the deterministic approach to diversity and defense in depth might result in the use of automatic diverse actuation systems that do not improve plant safety, and in some cases might actually degrade safety, because of the increased complexity and the potential for spurious actuations.

We believe that risk insights can help determine where defense in depth and diversity are of value from a plant safety perspective, and we've talked about this in a way that's similar to some discussions and maybe a concept that was -- that influenced the development of the ATWS rule. Where would these extra systems or functions really add value? Where could you really show that they reduced risk and improved safety?

And we began discussing this with the Risk-Informing Task Working Group, and only introduced the concept to the Diversity and Defense in Depth Task Working Group. So this is another area where we need to have some additional dialogue on what have we learned about risk and safety, especially from what we've seen in PRAs, and how can we apply that knowledge to the decisionmaking process for diversity and defense in depth.

The next two bullets here -- common cause failure applicability and adequate diversity -- are specific problem statements in the D_3 ISG, and these are -- these are areas where we think some additional refinement may be appropriate.

Where the ISG addresses common cause failure applicability, it says there are two ways to eliminate the consideration of a digital common cause failure. You can either build sufficient diversity into the system, or you can make the system 100 percent testable. And there is some concern about whether 100 percent testability is really achievable. If it's not, then we'd need to build diversity into the system. That sounds okay.

The example given is that for a four-channel system you could use two channels that have one type of digital system, and the other two channels would have a diverse -- a different digital system.

It's not obvious that a hybrid system of -- systems like that would really be the best solution. And diversity is not the only means to protecting against digital common cause failures. Other methods -- and we refer to them as defensive measures -- could be effective in precluding or limiting digital common cause failures.

Industry is working on a white paper with insights on the mechanisms of digital common cause failures to help determine when a digital system should or might not be considered susceptible to common cause failures.

And so we intend to over the next several weeks or months -- I'm not sure what the exact timing is at the moment, the paper is in the process of being worked on -- be giving NRC staff a recommendation, a white paper proposal, on further refining this guidance on common cause failure applicability.

MEMBER APOSTOLAKIS: So you are proposing, then, something that will replace this NUREG from the '80s that tells you how to do the common cause failure analysis? Or you are expanding on it? You are becoming more specific? It's amazing that we are still using a report from way back in '83 I think it is or something like that. And, you know, are you guys working on that, or is it something in addition to that?

MS. KEITHLINE: Well, much of the focus -- specific focus has been related to the Branch Technical Position 7.19. Mike Waterman might say more about NUREG-6303. I think that's the one he's referring to.

MEMBER APOSTOLAKIS: I think that's what it is, yes. Yes.

MS. KEITHLINE: And so -- are you guys

planning to talk about that at all?

MEMBER APOSTOLAKIS: Well, you can comment now if you --

MR. ARNDT: We'll talk about it very briefly. But it was actually a 1994 document. It was developed --

MEMBER APOSTOLAKIS: Then it's okay, Steve.

(Laughter.)

MR. ARNDT: No, it's not okay.

(Laughter.)

It needs work, but we are at both -- as part of an ongoing research program to improve and provide additional guidance associated with that, as well as part of the ongoing work of the Task Working Group planning to work with the industry on doing that.

MEMBER APOSTOLAKIS: So that's really what we're talking about, the methodology --

MR. ARNDT: Well, there's two issues. There's, how do you define the attributes associated with what is acceptable diversity? And, in addition, when you look at things like sufficiently testable or sufficiently simple, not required in diversity, that's something in addition to that. Diversity is in --

MEMBER APOSTOLAKIS: Well, you're already starting with a great weakness of the structure list defense in depth, aren't you?

MR. ARNDT: Yes.

MS. KEITHLINE: Okay. Moving on, the last thing on the --

MEMBER POWERS: Can I sneak --

MEMBER APOSTOLAKIS: We just see what is happening.

MEMBER POWERS: This is all rationalist defense in depth here.

MEMBER APOSTOLAKIS: Oh, they're trying to put some rationality into it. But right now they are caught in the tentacles of structuralism. Dennis?

MEMBER POWERS: I forgot what I was going to ask.

(Laughter.)

Pardon me. Excuse me.

MEMBER APOSTOLAKIS: It's okay, Dana.

MEMBER BLEY: I haven't read all the history of what has been going on here, but are you going to talk about -- or do we have documents that talk about the alternatives you were referring to to diversity? Explaining the --

MS. KEITHLINE: Like the example of the

four-channel system with two channels of one type and two of a different?

MEMBER BLEY: Okay. Well, you had said in -- well, you called that a diverse approach, a kind of diversity. But then you said, "We're not convinced diversity is even the best way to protect against common cause." You have defensive measures or something like that. Have you provided information on the kinds of things you're thinking about for those measures?

MS. KEITHLINE: We've had discussions. I believe that's addressed to some extent in a topical report EPRI submitted a couple years ago, and we've got a white paper being developed right now to address that in more detail.

MEMBER BLEY: Do we have that EPRI topical?

MEMBER APOSTOLAKIS: We probably do, yes. We have -- yes, we have -- make sure that Dr. Bley --

MR. SHUKLA: I do not know, sir, but I'll check.

MEMBER BLEY: Thanks.

MEMBER APOSTOLAKIS: I believe I saw it some time ago.

MEMBER BLEY: Thanks.

MS. KEITHLINE: All right. And then, the last thing on this list is adequate diversity. The problem statement for this group specifically -- it included consideration of the following questions. How much diversity is enough? Are there precedents for good engineering practice? Can sets of diversity attributes and criteria provide adequate diversity? How much credit can be taken for designed-in robustness? Are there standards that can be endorsed?

And these questions have not been completely addressed yet in the interim guidance, so this -- and there is research ongoing, so this is an area that still needs some further refinement, we believe.

And so my next slide is the path forward. Most of these I've mentioned. We want to continue working to develop that methodology for operator response time assumptions. We want to develop a process for considering risk, risk insights in D^3 decisionmaking. We'd like to further refine the interim staff guidance in some areas. Ultimately, we believe it would probably be a good idea to revise Branch Technical Position 7.19.

Now, to do these things, there are a couple efforts underway that will support these efforts, we believe. One is that the staff, Mike Waterman in particular, is working on and probably getting close to completing some research on adequate diversity. And Mike may say something about that later this morning, but that will help address some of these issues we think.

Also, industry and NRC are both working on reviewing operating experience data. What are we learning from digital system failures? And I have the next slide to talk a little bit about that -- what we're doing, the industry is doing.

EPRI is working on a project to review digital I&C operating experience in U.S. commercial nuclear power industry. Bruce Geddes from Southern Engineering Services is doing much of this work, with assistance from Ray Torok, Vic Fregonese, Thuy Nguyen, and Bell, -- our George Washington University student -- who is an intern at NEI right now. She's here in the audience.

MEMBER APOSTOLAKIS: That's the guy who's doing the work.

(Laughter.)

MS. KEITHLINE: So far this group, with a lot of help from Bell, has reviewed operating experience reports for more than 300 events that occurred between 1987 and this year roughly.

Bruce created a database for capturing the characteristics of each event, including the cause and corrective action, as reported by the plant. So we're starting with the documents that were generated by the plant, reporting the failure. What did they say about cause and corrective action?

The database also identifies the plant system involved, its safety classification, whether or not the event was really due to a digital failure, or whether it was a non-digital failure in a digital system, whether it was a common cause failure, and what -- we get into defensive measures or diversity attributes could be or could have been employed to reduce or prevent such an event.

MEMBER CORRADINI: May I just ask a clarification?

MS. KEITHLINE: Yes.

MEMBER CORRADINI: So these are like feedwater systems, turbine systems, secondary systems primarily?

MS. KEITHLINE: Those are the systems that mostly exist, yes.

MEMBER CORRADINI: So is this something that is -- since it's a student, available in such a manner that others can look at it, or is this something that is being held internally to the NEI?

MS. KEITHLINE: It will be. It will be made available. Right now we're in the process of writing a draft report and rewriting it. Some of the information has come from the INPO database. We didn't find it all through the NRC databases. So we're working with INPO to make sure we know what information needs to be removed from those events -- plant names specifically, maybe a couple other things -- so that it -- we can share it with others.

We've been discussing what we've been doing with the staff to make sure they have some idea of what we're doing with the data, and we do plan to make the white paper report available for wide distribution when it's ready.

MEMBER CORRADINI: But let me just go one step further. So if you're going to generate this in some fashion that's going to be database or some sort of simplified thing, the electronic version of being able to search through the 300 would be also just as nice as the report. So others might want to go back in mine and look at it themselves.

MS. KEITHLINE: And we are discussing how we could do that, whether we can remove enough information so that we'd be allowed to share it and still have it be usable.

MEMBER CORRADINI: Okay.

MS. KEITHLINE: I would like to be able to do that. That's still under discussion.

MEMBER CORRADINI: These different eyes that the basic data would make for very useful I think --

MS. KEITHLINE: Yes.

MEMBER BLEY: Another point. Since a lot of what you've said up to now deals with measures for dealing with common cause problems, is there any plan for events that might be interesting common cause events in this database to go back to the plants themselves rather than just look at the database records?

MS. KEITHLINE: We've talked about that. When looking at these events, are there questions that we would ask? Would we like to learn more than what was just in the report?

Now, it turns out that some of the people working on this were there for some of those events. And so that's real nice.

Some of the events happened several years ago, which makes it a little bit harder to be able to track down the knowledgeable people. We haven't decided where there will be a -- maybe a subset of particularly interesting events that we do want to dig into more deeply and see -- some are more interesting than others, and we have discussed whether we would try to do that for some events.

MEMBER BLEY: Well, you'll find a lot more -- I'll say more information, and maybe different, if you do that.

MS. KEITHLINE: Yes. I'm a little bit nervous about the finding different information. We're using documents that have been generated by the plants and gone through the proper approval cycles.

MEMBER BLEY: More is probably a better word.

MS. KEITHLINE: Okay. So on this one we have started and do intend to share more information with the staff. We want our efforts in this area to compliment each other, and we're going to document our findings in a paper that we hope to distribute widely in the near future.

MEMBER APOSTOLAKIS: A few months? Is that what you mean?

MS. KEITHLINE: Well, we were hoping for last month.

MEMBER APOSTOLAKIS: Oh, okay.

MS. KEITHLINE: So I --

MEMBER APOSTOLAKIS: It's imminent.

MS. KEITHLINE: I'm hoping it's this month, but I can't commit to that.

MEMBER APOSTOLAKIS: Okay.

MEMBER ABDEL-KHALIK: Is this a complete data set?

MS. KEITHLINE: No, it's not the complete data set. One interesting thing is in here you're going to tell me that we should all pat Mike on the back. Mike Waterman found some events that we have not been able to find the documentation on yet. There are over 500 events collectively that between Mike and us we've been able to find, and there's quite a bit of overlap between those two sets of data. But we're still working.

He must be a really good researcher, and we haven't found all of us, so ours so far includes over 300 -- I think it's around 324 for the ones where we have found the documents, the source documents. We've got more work to do.

Okay. I'm going to probably go through these pretty quickly, so that I give the staff enough time to do their presentations. Just briefly, on three of the other task working groups, communications -- this is Task Working Group Number 4. They had the benefit of having a very clearly defined problem and got a headstart on the effort.

This group is dealing with the need for better guidance for interdivisional independence and data communication. There is an IEEE standard, 7-4.3.2, that has an annex -- Annex Echo -- that provides guidance for communications independence in digital safety systems.

Now, Reg. Guide 1.152 endorses IEEE 7-4.3.2, but it specifically did not endorse Annex Echo, and in fact said that annex provided insufficient guidance. So Task Working Group Number 4 developed additional guidance that describes acceptable methods for addressing data communications issues in digital systems.

That interim staff guidance was issued for use last week, and in general the industry is fairly pleased with that guidance. Many of our comments and concerns were addressed. There was a lot of dialogue between the staff and industry on this one.

There may be a couple areas where we will need to make sure we really understand how the guidance will be implemented and interpreted, and we're going to continue to work with the staff to do that, and, if necessary, to further refine the guidance.

The IEEE Standards Association has a working group that is working on a revision to the Standard 7-4.3.2. They have been following what the task working group has been doing, and they hope to incorporate much of the newly-developed guidance into the standard. Ideally, we'd like to be able to incorporate that newly developed guidance into the standard, and then have the next revision of 1.152 endorse the standard. That's our goal there.

Human factors -- this is Task Working Group Number 5, and they have four problem statements which are listed here. The first two problem statements were determined to be the highest priority, and have been the subject of most of the effort over the last couple months.

The original plan was for industry to provide reports or white paper recommendations on minimum inventory and computer-based procedures before new regulatory guidance was developed. And the idea was that these reports -- and our hope was that these reports could be endorsed by the NRC.

We submitted a report on minimum inventory in late May, and then the schedule was accelerated to issue interim staff guidance by the end of September. With that acceleration, we had to -- we and NRC had to shift our efforts over to getting the near-term guidance out, and so we haven't quite worked through the more detailed minimum inventory report that we submitted to them.

That has also delayed our work on the next couple reports that we intend to submit -- computer-based procedures and a graded approach to human factors.

The remaining challenges for this group are implementing the ISG. We've got an interim staff guidance document out there now, and, of course, the next test will be how useful, how well does it work. You know, you really find that out when you try to go use it. The group worked on it. Lots of dialogue, comments, discussion back and forth. We think they are pretty good. We want to make sure that they really contain what the staff is thinking so we'll know what they expect when we make a submittal and do our design, and we'll see how that goes.

There are lots of longer term actions for this group. There are some significant ones with -- that are, you know, resolving these issues, and then addressing graded approach to human factors and a question about the safety parameter display system and whether it needs to be a stand-alone console. So --

MEMBER BLEY: Excuse me. What's the extent of actual operator participation in this group?

MS. KEITHLINE: We have some -- we don't have current operators participating.

MEMBER BLEY: How far removed are the --

MS. KEITHLINE: How far removed? He's not here. Chris Kerr from Exelon has given us excellent operator perspective with some comments in these discussions back in August, things that we were considering doing, putting into the guidance, and he said, "You know, if you do that, this is what's going to happen in the control room during an event." And that's not really what you want to have happen, is it? And so we incorporated that.

There are probably opportunities as we go forward to engage additional operators.

MR. RILEY: Yes, I'd like -- that's a good point, and what I'd like -- I'd like to take that away as an action. We'll check and see where we are with respect to that and make sure we --

MEMBER MAYNARD: Well, aren't most -- a lot of the members on your working group are from the industry. I'm sure they go back to their plants and they work with folks at their plants, so you may have people who aren't on the task force who are actually providing quite a bit of input, too.

MS. KEITHLINE: Yes. We can probably do more. One thing I should mention -- this particular group is being picked up by another new person to NEI, but not someone who is new to the industry. Russell Smith comes to NEI from Comanche Peak, where he has been the Director of Operations, and I think will naturally make that linkage to the operators. But we'll keep that in mind. That's important.

MEMBER BLEY: Just to follow that up -- one of the things we talked about earlier, in general on all of the I&C issues, has there been an effort to have operators involved in those issues as they progress?

MS. KEITHLINE: Not as extensively as I'm used to doing. However, some of this guidance has developed very quickly. And we do have people with operational backgrounds and linkages to all of the -- to all -- to plants involved in the discussions. But that's -- as we said, it's something we can do more of as we move forward.

MEMBER BLEY: I would hope that you would, yes.

MR. GROBE: This is Jack Grobe with NRR. Kimberley, could you just share with the ACRS relative fractions of vendor architect engineer type people versus operating plant people that are on your working groups?

MS. KEITHLINE: It varies from working group to working group to task working group, depending on the subject matter. We have -- we have a pretty good mix of utility and vendor people on D^3. They are really active people. I'd say it's close to 50/50 utility people and vendor people. I could start rattling off names, but I don't think that's a good use of time right now this morning. We'll make sure that we keep those utility people and reach out to even more operational type people. Okay.

MR. RILEY: And there's a large number of people involved in the D^3 groups. There's a lot of interest there, so we've got a pretty good cross-section and a pretty good sampling at the same time.

MEMBER BLEY: I'm sure they'd be really interested in participating.

MS. KEITHLINE: Oh, we have -- we have a lot of them. We have very large distribution lists. It is a very large group of people.

Path forward on human factors -- as we said, we're reviewing right now these final issued interim staff guidance -- this document, and it may be appropriate to refine it as we move forward in the future.

We've got three reports that are either -- that are in progress. Two of them have not been submitted yet -- on computer-based procedures and graded approach. We would ideally like to get NRC endorsement of those reports in the future as industry guidance documents. And then, there may be additional guidance that needs to be developed or modified. There are some NUREGs out there, that type of thing. So that's human factors. It's going forward.

The last one that I'm going to say something about is cyber security. This is one of the groups with near-term interim staff guidance being developed. It's not quite out yet, but I'll just give you a brief -- brief synopsis of what's going on.

Last October, industry met with the NRC and discussed differences between the cyber security guidance in Reg. Guide 1.152 and in industry document NEI 04-04. Task Working Group Number 1 was established to address these issues and to ensure that the cyber security guidance provided by coherent and consistent.

These two documents came out about the same time, at least the most recent revisions. NEI 04-04 contains information that is more programmatic in nature, while Reg. Guide 1.152 contains guidance that's more design-related.

But industry desires the ability to use a single document for their cyber security programs, and ideally they'd like to be able to say we could either use Reg. Guide 1.152 or NEI 04-04. To resolve the differences between the two documents, the task working group has conducted a gap analysis to identify areas where they overlap or are inconsistent with each other. And based on that gap analysis, industry has made some changes to NEI 04-04.

In August, the NRC staff expressed concern regarding the ability to directly correlate the topical elements that are in Reg. Guide 1.152, with the programmatic guidance that's in NEI 04-04. So to address that concern, industry has created a draft cross-correlation table.

There was a public meeting last month to discuss that table with the staff and industry, and there will be another public meeting I think in about two weeks to further discuss additional comments and how the table could be modified to be more useful, especially more helpful to the reviewers, the NRC reviewers, who are going to be the ones who need to make sure that they've looked for the right things in these submittals and with the cyber security plants.

And hopefully, when we get to the end on this one, the NEI 04-04 will address the NRC's concerns such that it can be used in lieu of Reg. Guide 1.152 for cyber security. Reg. Guide 1.152 has other things in it that need to be used for those things.

And there will be an interim staff guidance document developed, and then probably some revisions to IEEE Standard 7-4.3.2, maybe the reg. guide, and maybe the standard review plan as we move forward.

And that's a quick summary of what's going on in four of the task working groups. The staff will say more, in more detail I'm sure, and be able to answer even more of your questions.

MEMBER APOSTOLAKIS: Any questions for the NEI representatives? Comments?

(No response.)

Well, this was informative, as usual. I hope the members have noticed that NEI has started using slides. Our complaint in the past was that they never did that. Now we have slides in full color. Thank you very much.

MS. KEITHLINE: You're welcome.

MEMBER APOSTOLAKIS: And now we are turning it over to the staff. Jack, are you going to say a few words? Or we go straight to Belkys and Steve, two familiar faces.

I understand Belkys is also leaving us. Where are you going?

MS. SOSA: I'm going back to the EDO's office. It was a rotation for me, so --

MEMBER APOSTOLAKIS: Okay. All right.

MS. SOSA: -- for four months.

MEMBER APOSTOLAKIS: So all the ladies who appear before us today is for the first time -- last time.

MEMBER POWERS: George, you've got to look on it as they couldn't leave without visiting us.

MEMBER APOSTOLAKIS: They couldn't what?

MEMBER POWERS: They couldn't stand to leave without visiting us.

(Laughter.)

MEMBER CORRADINI: Stan, too? I don't think so.

MEMBER APOSTOLAKIS: Can you have somebody bring me the new version, please? I know you are busy here. The interim guidance for D^3 -- I really need it in front of me.

(Pause.)

Okay. Let's go.

MS. SOSA: Good morning. My name is Belkys Sosa, and I'm the Director -- I'm here as the Director of the Digital I&C Task Working Group, as George just mentioned. This was a rotation for me, and I'm moving on. There will be a new director. Her name is Patricia Silva, and she is with NMSS. She comes to us after nine months in the Chairman's office, and she will be --

MEMBER APOSTOLAKIS: Is she here today?

MS. SOSA: She is not here today.

I apologize. Some -- the D^3 interim staff guidance was revised on the 22nd, then the new version came out on the 28th, and --

CHAIRMAN SHACK: So the 28th is the current version.

MS. SOSA: That's correct, yes. It's the latest, yes.

CHAIRMAN SHACK: I just wanted to make sure I was up to date.

MEMBER BLEY: It doesn't have a time stamp on it, Bill.

MS. SOSA: Now, the purpose of today's meeting is to provide the ACRS with an overview of the digital I&C activities as well as the development of the interim staff guidance.

This is an information briefing. A formal ACRS review and approval is included as part of the digital I&C project plan, doing the reg. guides or SRP updates formal review.

The staff of course appreciates any feedback or any comments that you have at this time.

MEMBER APOSTOLAKIS: We may write a letter, Belkys.

MS. SOSA: Okay. Now, I'm planning to provide a high-level view on the digital I&C project plan, and the status of the interim staff guidance. And Steve is going to cover the significant issues in the interim staff guidance, as well as the status of the staff's efforts to address the ACRS recommendations on D^3.

I'm pleased to report that the interim staff guidance on D^3 -- highly integrated control room communications and human factors -- has been issued. And you can find them on the website, hopefully.

Now, regarding the digital I&C cyber security ISG, as Kimberley mentioned, the staff -- essentially, the Steering Committee decided to hold issuing that interim staff guidance until we complete the correlation table that was mentioned. This table is an important licensing tool, both for the staff as well as industry. And we are looking at issue that at the end of October.

The near-term activities are, again, to develop interim staff guidance. The project plan identifies the major milestones and the planned deliverables at a very high level. The near-term due dates are driven by the need to have interim staff guidance in place to review the anticipated licensing actions for operating reactors, new reactors, and fuel cycle facilities.

The interim staff guidance is intended to clarify staff position and expectations on a timeframe that supports industry needs and will provide a regulatory framework that assures a high level of confidence in NRC staff's acceptance of an application.

The longer-term objectives of the project plan are to complete additional technical development work, further refine the interim guidance as appropriate, and incorporate that guidance into existing regulatory framework through the standard revision processes, like the reg. guides and the SRP updates.

The long-term focus of the project plan is on the risk-informed TWB, the fuel cycle facilities, the remaining human factor issues, and to continue to refine and enhance the digital I&C guidance as necessary through the task working group interactions.

Now, the development of interim staff guidance is well underway. As I mentioned, we issue ISGs on D^3 communications and human factors at the end of September. The website contains the draft ISG on cyber security, which we plan to finalize by the end of October. We plan to include the table with the ISG as an enclosure.

Now, regarding the licensing process ISG, the task working group, has developed a matrix to identify the type of information that needs to be provided on the docket, the information that should be available for the staff to audit if they choose to do so. A similar matrix will be developed for the new reactors identifying the expected timing for that information to be provided for COL or design certification applications.

The licensing process ISG is currently scheduled to be issued at the end of November. We expect to complete most of the interim guidance in 2007, with the exception of risk. We also expect to continue working with industry through the task working groups to develop recommendations to improve or enhance the guidance through established processes.

Now, let me clarify it if I may. The risk-informed ISG, which is scheduled to be issued in March of '08, is to address modeling of digital systems in PRA for design certifications and COL applications. That's the guidance that we are planning to issue in March of '08.

The remaining items -- risk insights on the --

MR. ARNDT: As opposed to risk-informing guidelines, the issue here is what is acceptable in terms of level of detail and modeling assumptions for the Chapter 19 required PRA analysis for --

MEMBER APOSTOLAKIS: Yes.

MR. ARNDT: -- different modeling threshold than if you're going to actually ask for regulatory relief once you've terminated your --

MEMBER APOSTOLAKIS: I am a little confused, if you can clarify that a little. Maybe it's me.

MR. ARNDT: In terms of providing a PRA that is complete and accurate and sufficient, the guidance is it needs to be sufficient for the regulatory application it's being used for.

In terms of is it good enough to make a determination that you've looked at everything that you need to in terms of, say, safety goal and things like that, in terms of Part 52 applications, that looks at sensitivities and have you captured all the major failure modes, and issues like that.

If you're going to actually risk-inform a particular regulatory application, like the D^3 analysis, level of modeling detail, the amount of scrutiny, the amount of completeness is a different level. The part that we're going to hopefully finish in March of next year is the prior one, not the latter one. That's longer term applications based on work that we're currently doing in the research area as well as discussions we're having with NEI.

MEMBER APOSTOLAKIS: So in different words, there is one issue which you already have a problem on of how to bring digital I&C into the PRA in general.

MR. ARNDT: In general.

MEMBER APOSTOLAKIS: And obviously that's not what we're talking about here. So what you are -- you will try to do with this document would be to see what kind of risk information one could use convincingly in the context of the interim guidance that you are issuing, without really claiming that you have brought --

MR. ARNDT: Correct.

MEMBER APOSTOLAKIS: -- the digital I&C into the PRA.

MR. ARNDT: Correct.

MEMBER APOSTOLAKIS: There may be other ways of bringing risk insights that will be useful in determining, for example, whether you have sufficient diversity or whether you need diversity.

MR. ARNDT: There are a number of different potential applications of risk-informing in the digital I&C area -- that being one.

MEMBER APOSTOLAKIS: Okay. Okay.

MR. ARNDT: But that's not what this is. This is -- specifically is what the licensees are proposing in their design cert PRA is sufficient in terms of modeling the digital I&C.

MEMBER APOSTOLAKIS: So these will not address the interim guidance documents that you are issuing now?

MR. ARNDT: No.

MEMBER APOSTOLAKIS: No.

MR. ARNDT: It's the follow-on ones, the longer term applications. But this is very specific to design cert PRAs.

MEMBER APOSTOLAKIS: Okay. So, then, this we can use for the ESBWR design certification.

MR. ARNDT: Correct.

MEMBER APOSTOLAKIS: Okay, okay, okay. Thank you.

MS. SOSA: Now, Steve is going to go into the details of where we are regarding the ACRS recommendations on D^3. I'm just going to recap very briefly here.

You may recall the Commission in the June 22nd SRM directed the staff to incorporate the ACRS recommendations on diversity and defense in depth in the project plan, which we've done. The Steering Committee approved the project plan July 12th, and on September 28th the staff completed the near-term staff assessment on D^3.

A copy of the preliminary assessment on inventory and classification was provided to the ACRS staff on October 1st, and the staff is on schedule to complete a white paper identifying the potential impacts on the ISGs and capture the assessment results of inventory and classification and operating experience by the end of December. A copy of this paper will be provided to the ACRS.

The longer term efforts include continuing with the assessment of operating experience to provide insights to refine the guidance as necessary. The staff is currently planning periodic updates with the ACRS Subcommittee on I&C, and these information meetings are designed to coincide with the development of draft ISGs.

The next Subcommittee meeting is planned for November, and we expect to discuss the licensing process and the risk-informed draft ISG at that time.

MEMBER APOSTOLAKIS: Is this -- the document you mentioned, is this the memorandum from Mr. Ian Jung to Russell Sydnor?

MS. SOSA: Yes. There is an attachment, which is the --

MEMBER APOSTOLAKIS: Yes.

MS. SOSA: -- breakdown. Now, at this time, I'd like to turn the presentation over to Steve, please.

MEMBER APOSTOLAKIS: So we will not

discuss this today, or you will discuss it?

MR. ARNDT: I will discuss it.

MEMBER APOSTOLAKIS: Okay.

MR. ARNDT: All right. Thank you, Belkys.

As was mentioned earlier, my name is Steve Arndt. I'm actually in the process of transitioning from my old job in Research to my new job in NRR.

MEMBER APOSTOLAKIS: So we will not see you again in this context here?

MR. ARNDT: Oh, you'll see me plenty in this context. I'll be still working in the I&C area, just a different office.

MEMBER APOSTOLAKIS: Oh, okay.

MR. ARNDT: Less research, more implementation.

What I'm going to do today is rather quickly go through some of the draft guidance, not all of it -- because we spent more than a full day at the Subcommittee associated with that -- but give you some general overview of what the guidance is as well as what it's not.

As Kimberley mentioned, and as was discussed in the Subcommittee, each of these guidance have specifically called out in the preamble the fact that the methods described in the guidance are not the only methods that the staff may find acceptable. The staff may also find other methods acceptable, but the methods that are described in here are basically the ones that we pre-looked at and we anticipate having less issues associated with that.

Jack Grobe referred to it as the HOV lane. We've looked at these issues, and we understand what the ramifications are.

In cyber security -- I'll go through this very quickly -- we originally -- this group was stood up to look at some inconsistencies in the current staff guidance between Reg. Guide 1.152 and the SRP. Those inconsistencies were resolved with the SRP update in March. The group then took on the task of looking at the inconsistencies and additional information that is needed to resolve issues associated with the industry guidance, NEI 04-04, and the reg. guide.

These two documents were developed for two different purposes. Reg. Guide 1.152 is a design licensing document associated with how do you design a digital safety system. NEI 04-04 is an assessment document. It's designed to assess the quality of cyber programs at a plant. It's designed for a much broader application. So there's naturally some inconsistencies associated with that.

And as was discussed earlier, the outcome of this will be an ISG that will discuss this, including a cross-correlation table that maps the requirements from one document to the other. And because the documents were written basically for different purposes, it has been a bit of a challenge to develop this cross-correlation table, but we're on track to do that.

As Kimberley mentioned, diversity and defense in depth, there is seven problem statements. What we've done in each of these --

CHAIRMAN SHACK: Coming back to that for a second, Steve. So from your point of view, you don't think there's much chance they're going to have one guidance document.

MR. ARNDT: Well, the documents are -- serve two different purposes.

CHAIRMAN SHACK: Yes. I mean, but I thought Kimberley wanted them to be able to use either/or, and you keep --

MR. ARNDT: Yes.

CHAIRMAN SHACK: -- see, you have an "and" in here I think.

MR. ARNDT: Well, you could -- assuming

that we are successful in coming up with a cross-correlation table that adequately addresses all of the issues, you could use NEI 04-04 for all cyber applications.

As Kimberley mentioned, Reg. Guide 1.152 goes into a lot of other things associated with how you design and implement a digital system. It's just those particular provisions in that -- the most recent version of 1.152. That's our goal.

MR. GROBE: If I could -- Jack Grobe, NRR. The current version of NEI -- the NEI document is not sufficient. The interim staff guidance will provide guidance on what needs to be addressed in addition to the current version of the NEI document to be sufficient.

If NEI chooses to revise their document and submit it, and we endorse it, then that could be a one-stop shop. But the ISG will be the guidance that we put out on the table.

MR. ARNDT: If you look at the last line of the slide, the draft version is what we're talking about -- if they update their draft, and if we find that acceptable.

CHAIRMAN SHACK: But it's just one stop for this aspect.

MR. ARNDT: For this aspect.

CHAIRMAN SHACK: 1.152 will still be covering other things.

MR. ARNDT: That's correct.

In the diversity and defense in depth area, as Kimberley mentioned, there are seven areas. The most challenging has been the adequate diversity and manual operation issues. There are others, which I'll go through relatively quickly. I won't go -- I don't have a slide for BTP-19 Position 4, but that has to do with the issue of clarifying whether or not you can do diverse backup actuation at the system or component level, and the position on that.

We'll talk a little bit about the effects of CCF and CCF applicability. This has to do with the issue of what is an acceptable design attribute and what kinds of common mode failures you have to take into account in your analysis.

Echelons of defense -- this is the issue that we had with earlier applications, combining the same hardware for RPS and SFAS. I won't talk about that in detail, but the result of the ISG is basically if you can meet the safety function, we've determined you don't need to necessarily have different kinds of systems doing RPS and SFAS, if you can still meet the criteria and adequate diversity and manual action.

The single failure criteria also I'm not going to talk about in detail, but that has to do with how do you define a single failure and common modes software failure.

The big-ticket item, obviously, is the issue of adequate diversity and manual action. This basically looks at the issue of how much diversity is acceptable, and when can you rely on manual action as part of that.

The guidance is -- makes no distinction between future reactors and operating reactors, relies on our current process for evaluating the implications of common mode failure. That's BTP-19 that was talked about earlier that's part of the standard review plan. It's part of Chapter 7 of the standard review plan, and the related supporting documentation in NUREG-6303.

That provides a mechanism by which designers of the system can go through an analysis to determine if additional diversity is necessary. And it basically says you take the worst common mode failure and you see whether or not your remaining systems that are not diverse to those systems can adequately protect you. And it has a set of criteria associated with that.

MEMBER APOSTOLAKIS: So we know now what is adequate diversity, or is it a matter of judgment?

MR. ARNDT: It is a matter of judgment in terms of how you credit certain things and what kinds of particular diversity is considered acceptable in the analysis. But there is an analysis procedure that basically says you start here with these assumptions, you go through this particular set of processes in the Chapter 15 analysis, and you come up with an answer, yes, it passes, or no, it doesn't. If it doesn't pass, you have to go back and add an additional diverse system.

MEMBER APOSTOLAKIS: But there is also judgment as to what kind of common cause failure one would assume, isn't there?

MR. ARNDT: And that's one of --

MEMBER APOSTOLAKIS: And that's a big one.

MR. ARNDT: Well, that's one of the things that the ISG is trying to provide additional guidance on. How do you define that, and how do you articulate that particular finding? And we'll talk about that. Give me a slide or two.

MEMBER APOSTOLAKIS: Okay.

MR. ARNDT: In terms of manual action,

Kimberley stated it explicitly -- where protective actions that should have been automatically performed by the system, subject to the CCF, require less than 30 minutes to meet the acceptance criteria, then an independent diverse automatic backup -- let's use the same or equivalent function -- is provided.

Basically, you go through the analysis. If you can't meet the acceptance criteria without a manual action within the first 30 minutes, then you need an automatic backup.

The ISG goes on to talk about some other issues associated with that, but the automatic backup does not apply to follow-on actions, and that you need to have sufficient displays and controls, either safety or non-safety, to allow the operator to make those decisions.

But the real crux of the issue, as was discussed earlier is, is 30 minutes a correct or acceptable, or is it the best way to do it? One of the issues here is of course that common mode failure due to software is, by its very nature, an extremely difficult thing to analyze and to predict, because if you knew you had the problem you would have fixed it. It's a context-based failure.

So one of the concerns we have is it's

difficult to pre-analyze what kind of acute demands you're going to have on the operators, and things like that. So what we've determined, based on the amount of burden that is likely to be placed on the operator, the past regulatory decisions and engineering judgment, 30 minutes is a good acceptance criteria for this ISG.

MEMBER BLEY: Steve, I want to ask you the same thing I asked NEI. Can you tell me about the extent of involvement by people with operations experience and human factors expertise in the development of the staff position on this issue?

MR. ARNDT: I probably can't tell you all of it, because there has been an enormous amount of people looking at this across the agency and across other agencies and other industries.

MEMBER BLEY: I'd say direct involvement is --

MR. ARNDT: This was developed by the ISG, which is chaired by Ian Jung, who is sitting in the back of the room. There was representatives from all of the different offices. There was interactions with our human factors groups in both Research and NRR and NRO. There was a significant discussion, both on what the right number should be, but more importantly whether we know enough at this point to have a performance-based criteria instead of a specific number.

MEMBER BLEY: Is the idea here -- I know one idea is the system should take care of itself for --

MR. ARNDT: Right.

MEMBER BLEY: -- this time period. Is there an embedded idea that operators should be definitely hands off? And if that's the case, has there been any discussion about the impact on operator performance and keeping the operators engaged as you implement this kind of a process?

MR. ARNDT: I would go back to your first statement and rephrase it a little bit. It's not that they should be kept out of the process. It's they should not be relied upon to be able to diagnose and take mitigative actions within this timeframe.

MEMBER SIEBER: Same as it is now.

MR. ARNDT: Same as it is now.

MEMBER APOSTOLAKIS: Same as what? What did you say?

MR. ARNDT: Same as it is now.

MEMBER BLEY: It has been termed at times in the past it ought to be absolutely you don't touch it. I just asking if that's the --

MEMBER SIEBER: Different plants do different things.

MEMBER APOSTOLAKIS: And this refers to both failure to actuate safety systems, and if they actuate to deal with problems of running. I mean, it's a blanket thing, you know.

MEMBER CORRADINI: So if I took away the number, is there -- are you and industry on the same page about how Jack just described it, which is -- which is that it's an approach where it's not the operator has hands off, but the operator should allow the systems to perform -- evaluate, monitor, and respond accordingly over some time period to be determined. If you took the number out of it, are you guys on the same page on this?

MR. ARNDT: I'm seeing --

MEMBER APOSTOLAKIS: No, let's understand. What do you mean taking the number out of it?

MEMBER CORRADINI: Well, in other words, if it weren't 30 minutes, if it were something that both of you could agree to the philosophy without the quantitative number, are you on the same page about how the operator performed? Because what Jack said to me is most important, which is it's the same philosophy on the way the plants are running now.

MR. ARNDT: Well --

MEMBER CORRADINI: And if that's the case and all you're doing is quibbling about what the number should be, that's one thing. But if you're philosophically running the plant differently with this, then that's a different way in which the operators are going to be trained. I want to understand that.

MR. GROBE: This is Jack Grobe again. I don't think we're quibbling on what the number should be. The number was established based on what the staff would find acceptable, which would minimize the impact on the licensees. It's strictly a financial decision on the amount of effort licensees want to put into design analysis and dialogue with the staff.

The number is there, so that they understand that if they choose, given their particular plant design, to implement a design that does not require operator action within the first 30 minutes. Certainly not meaning that the operators are not to be engaged, but it doesn't mandate operator action within the first 30 minutes, that the staff would find that acceptable with very limited review.

I agree 100 percent with NEI that we need to develop guidelines that if a licensee finds that it would be beneficial to them to argue differently, there needs to be a standardized approach on how to do the human factors aspects of the analysis of the operator action. And we're going to be working with the industry to develop that. But taking the number out is contrary to the purpose of the interim staff guidance.

MEMBER CORRADINI: No, I didn't mean to take a number. I'm trying to understand -- if you -- if you had agreed on the number, is the way the operator is going to be trained for these advanced plans similar to -- I'm just going back to what Jack said, you agreed with, and I'm just making sure -- is everybody on the same page about that?

MR. ARNDT: Yes. The issue here is I think you're characterizing the decision criteria the wrong way. This is a decision criteria on the design decision. Whether or not you have an additional diverse system does not have anything necessarily to do with how you train the operators or the operational philosophy. It's whether or not you have an additional system or not.

MEMBER CORRADINI: And then, given the system, the way you train operators will not change.

MR. ARNDT: Correct.

MEMBER CORRADINI: Okay. I'm sorry.

MEMBER APOSTOLAKIS: This is not only for advanced reactors, by the way. This is for all reactors.

MR. ARNDT: This is for all reactors that choose to do a digital system control room.

MEMBER SIEBER: And the operator's job is to make sure the functions occur when they're supposed to occur and under the conditions they're supposed to occur.

MR. ARNDT: Correct.

MEMBER SIEBER: And if he were to do it manually, he may do it a different way, different control.

MEMBER CORRADINI: So let me ask you a different question. So this is a -- this is something that determines whether I have a diverse system, whether I should have a second or additional systems.

MR. ARNDT: Correct.

MEMBER CORRADINI: And then, what -- well, let me just stop there for a minute. I want to think about it.

MEMBER SIEBER: Well, the operator follow-on following the course of an accident, and perhaps actuating a device as a backup, is diversity in itself. On the other hand, the 30-minute rule does not allow you to take credit for that operator rehearsing.

MEMBER CORRADINI: Fine. Thank you.

MR. ARNDT: Let me skip through the rest of this relatively quickly, so we can have some time for discussion. Another issue is the issue of understanding the effects and how do we clarify what is required regarding how you do that analysis, and also associated with whether or not spurious actuations are a significant issue associated with that.

The primary concern here is undetected failures within the digital system, and spurious failures tend to be self-revealing. So that is not as significant, in the opinion of the staff, as silent failures or features to actuate.

MEMBER STETKAR: Steve?

MR. ARNDT: Yes.

MEMBER STETKAR: Let me ask you a question on that. The statement here that says, "Spurious trips and actuations are of lesser safety concern than failures to trip or actuate." What's -- I'd like to understand the basis for that statement. That seems contrary to what we've learned from extensive analysis of fires.

I'm aware of some digital control systems in Europe that actually stop high-pressure injection under certain criteria --

MR. ARNDT: Yes.

MEMBER STETKAR: -- and prevent the operators from actuating it. Spurious actuation of that during a small LOCA would seem to be relatively important. So I'm curious why this dismissal of spurious actuations globally from a safety basis is a premise.

MR. ARNDT: It's not intended to dismiss it completely, just that it is of less concern than some of the other concerns.

MR. WATERMAN: This is Mike Waterman. I'm in the Office of Research. I was on the Task Working Group for Diversity and Defense in Depth.

On the effects of common cause failure, we took a look at it, and generally when a system is spuriously actuated the operator knows fairly quickly that he has a spuriously-actuated system, and he can take steps to address that. It's when systems don't actuate, or maybe they're indicated to have actuated but didn't really actuate, that's when you get into issues of whether or not the operator actually can respond in a timely manner to address it.

For example, if he thinks he has safety injection going on because his indications on the board say it actuated, and he is sitting there waiting for his safety injection system to address the issue that is going on in the plant, and nothing is happening, then you get into the issues of, what does the operator do then?

And so we sort of looked at spurious actuations as not nearly as important to consider as just failures to actuate where the operator may be misled.

MEMBER BLEY: I'm a little more concerned not in terms of sitting there cold and something comes on, I'm concerned about as an event is progressing the system decides that I have a low pressure condition, stops high pressure injection, tries to align low pressure injection, and, in fact, prevents the operator from doing -- reversing that process without performing a reasonably large number of manual interactions, and perhaps defeating the system.

That's not the same as spuriously initiating high pressure injection when I'm operating at full power. It's very much different.

A similar concern would be conditions to automatically isolate injection because of containment parameters that are incorrect. Those tend to be somewhat troublesome.

MR. WATERMAN: They do, but generally they are also announced, annunciated, and the operator working through it -- post trip, working through the EOP, the operator typically watches the symptoms. And if something spuriously actuates, he usually has something in his EOPs or in his plant procedures that will allow him to isolate that.

Generally, spurious actuations are fairly obvious when they occur. It's the failures to actuate that we felt were probably more serious concerns with regard to the BTP-19 spurious actuation issue.

MEMBER BLEY: I see both points here. I think there's a -- there's a class of events that I think from the operator's point of view it's one of the reasons I'd really like to see a lot of operator involvement in the groups working on this.

We see them in existing plants with things like pneumatic systems where things start acting funny in the plant and not in obvious ways. And now we have systems -- and I don't know how they'll actually be -- where some kind of a problem within one system can create more than one, or one serious one as John mentioned, that really draw the operator's attention trying to figure out what's going on.

And I would guess I would call those things spurious actuations. Maybe you folks have another name for them. But I think they can be really important -- have really important impacts on how the operators perform. Operators don't close off what's happening and focus on one thing, quite the way engineers do when we're looking at a problem.

MEMBER SIEBER: I think even more important you may not have a parameter that links directly to what that failure is. Maybe the operator is scratching his head saying, "I'm not quite making it here, but I don't know what's wrong."

MEMBER BLEY: Exactly.

MEMBER SIEBER: That's where the mechanical and electrical and computer diversity is important.

MEMBER STETKAR: Especially if they're trained to really trust this now system that --

MEMBER SIEBER: Well, but they don't.

MEMBER STETKAR: They will be in the future. I'm a little bit familiar with the way operators are trained in Europe, and they really trust those systems. The system knows more than the operator does.

MR. WATERMAN: That's why most --

MEMBER STETKAR: Unfortunately, that's the attitude that I get.

MR. WATERMAN: And that's why most countries in Europe have the 30-minute rule, right?

MEMBER APOSTOLAKIS: What did you say, Mike?

MR. WATERMAN: That's why most countries in Europe use the 30-minute response time rule. In Germany -- Germany uses it, France uses it, Sweden uses it.

MEMBER STETKAR: And it's why some risk assessments have shown that spurious actuations within that 30 minutes where the operators are locked out can cause problems.

MR. WATERMAN: They're not really locked out. It's more an issue of how much time do you give the operator to understand exactly what went wrong with what was supposed to work, so that he can take the appropriate steps to address it.

If we rely on the operator to just simply respond in two minutes, you know, what's the basis for the common cause failure that justifies a two-minute response?

MEMBER MAYNARD: Well, I hope we don't take a step backwards, though, and try to go back to where the operator has to be able to know exactly what went wrong before they can fix it, because that's what got us in trouble before. The way the procedures and the training is now you don't have to know what went wrong. You can methodically step through, and you take care of the --

MEMBER SIEBER: Well, if there is an optimum course of action that has been pre-thought out.

MEMBER MAYNARD: And so they don't always have to know what's -- what went on or whatever. I mean, I believe that the procedures and the training can be such that it will deal with that.

And the 30 minutes in the U.S. hasn't been a hard and fast that the current plants all had to meet 30 minutes. And a number of them have actions that it may be needed in 20 minutes or 25 -- have gone through the regulatory process for approval and stuff.

But I am not at all a fan of locking the operators out for -- to say you can't do anything for 30 minutes. I think that's absolutely the wrong thing to do.

MEMBER BLEY: Well, they are actually not locked out, but they have to actively intervene, typically with codes and things like that, that are only available to the supervisors. And, you know, it's an additional complication. They are not completely locked out, but they can't just immediately intervene either.

MR. WATERMAN: The 30-minute rule is not designed to say, "Operators, you cannot touch this system." The 30-minute rule was designed to say that a plant ought to be robust enough to take 30 minutes of operators not understanding what to do.

Now, if the plant is -- cannot withstand an accident for 30 minutes without the operator taking the appropriate actions, then it seems reasonable that there ought to be a diverse actuation system in there to back up what needs to be done. And that was why we established the 30-minute rule. It wasn't to say, "Operators, you can't do anything for 30 minutes."

It was to say, "Operators, if you're really confused, and something outside design basis can happen within that 30-minute timeframe, you're backed up by a diverse actuation system." That is not affected by the common cause failure that has got everything messed up. That was what the 30 minutes was for. It's not to say when operators can or cannot respond.

MEMBER APOSTOLAKIS: Have we discussed this enough?

(No response.)

Okay.

MR. ARNDT: Thank you. I'll real quickly finish this part of it up. Another big issue was the applicability. Kimberley talked about this extensively. The two issues associated with that are internal diversity with a digital system and whether or not that is acceptable.

The example that is used in the interim staff guidance is, if you have a four-division system, two divisions are of one particular kind of processor and operating system, and things like that, and the other are a different set, that may be sufficient diversity, without having to have an external additional system.

And there is examples of this in the international community as well as other industries as well. The other issue is if a system is sufficiently simple to be fully testable -- and of course that's something that we probably need to work on a little bit more, because of the criteria associated with that. But the concept is you can design systems that are extremely simple in terms of the hardware and firmware that can be completely tested.

NEI's issue on defense measures associated with basically systems or ability of the systems to know that they are effective and can have a much lower likelihood of failure in common mode associated with fault tolerant design and number of closing is an area that we're looking at in Research in a general sense.

Our big concern in that area is not that these aren't good things to do. It's that we don't think we are at the point now where we can quantitatively credit those things, because we haven't seen an update on what effect -- what the positive effect would be and whether or not it might have negative effects.

In this area, as was mentioned a couple of times, we're going to continue to work with the industry, particularly on this issue of diverse strategies and adequate diversity strategies. Mike Waterman is leading a research effort in that area.

We're proactively working in the area of operator experience. And as we complete this, we're going to hopefully update the standard review plan and BTP-19 associated with any revisions that we might have.

MEMBER APOSTOLAKIS: The next seven slides or so deal with highly-integrated control rooms, and then you go on to operating experience, which is really of great interest. Do you think there is anything really significant you want to talk about in these seven slides? Go to 19.

MR. ARNDT: We can skip through them if you'd like. At the Subcommittee meeting, there was not a lot of discussion --

MEMBER APOSTOLAKIS: Yes.

MR. ARNDT: -- associated with this. And the information is provided in the draft guidance, too.

MEMBER APOSTOLAKIS: So I would suggest we go to 19.

MR. ARNDT: All right. As Belkys mentioned earlier, one of the Committee's recommendations to the staff and that was later picked up by the Commission in an SRM was to make a significant effort to look at operational experience and also --

MEMBER APOSTOLAKIS: So that's what it takes for you guys to listen to us.

MR. ARNDT: No. Let me finish.

(Laughter.)

And to also look at an inventory classification system of digital systems. What we did was developed a little short-term action plan, which is characterized by this chart, and we discussed it with the Subcommittee chair, to take the current operational experience evaluations that we are already doing and have been doing for a number of years.

And look at what the information is telling us right now. The first action, which is the kind of center box there below the pink one, staff assessment to look for major issues or common themes in what we currently have. That was to be done by the end of this month, which is the document that George referred to earlier from Mr. Sydnor to Mr. Jung. That was basically looking at all of the different things we know and a preliminary look at an inventory classification scheme.

The next step is to flesh that out better, try and do a pilot inventory classification effort, and then write a white paper on that. And then, look at the longer term activities -- we're going to continue the work on the classification scheme and continue the operational experience and feed that into the longer term activities.

As we talked about earlier, the interim guidance will be -- over the course of the next year or year and a half -- turned into long-term reg. guides and SRP updates. Longer term operational experience will feed into those final documents.

So what we did, we looked at available operational experience. There has been several different studies of LERs, both by the NRC and by other groups. There has been a look at the ISE failures. This is the chart that Mike Waterman put together and NEI is -- EPRI is working on. There is an international database that we're starting up right now. It's the computer systems important to safety, or COMPSIS database.

We also looked at a number of external non-nuclear databases, including the aerospace industry and others, to see whether or not the kind of information we were gleaning from our data was similar to the kind of information they were getting from the industry.

So based on our quick look of where we were today, our findings basically were we've got some challenges in terms of what data we can access, the quality of the data, particularly in causal data.

There has been a number of LER studies on digital systems. There's a journal that's publishing one in a few months on LER datas for the -- some CE systems. There's data out there, but a lot of times it's very difficult to extract the causal data, which is the most important information.

The data is not always easy to quantify in terms of whether or not we're getting exactly the same failures and the exact same data sets. Kimberley mentioned just correlating her data set and Mike's data set has been a challenge. So it's difficult challenge.

What we have found is there are both CCF events out there, and there is also a lot of precursors to CCF events. What we're trying to do is integrate what we have found in nuclear, improve what we are doing in terms of nuclear, and understand what other industries are seeing in terms of common mode failure and digital system failures in general.

We have an ongoing operational experience program, which is an anecdotal review of failures as they occur, as well as several efforts associated with collecting and analyzing the data.

In terms of inventory classification, what we've done is look at how inventory classification schemes have been done in the past by other people and then try and understand whether or not we can use any of that information for an inventory and classification scheme in the nuclear industry.

There has been probably dozens of different inventory and classification schemes developed, and they are developed for different purposes. For example, there is regulatory base classification schemes, as simple as safety/non-safety, and things like that. These have been primarily developed for distinguishing classes of systems for regulatory treatment.

One example of that, of course, is the work we did in risk-informed grading of systems for special treatment activities. Another way of doing it is design-based. How do you design systems? And there have been a number of studies associated with that, associated with how important it is to have particular characteristics in a system depending upon the design application of that system.

Perrow did a study that's referenced in our quick-look review that looked at how important complexity of the system is to design performance, how important coupling of the system is to design performance.

The coupling aspect is particularly

interesting in nuclear, because one of the issues that we keep finding is, well, these things are so independent, they have to make very simple decisions versus systems that have more feedback. So you might be able to categorize systems, like trip systems in a load coupling type category and control systems and feedback systems and high coupling category.

There has also been an operationally based classification scheme associated with how do the systems fail. NASA did a report here recently that classified systems based on their predominant failure modes, basically failures associated with specification errors, failures associated with improper or incomplete V&V failures associated with translation errors, things like that.

So when we did the analysis, basically, we tried to understand whether or not these systems had the same basic kinds of failure modes, the same basic kinds of issues that we care about. And what we found was the systems were failing in similar ways than the ones that we care about, both from the operational experience we looked at and from the coupling classification systems that we investigated.

So we took from that that using an extension of what has been done in other industries is probably an acceptable way of doing that. So based on that, we came up with a preliminary methodology that is based on the complexity of the system.

MEMBER APOSTOLAKIS: But there is no definition of complexity, Steve. What is complex? What -- something that was complex 10 years ago may not be now.

MR. ARNDT: Well, complexity has to do with how you implement the function.

MEMBER APOSTOLAKIS: Still, I mean, if you show me a system, I would be very hard-pressed to say it's complex or it's not. The things that we can do now, even with PCs, were unimaginable 20 years ago.

MR. ARNDT: Yes. The -- let me pull the report, because I don't have the -- this right off the top of my head. The kinds of issues we're talking about in complexity is how complex or how large or how many different functions does the software have. When we talked in D^3 space a few minutes ago about is it sufficiently simple to be completely testable, that is a very uncomplex system.

If it is not sufficiently simple to be untestable, it is a more complex system, the attributes associated with complexity are basically binning it in two or three or four levels based on metrics that already exist. Like for software, there is a metric called cyclometric complexity, and it looks at how many branches and how many different ways the software can actually perform. And there's a metric for that.

MEMBER APOSTOLAKIS: But isn't it -- I mean, to declare something as simple would have to consider, it seems to me, the context within which it is supposed to function.

MR. ARNDT: Absolutely. It --

MEMBER APOSTOLAKIS: So that you may have a very simple computer code, you know, in -- say scramming the reactor under certain conditions, but the number of conditions may be very, very large.

MR. ARNDT: Correct.

MEMBER APOSTOLAKIS: So it's not completely testable.

MR. ARNDT: Correct.

MEMBER APOSTOLAKIS: Now, would that system be simple or complex?

MR. ARNDT: It would probably be complex, or at least halfway in between, simply because of the function -- the functional complexity. This is a functional complexity.

MEMBER APOSTOLAKIS: So it's not just the system itself; it's also the context within which you expect it to function.

MR. ARNDT: Absolutely. A system that, for example, can be tested completely. You can demonstrate its simplicity, a system that has a lot of internal diagnostics. It may be more robust, but it's going to be a lot more complex.

MEMBER APOSTOLAKIS: Now, regarding your proposed classification scheme, I still like the -- as you mention on one of the pages here, that in the U.S. nuclear industry I&C systems are also functionally categorized as protection systems, engineered safety features, actuation systems, control systems, and monitoring implications.

MR. ARNDT: Correct.

MEMBER APOSTOLAKIS: And I like that. So I think maybe what you need is some sort of a hierarchical scheme, so you -- where you might start at a higher tier with this classification, and then each one of these will be categorized according to these three attributes.

In other words, the categorization scheme or classification scheme doesn't have to be simply in the sense of 1, 2, 3.

MR. ARNDT: No.

MEMBER APOSTOLAKIS: It can be some sort of hierarchy, you know, if you have a monitoring indication system which happens to be, you know, Category B. Something like that.

MR. ARNDT: Yes.

MEMBER APOSTOLAKIS: I mean, I'm not very -- but I wouldn't want to lose this. I think this is important -- to know what --

VICE CHAIRMAN BONACA: Well, one concern I have is -- you know, regarding the data that you're going to get is that, you know, the most reliable source would be the LERs, but they are only relating to events where you have regulatory significance. And that's based on the classification of safety-related or non-safety-related, which really goes counter to importance here as you defined --

MR. ARNDT: Yes.

VICE CHAIRMAN BONACA: -- which is risk-based. So I'm concerned that, you know, in older systems where you have essentially feedback or control systems, which typically are in balance of plant applications, you may have no information that you are drawing on to really get a better understanding of the issue or where the concern is.

I don't know how you're going to get that information. I know there is the risk that you'll get out there, but --

MR. ARNDT: The challenge with getting information is broad, both in terms of operational experience and categorization, and all sorts of other things. What we're trying to look at is not only LER data but maintenance rule data, EPIX data, corrective action program data, and a number of other areas.

We're talking with Benny Lyon about getting access to some corrective action program data.

But as George pointed out, the point of doing this exercise I think is, one, to get more information on insight. If we actually end up with something that we can use on a regulatory decisionmaking criteria, so much the better.

But the primary idea is to get -- gather the insight associated with it. And I think we're starting to get that as we go anyway, and it is an evolutionary process. And as we start actually trying to pilot this in terms of actual systems, we may lean additional things.

MEMBER APOSTOLAKIS: So this is just a progress report. I mean --

MR. ARNDT: Yes.

VICE CHAIRMAN BONACA: Yes. Corrective

action --

MEMBER APOSTOLAKIS: And this is really something that we should spend some time on at the Subcommittee meeting.

MR. ARNDT: We can put the more detailed review --

MEMBER APOSTOLAKIS: Okay.

VICE CHAIRMAN BONACA: What is our preliminary comment? Sorry.

MEMBER BLEY: Steve, has the focus of this group been strictly on the digital -- the new digital system itself or the whole system in which it operates, including out to the sensors, that sort of thing? One thing I don't see up here that I know has caused many problems in the past is if -- if you're not actually sensing what you're trying to monitor, but you're doing a lot of signal processing on it, and algorithms, then problems in processing the algorithms create a lot of confusion either to the systems or to the people using them. And I don't see that kind of thing in the list.

MR. ARNDT: The exercise here was particularly the digital system, but it can be certainly expanded to that. One of the issues obviously in digital systems is the setpoints and the trip points and the -- how do you -- whether or not that can be done on a common input parameter.

It goes back to some of the stuff we skipped in the earlier presentation associated with, how do you look at the communication data, and things like that? And that's indeed included; the actual sensors themselves are not.

MEMBER APOSTOLAKIS: But that's why also in support of that I would like to preserve the functional categorization --

MR. ARNDT: Sure.

MEMBER APOSTOLAKIS: -- that we mentioned earlier. So I can see some sort of a hierarchical structure here that focuses on individual --

MEMBER BLEY: And all of this is aimed at applying to, I would assume, any systems that include digital parts, hybrid systems of one sort or another.

MR. ARNDT: Yes. At the risk of cutting this off, let me finish up, so we can have a general discussion. The preliminary assessment was done based on what we know today.

MEMBER APOSTOLAKIS: I have a problem. At the risk of --

MR. ARNDT: While you look for that, let me finish my statement, and then --

MEMBER APOSTOLAKIS: Finish your statement.

MR. ARNDT: Based on what we know today, in terms of operational experience and inventory classification, we did not see anything that would make us change what we proposed in the interim staff guidance for D^3. As we continue to work in this area, both in terms of operational experience and inventory classification, as that original chart said, we plan on providing input to the long-term guidance associated with BTP-19, the reg. guides, etcetera.

But as of this minute, actually as of last week when we were trying to put out the draft interim staff -- the interim staff guidance on D^3, the group that was working on this provided to Ian basically their recommendation, that we haven't learned anything that would make us do something differently in D^3.

MEMBER BLEY: Quick question. You mentioned that NASA study on categorizing failure modes. Is that a public study? And do we have it?

MR. ARNDT: It is not a public study. There is a short discussion of it at the Commission meeting on -- when was the Commission meeting?

MEMBER APOSTOLAKIS: Do you know how my -- do you know -- I know him, and you know me, so --

MEMBER BLEY: I think that will be important for us to look at, because it sounds like that --

MR. ARNDT: The primary purpose of that report was to look at -- try to come up with an analysis methodology. And the categorization was secondary to that, but it was an idea of -- what are the failures we care about, and how do you categorize them? And based on that, how do you develop an analysis methodology?

MEMBER APOSTOLAKIS: There is one comment I want to make on this memo to Mr. Jung.

MR. ARNDT: Yes.

MEMBER APOSTOLAKIS: But it's something I really don't understand. You are making a big deal out of V&V errors, and I find -- I have a hard time understanding why. You say, "An example of the software-based V&V error was reported," blah, blah, blah.

The causes were -- first, a hardware failure in the digital feedwater control card failed. Two, a failure to implement in software a design specification to have a redundant set of signals trip the main turbine. And, third, a design error in configuring the relays that were to provide the redundant trip signals.

And then, you declare this a V&V failure. I mean, of course, it was a V&V failure, because it didn't catch it. But that's not really what we're after here. I mean, everything then is a V&V failure, because, you know, there is some V&V done. And if you don't catch an error, you don't catch an error.

I have -- and then, you go on -- maybe not you personally, I mean, the memo -- the memo says software failures comprised 33 percent of the total number of digital I&C failures, and the majority resulted from incomplete requirements and errors in performing verification and validation.

The review validated the concern for software-induced common cause failures. It seems to me there is a jump there. How did you do that? Just because there were incomplete requirements? It's not clear to me that that results in a conclusion that common cause failures do happen significantly -- at a significant rate.

I think there is some loose language here that needs to be tightened up. But in particular, this V&V -- and later on, I mean, you say -- well, the document says, "V&V is a big deal." Well, of course it is a big deal, but what we are trying to understand here is the causes of failure, not that the last safeguard failed. I mean, that's important, too, but I -- I think this needs a lot of work.

That's all. And you don't have to disagree with me. You don't have to agree with me either.

MR. ARNDT: Okay.

MEMBER APOSTOLAKIS: All right.

MR. ARNDT: That works for me.

MEMBER APOSTOLAKIS: Okay.

(Laughter.)

Very good answer, Steve. I just wanted to voice my concern, because this is a very recent document dated September 28th, which I believe was last Friday.

MR. ARNDT: Yes.

MEMBER APOSTOLAKIS: So, you know, when you come back next time to discuss this in more detail, I wanted to make it clear -- just saying everything is V&V failure doesn't help me.

MEMBER BLEY: Tiny follow up on George's point. I don't remember, was that in your list of complexity issues, the ease with which good V&V can be done on the software, which has to do with how it's built?

MR. ARNDT: The issue is really how testable is it exactly, and that partially has to do with V&V.

MEMBER BLEY: Okay.

MR. WATERMAN: This is Mike Waterman, Research.

MEMBER APOSTOLAKIS: Okay, Mike.

MR. WATERMAN: If we see that we've got 25 or 30 percent of our errors are because of breakdowns in V&V, then that would say in an appropriately diverse system you probably ought to have some diverse verification and validation, like an independent V&V team, also looking at the system. That would be a justification for that as opposed to just relying on V&V.

MEMBER APOSTOLAKIS: And I agree. I agree with that.

MR. WATERMAN: And so that's -- I think that was the whole idea.

MEMBER APOSTOLAKIS: Failures as failures of V&V.

MR. WATERMAN: Yes, and which means, well, let's put in some diverse V&V on that, and -- so that we can address that.

MEMBER BLEY: They aren't there because of the V&V, that's what you're saying, George. That's right.

MEMBER APOSTOLAKIS: Yes.

MEMBER BLEY: they're there for some other reason. They just weren't -- it would be good not to have them in the --

MEMBER APOSTOLAKIS: They listed the three reasons.

MR. WATERMAN: And I guess I'd like -- we tend to -- we tend to make V&V the same thing as a software quality assurance or life cycle development processes. V&V is only a subset of that. You have a lot of other things that go on in software quality assurance, or even system quality assurance, such as configuration management and issues such as that.

MEMBER APOSTOLAKIS: So unless --

MR. ARNDT: I'm going to let Belkys summarize.

MEMBER APOSTOLAKIS: Okay.

MS. SOSA: Okay.

MR. ARNDT: Make her earn her keep.

MS. SOSA: In closing, the Steering Committee and the task working groups are working effectively. The project plan is in place. The interim staff guidance developed to date is available on the website, and we plan to continue interactions with stakeholders through the public task working group meetings.

The staff is on schedule to complete the near-term objectives of the project plan, and we will continue to coordinate efforts with industry to resolve digital I&C issues in the long term in order to refine and enhance the guidance.

We appreciate the Committee's interest in this area, and I also would like to mention that we are planning to have an internal seminar for the staff in November to roll out the interim staff guidance to reviewers to make sure that implementation is applied consistently for new reactors, operating reactors, as well as fuel cycle facilities, digital I&C reviews.

And that concludes my presentation. Any questions?

MEMBER APOSTOLAKIS: Any questions from the members?

(No response.)

Thank you very much, Belkys and Steve. As informative as ever, interesting. Yes?

MR. ARNDT: And I would like to acknowledge that as the Subcommittee heard, but the full Committee didn't, this was an effort of an enormous number of staff across all of the different offices. We had seven different task working groups, seven different leader -- managers, lead personnel, so it's not -- certainly not just me and Belkys. I was just the guy that volunteered to sit up there.

MEMBER APOSTOLAKIS: Now, for your information, the Committee will discuss the possibility of a letter this afternoon starting at 5:30, decide whether we want to write a letter or not, and if we do what that letter would say.

And on that happy note, back to you, Mr. Chairman.

CHAIRMAN SHACK: Superbly done, Academician Apostolakis.

(Laughter.)

You've given us five minutes to spare, so we have a break until 10:45 -- an extra long, civilized break. So we'll recess until 10:45.

(Whereupon, the proceedings in the foregoing matter went off the record at 10:23 a.m. and went back on the record at 10:46 a.m.)

CHAIRMAN SHACK: Back into session. Our next topic is a draft generic letter on managing gas intrusion in ECCS, Decay Heat Removal and Containment

Spray Systems, and Professor Abdel-Khalik will be leading us through that. Said.

MEMBER ABDEL-KHALIK: Thank you, Mr. Chairman. Gas intrusion into ECCS, Decay Heat Removal, and Containment Spray Systems can potentially either damage them or degrade their performance when called upon to perform their function. Despite the design and operational measures aimed at preventing them, and the high level of awareness regarding their consequences, these events have continued to occur on a relatively frequent basis. Hence, a generic letter addressing this issue was issued for public comment several months ago. The comments have been dispositioned by the staff, who are now ready to brief the ACRS on the final draft. Mr. David Beaulieu of NRR will make the presentation. We will also hear from NEI representatives. Mr. Beaulieu.

MR. BEAULIEU: Okay. Welcome. This is -- I'm going to move rapidly through these slides here to stay within the time frame, but, obviously, feel free to ask questions. The outline here, we're going to discuss background, purpose of the generic letter, desired outcome, the principal concerns that we've had with licensees, requested actions and information, public comments, and a final recommendation for you folks to endorse this draft generic letter.

The purpose of the generic letter, request that licensees submit information that demonstrates that NRC regulations are being applied to the subject systems with respect to licensing basis, design, testing, operability, and corrective actions to assure that gas intrusion is maintained less than the amount that challenge operability of these systems. And that appropriate action is taken when conditions adverse to quality are identified.

In terms of background, there's a long background. Gas intrusion events have occurred since the beginning of nuclear power, commercial nuclear power in the United States. There have been numerous previous generic communications in terms of information notices, primarily, and related generic letters and NUREGs.

In 1997, there was an event at Oconee Unit 3 where all high pressure injection was rendered inoperable due to gas intrusion due to hydrogen from an incorrect level indication on their volume control tank, or their let-down tank, and they had no water left. And they actually in opted two pumps and would have in opted the third had they started it. So we left it to the industry in 1997 to tackle this issue, and we decided we would not take NRC generic actions at that time, and let the industry try to resolve the issue. But since then, there's been 60 gas intrusion events, and due to the number and the significance of these events we -- it really does raise a real concern that there is a possibility that this could exist right now as speak at one or more plants that the systems are inoperable, and they just simply don't know it. Some of them have sections of piping that have been filled with air since forever, and they've never recognized it.

MEMBER MAYNARD: What are you calling a gas intrusion event? In large piping systems you're always going to have some gas intrusion and stuff. What are you considering a gas intrusion event?

MR. BEAULIEU: Good question. In terms of the design and licensing basis, the FSAR describes the system either explicitly or implicitly as being filled with water, so technically you could say that any gas is an intrusion event. Realistically, does any gas really matter? No, when it reaches a certain threshold, a certain volume is when it matters. Events are things that would be significant, that we would be aware of them in headquarters through some means, reportability, significant enough to be documented in an inspection report, licensee event report. But that precise question, I'll be expanding upon that and addressing that more a little bit later about what's acceptable, and what's not acceptable, and what the expectation is.

MEMBER CORRADINI: So can I just read something that I have from the generic letter, because this makes sense, but it's qualitative. It says "Requested actions, each addressee", blah, blah, blah, "should do testing, design operability and corrective actions to assure that gas intrusion is maintained less than the amount that challenges operability, and that is validated to confirm operability." So operability is the key attribute, and so my question is, later, if you'd like, and then I'm going to ask the same thing of NEI, I'm assuming for a generic system, containment spray, decay heat removal, whatever, there's a typical pump, there's a typical line, so, therefore, there's a typical amount of gas that either challenges operability or doesn't, so there's go to be some quasi fuzzy line where I need to cross. And so that's what I was looking for somewhere in here to give guidance.

MR. BEAULIEU: And we will.

MEMBER CORRADINI: Okay.

MR. BEAULIEU: I'll cover that in detail.

MEMBER CORRADINI: Okay.

MEMBER APOSTOLAKIS: You said earlier that there are some plants where pieces of pipe have been full of gas for years.

MR. BEAULIEU: Yes.

MEMBER APOSTOLAKIS: And I find that a little strange. I mean, don't they do any tests at all that would reveal these things? Not as a result of the generic letter, I mean before, didn't we have anything that -

MR. BEAULIEU: Well, we had a tech spec surveillance requirement that says verify ECCS systems are filled with water, and I'll be covering that. The bottom line is that the licensee's efforts were not complete with respect to that. They have -- I think it was the TMI event where a certain dead leg was identified, and Warren, if you wish to expand.

MR. LYON: Yes, Warren Lyon. Just a couple of comments. You said typical. I'm not sure there is such a thing as typical here. It depends on a number of circumstances, the individual pump, its location, the piping upstream, downstream, so those are aspects, all of which would influence operability.

In regard to can folks find some of these things, in some of the testing that can realistically be conducted you do not challenge the system in all of its potential operability modes, so the testing that's available doesn't really fully cover everything that might happen. And in the generic letter, we've got a couple of examples of exactly that kind of a situation.

MEMBER SIEBER: If you look at the pump manufacturers' curves, you'll find that they often will test a pump with some level of gas or steam, or what have you in suction, and most of the surveillance tests pump at some low flow or shutoff head where -- and that gas intrusion, the effect on discharge pressure is not linear, and so it may work during the surveillance test, and not work in actual performance.

MR. LYON: That's an excellent point, and there was some industry tests a year or two ago you may be aware of where they tested an actual high pressure safety injection pump, and the test sequences basically were at high flow rates so that gas basically did not accumulate within the pump. And they fed it some rather high void fractions, and it didn't bother the pump a bit. Apparently, the first stage or two compressed the gas, and it continued to work. Had they tested it at the low flow rates, they basically, and we certainly concluded, the pump would have failed.

MEMBER CORRADINI: Actually, you've gotten to the point I was going to make, which is, it's not the pressure head, it's the volumetric flow that either is going to entrain the gas or not going to entrain the gas, so that if I go into a high pressure injection in the recirc mode for testing, which is the typical way you do it, you shut off the outlet, and you essentially have the small recirc line, you could kill the pump pretty easily from gas, but if I had it in a delivery mode as I want it, there's a lot of gas that it could essentially just suck right through, and work just fine.

MEMBER SIEBER: Maybe you could, maybe not. An example that's not gas intrusion, but similar properties is aux feed systems where you have a check valve connection between the pump and the steam drum. That check valve leaks, you end up heating up the suction so that you have a steam pocket. It won't pump. It won't run under those -- it'll turn but it won't pump anything. That's not included in your generic letter.

MR. BEAULIEU: You're right. It specifies the temperature above the local saturation.

MEMBER BANERJEE: Can I just make a point? There has been a lot of pump testing done on the void conditions, and it's mainly been done for LOCA, but some of that might be applicable here. There are pump characteristics drawn with various inlet voids, and a lot of these tests were done by Ontario Hydro, actually, but they were also sponsored by the U.S. NRC. So there is information on void versus flow characteristics pumps at different shutoff heads. These were large centrifugal pumps, more like -- and recirc pumps, not heat HPI pumps and things like that. Might be useful to look at that.

MEMBER MAYNARD: I'd like to go back a moment. Just my original question or point on this is that I believe that there's enough events, enough conditions out there that warrant some action. I think you can discredit yourself sometimes if you try to encompass everything that might have been found with gas in it, and create room for arguments as to well, those really weren't events, or whatever. I think you need to focus on those things that are potentially damaging situations, and I think it would add more credibility to the discussion, rather than just say that 60 gas intrusion events, that some of those may not have had any -

VICE CHAIR BONACA: But the central issue, I think, is operability. Right?

MR. BEAULIEU: Right. The bottom line -

VICE CHAIR BONACA: Which is a very specific definition in the law, and also it's plant-specific, and pump-specific. I mean, putting the burden on the licensee, I mean, to demonstrate that he has operability.

MR. BEAULIEU: Hold that thought for just one -- I'll get to that, specifically. Just to continue in this order, so what is the desired outcome of the generic letter that's in plain English. The requested actions and requested information are ultimately intended to achieve this, is that -- the next slide, please. Okay.

We want periodic testing of the subject systems that include measuring and recording of the volume of gas voids at each point in the subject systems that could impact operability. Venting of gas voids to restore the subject systems to a filled condition, which may necessitate installation of vent valves. We'll get to that in a second. Vent valves I think is a key. And then the location-dependent acceptance criteria for gas void volume is exceeded, you would expect the licensee to initiate corrective actions that provides reasonable assurance of operability until the next surveillance. That could involve accelerated test frequency to get their arms around what is a rate that gas is being -- gas intrusion is, and then vent it at a frequency that maintains operability.

Secondly, would be identifying and correcting the source of the gas. I say that's somewhat secondary, if they maintain it, and the system filled, precisely identifying and correcting the source of the gas can occur at a later time, as long as they keep the system filled, because, for one, they may not be able to identify where the gas is coming from right off to establish system operability. And, secondly, they may not be able to correct the source of the gas depending on plant conditions, might be a valve that's inaccessible, it may be -- so, therefore, I think an accelerated test frequency would address that.

MR. LYON: In just one sentence, the objective is to reasonable ensure these systems will be operable if they are needed.

MR. BEAULIEU: Yes. In terms of the -

MEMBER SIEBER: If you increase the test

frequency, you're saying that you're depending on the gas intrusion to be a constant. You don't really know that that's the case.

MR. BEAULIEU: Right. That would necessitate that they would have -

MEMBER SIEBER: You have to have some other warning.

MR. BEAULIEU: Well, yes, that they would have to test it soon after to understand what is the rate. It could be that it began leaking yesterday, and the rate was enough to get to exceed the acceptance criteria, so they have to get a handle on the rate, or fix the source.

MEMBER SIEBER: You can't rely on the rate being a constant.

MR. BEAULIEU: Correct.

MEMBER CORRADINI: I don't want to deter you too much, but these 60 events that you wrote in a letter as background, is there some place I can look at the 60 events and understand the root cause? If you give a number that big, I assume there's a database that somebody can look at and say okay, this happened, and this was the cause, and this was the corrective action. Does such a thing exist?

MR. BEAULIEU: I -- the -

MEMBER CORRADINI: Otherwise, I wouldn't put that in your letter. That's just a suggestion.

MR. BEAULIEU: Warren is -

MR. LYON: Would you like us to provide such a list?

MEMBER CORRADINI: Well, I mean, my logic goes very simply, if there's four or five really big-ticket items that clearly show there's a worry, and there's a root cause, then I think that's fine. But if you label 60, if I were on the other side, if I were the industry, I'd want to find the 60, find the root causes, and make sure all of them affect operability. Otherwise, I'd challenge you on that.

MR. LYON: In our examples, we selected sort of a range to span the various types of plants and to provide ones that we recognized as being most serious.

MEMBER CORRADINI: But the only reason I - and can delay this or defer it, but I would like to see it eventually, because I'm curious if the root cause -- in all cases, did they affect operability, and how?

MR. LYON: In all cases, no, they did not affect operability. They more were illustrating symptoms of real or potential problems.

MEMBER ARMIJO: Were they all surprises, or was this routine?

MR. LYON: I think you could say some were basically routine. In the case of one of the plants that we illustrate, they basically would just continue to try to treat the symptoms, rather than getting to the root cause and fixing it.

MEMBER ARMIJO: Okay. Thank you.

MEMBER SIEBER: The database is the licensee event reports, those are really written shortly after the event, and sometimes plant people don't understand what the event was, so you have to take those with a sort of grain of salt. And, also, if it didn't result in inoperability, there's no report.

MR. BEAULIEU: Good point.

MEMBER SIEBER: So you could have hundreds of them rather than 70. And if they didn't result in inoperability either during a surveillance test, or when it was actually needed, you wouldn't get a report after that. Might get a non-conformance in your QA systems. That's about it.

MR. BLEY: Is there -- I don't see it here, but was there any attempt to ask them to look for evolutions, operations they do that have the potential to introduce gas on periodic basis?

MR. BEAULIEU: What you're going to find is that -- and you notice that the generic letter does not focus on prevention, it focuses on identification and correction. And when you identify correctly, prevention will take care of itself, because what you find is that there are many different possibilities, many different scenarios that could introduce gas. And the reason these systems are particularly susceptible is because of the system interactions, because of multiple suction sources, and that's the bottom line. And just because a system -- and it affects good performing licensees, as well as not so good performing licensees. Valves leak, and I think it was Indian Point, three valves leaked in series to introduce gas, so that, ultimately, efforts to -- a total focus on prevention will ultimately be unsuccessful because of things just like that, three valves in series. A pump starts, a check valve typically seats, this time when it didn't quite reseat, things can and will happen like that, that are not necessarily fault of the licensee. And testing is something as a regulator that we can hang our hat on, depending on varying degrees of licensee's effort to solve this problem, prevent the gas intrusion.

Ultimately, for the regulator, we can have confidence that the systems can and will be operable, because they are verifying through adequate testing that they're operable. And from that perspective, if you get to the principal concern slides, it's under licensing basis.

The FSAR says either implicitly or explicitly that the systems are filled with water. Tech spec surveillance says verify, by definition confirm to be true, so it establishes that the design and licensing basis is that the systems are filled with water. So, therefore, any amount of gas in the system is considered a degraded or a non-conforming condition, as legally -- whether it impacts operability or not, is a different question. That's also a problem. But any amount of gas is a degraded or non-conforming condition, so that the licensee has to be aware of when this gets to the point where it renders the system inoperable. And what you'll find is that the tech spec surveillances that are currently in place, some plants do not have tech spec surveillance at all, some cover only a portion of the system, boilers, typically cover discharge piping. And that -- and in spite of that, even PWRs, there are sections of piping that, like I said, have been filled with air, essentially, since day one that licensees have just recently identified.

MEMBER CORRADINI: So can I just -- I mean, I don't mean to use this word too much, but I -- my reaction to that as a bit of an alarmist sort of statement, as the 60 in my mind is an alarmist statement, so I'll be somewhat provocative about this. And the reason I say that is, I would expect that the evolution of gas being present is probably due many times to maintenance, and potentially procedures on how you have to vent after "buttoning-up" a system, as well as they're there from the very beginning.

MR. BEAULIEU: If you look, you'd see that there are a multitude of reasons. If it were that simple that you could focus on certain reasons initial system fill, the problem would have been solved years ago. There are a multitude of reasons why -- how gas gets in -

MEMBER POWERS: You had a superb presentation at one of the ANS meetings by Duke Energy showing when they had a gas accumulation in the high spot, and it was an absolute detective story to figure out where it was coming from. And it was, in fact, simply coming because they were taking feed from a low temperature source, putting it in the piping system, and it would sit there for a month and warm up, and the gas would just come out a solution, collect in the high spot. And they tried all kinds of things, and eventually went to the expense of just taking it from a pre-heated water source, and running 30 feet of additional piping to get rid of it, because otherwise it just came out too quickly. They just couldn't vent fast enough, I mean, often enough to keep it from coming down. And it was a major detective story. I mean, the guys did -- it was one of the best examples of a questioning attitude I'd ever seen in any licensee presentation. These guys really went after it like a dog after a bone.

MEMBER SIEBER: But you could have situations where high point vents weren't installed.

MR. BEAULIEU: That's precisely a large part of this problem.

MEMBER SIEBER: And in the early plants, anyway, some of it was the piping was fit in the field, and it was a matter of judgment where you put the vents and drains. So there's nothing to operate, and no way to detect it if you don't have a vent.

MR. BEAULIEU: Great point. Two licensees that have undergone escalated enforcement activities as a result of a true air intrusion event, one installed 17 vent valves, the other 21 additional vent valves. And I think, in fact, if there were a sufficient number of vent valves at every plant, that we probably wouldn't be sitting here today. That would largely resolve part of the problem. But you're right, it was an initial design, precisely as you said. They just didn't anticipate the vulnerability of these systems to this.

There is no explicit requirement, like you said field run, to install vent valves; however, design control, we would expect adequate provisions in the systems to satisfy the design basis, the design basis that the system is filled, so it's indirectly testing.

We require written test procedures. The next slide. And we require them to record the results of testing. The licensees do -- they are not really -- they are not measuring the gas in most instances. In the vast majority of instances, they don't measure, they don't know how much gas that there is. They're not measuring or recording it, or taking actions to address it.

In terms of under the test control, the -- we point out in here that Appendix B, Criterion 11 requires adequate test control. This includes tech spec testing, but is not limited to tech spec testing. So that's why we did not wait and try to address this problem through the tech specs. We have ample regulatory basis to ask what we're doing right now, and what's learned by the industry as a result of this, there'll be a TSTF effort to modify tech specs. And, in fact, maybe relax the 31 days. And it could be a give-and-take, based on what's learned as a result of this effort, so it actually will serve as gathering data for what the tech spec should look like.

The next slide, in terms of requirements. Operability, obviously, tech specs require systems to be operable. And under corrective actions, we -- the key point here is that -- what you point out is gas is so common, is that licensees treat it as an expected condition, and not a non-conforming condition. The tech specs and FSAR say that the system should be filled. Any amount of gas is a non-conforming condition. There are varying degrees. Criterion 16 addresses significant conditions adverse to quality, so do we expect them to do an accelerated testing for every blip of gas that they identify? The answer is no.

So the requested actions - the next slide just state what the requested actions are, and the requested information. And that's consistent with what I've already discussed in more of a plain English version of what this is, and the underlying regulations of what we hope to achieve by this.

Under public comments, licensees point out that studies will have to be completed in order to develop realistic criteria regarding the amount of gas that could impact operability. And, also, studies will have to be completed in terms of gas detection techniques, and the associated inaccuracies about the ability to identify gas in different locations.

We are well aware of this, and we discussed this with the industry in advance; that, hey, we're not going to answer these questions for you, in terms of how much gas is too much gas, because the reality is, and you discussed this somewhat earlier, to try to determine for a given amount of gas at a given location, and all the various possibilities, there are literally thousands of different possibilities of gas volumes at various different locations, various pumps, various piping configuration, the slope of the pipe, what is the buoyancy, how much vertical drop is there, how much flow rate is there, will the gas flow into it as a slug, or will it flow in as bubbles, and can the pump handle a few bubbles, and not be able to handle a slug? And then the criteria in terms of percentage of gas that a pump can handle, you hear percentages discussed in the technical considerations of 5 percent, 10 percent. Well, those percentages are a continuous flow of gas, they're not a slug of gas. So it might be experience like through vortexing through examples. In most cases, what they identify during a surveillance will not be a continuous source of gas. So, therefore -- and then, another thing is that to understand the complexity of determining how much gas is too much gas, is one of the licensee that was undergoing escalated enforcement had a known quantity of gas at a known location, known configuration, known pump manufacturer, so you think that if you know everything, it would be quite straightforward just to say was the pump inoperable, or was it not inoperable?

I could tell you that the licensee found it was not straightforward in terms of determining, through developing specific modeling for that configuration, and they found that they actually had to do -- develop, what do they call it, an actual fiscal configuration of it to try to test -

MEMBER SIEBER: Model it.

MR. BEAULIEU: Model it, actually a physical modeling of that configuration. And like I said, and that's a case where everything is known, so this just describes somewhat the complexity of determining how much is too much, that licensees will have to determine during this, as part of this surveillance. But do they, at the end of the day, do they really have to answer that question of operability precisely? Maybe, maybe not. They have to have an understanding of generally how much gas, what it would take to in opt a pump, but the acceptance criteria is an acceptance criteria for initiating corrective action, so we would expect the acceptance criteria to be much smaller from the discharge pipe, at 15 cubic feet of gas is acceptable. In reality, it would take to in opt a piping to water hammer. Would we expect them to establish an acceptance criteria of 10 cubic feet? No. You'd say that's an opportunity -- that's a red flag that says like when they expect zero cubic feet, the system is supposed to be filled and you get 10, obviously, you would expect and want a licensee to take corrective action much sooner than that. So if they can establish acceptance criteria that are conservative, and the precise point at which your pump would actually become operable does not have to be, necessarily have to be defined, as long as acceptance criteria are -

MEMBER SIEBER: There's a whole range of operating conditions that most of these safety-significant pumps would operate under, like safety injection pumps would be for low fill up to pretty high flows. And the amount of void, or air pocket, or whatever gas pocket that you can tolerate is different depending on what the application is. So they have to cover the full range of applications, as far as flows, temperatures, and so forth are concerned in order to determine what surveillance requirement they have to meet so that it's operable every time that it's needed. That's not a simple job.

MR. BEAULIEU: Right. And they could specify in the procedure that the acceptance criteria is not based on operability, it's based on the need for corrective action, and exceeding it. It doesn't necessarily mean the system is inoperable, unlike many surveillances.

MEMBER SIEBER: That's right.

VICE CHAIR BONACA: This would be to over call. What I'm trying to say is that, I mean, the licensee tends to be conservative. They don't know at the beginning whether or not they're operable, they're going to declare it inoperable. They have no choice. So you want to make sure that you're preventing a situation where people are over calling all the time.

MR. BEAULIEU: Well, you say declare inoperable, but you've got to remember that at the end of this surveillance, the important fact is that they refill the system, so they re-establish operability at the end of the surveillance, regardless, so whether -- and then, also, prior to surveillance, that there's always a presumption of operability, meaning that if it passed its last surveillance, that we allow licensees to presume it's operable until the next surveillance. So if the licensee -- if this is the first time that the licensee becomes aware that a pocket of gas exists in the system, and not necessarily they could have or should have known that that gas existed, we don't necessarily hold the licensee accountable, and beat him up for an inoperable system. That's what surveillances do, and surveillances -- so, therefore -- I guess that's it.

MEMBER BANERJEE: How do they know there is gas in the system? What's their surveillance tool?

MR. BEAULIEU: That's the second question

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MEMBER BANERJEE: How do they find out?

MR. BEAULIEU: That's the second question that we don't specifically answer for them in the generic -

MEMBER BANERJEE: How do they do it now?

MR. BEAULIEU: That's a good question, how do they do it.

MR. LYON: There's a number of techniques. The primary technique is venting of high points. Another one that's quite effective is to do ultrasonic testing, and for that you don't have to have a vent. And if you do it properly, you can get a good volumetric determination of what is there. Then there are additional number of things that can be done. We identify some of those in the generic letter, to qualitatively assess whether or not you've got gas in your system. For example, you could start a pump, see how its pressure develops as it's coming up to speed, and from that kind of a characteristic, you can tell whether or not there is gas downstream of that pump.

MEMBER BANERJEE: Do you have portable ultrasonic detectors which can scan a pipe then? Is that possible to use that?

MR. BEAULIEU: Yes.

MEMBER SIEBER: The problem is that some of these pipes where these pockets of gas form are not accessible.

MR. BEAULIEU: That's one key point.

MEMBER SIEBER: So you can't get in there. There are portable hand-held instruments that you can use.

MR. BEAULIEU: Good point. That happens to be my next slide, is that the -

MEMBER BANERJEE: Thank you.

MR. BEAULIEU: -- generic letter does not consider ALARA, personnel safety, or accessibility. That was the public comment, and the key is accessibility. And the words that I specify here are the words that the generic letter says, that we expect all the piping to be tested, to confirm acceptance and operability, unless it has been acceptably established that some items can be excluded. If a particular point is inaccessible, but they know an upstream point, for example, is accessible, and that the only way for gas to get there, they would always see it at the upstream point, that's one way.

MEMBER SIEBER: Well, another way -

MR. BEAULIEU: That's -

MEMBER SIEBER: -- to avoid violating the

ALARA principle, you may not want to do it manually, you want to install some fixed device where you can get a readout at a shielded location. So that may cause a plant modification.

MEMBER MAYNARD: And some of these you can just run the pump, as long as you can do it under the design-basis conditions.

MEMBER SIEBER: Right. But most of the surveillance tests on things like high head safety injection pumps, and so forth, are not run at accident conditions. And so, you're only approximating the condition that the pump has to run under.

MEMBER MAYNARD: But I think the key, as you're saying, it's up to the utility, the licensee to come back with justification of why -

MR. BEAULIEU: In terms of how they're doing it, and the accuracy, and why that accuracy is good enough. And it would be dependent on where -- if it's suction, you'd expect something more precise than on the discharge. Mr. Maynard, do you have anything else that -- Mr.?

MR. BLEY: Dennis Bley.

MEMBER CORRADINI: Bley, I'm sorry.

MR. BLEY: We've kind of danced around it, and I've been hanging on your tech spec back there about periodically measuring and recording the volume of gases. I was focused on the vents and things, if you've installed all these 15 or 20 vents on modable systems, if you had to go in and vent each one into a bottle or something to measure it, that's not going to happen. If we were forced that way, you'd probably see some kind of automated venting system put in. The ultrasonic test might get around that, or the performance tests you mentioned, if you can do something like that. Otherwise, I was going to say in the beginning, we'll hear from the industry how they've thought about dealing with this, but I think it didn't sound very optimistic.

MR. LYON: Some of the folks actually do attempts to measure the volumes as they vent, and some of them can do it fairly successfully. But, as you've correctly pointed out, it's not always straightforward and easy.

MR. BLEY: And I suspect it's an ALARA issue, and it's -

MR. LYON: In the case of an ALARA consideration or something of that nature, our primary responsibility is back to that basic, do we have reasonable assurance the thing is going to work? And if, as was just correctly stated, ALARA is a consideration, and it's a problem, then perhaps a physical modification is necessary.

MEMBER ARMIJO: Would you like to make a comment?

MR. RILEY: Yes. This is Jim Riley, NEI. I just wanted to throw in, this is a very interesting conversation, I mean that. I want to let you know, Gordon, I hope, is going to have a couple of minutes to talk about what the industry is planning to do, but when we provided our comments on the generic letter, we pretty much agreed that this was an issue that we needed to look into. And we've already started to do that. We've got the owners groups are both involved in separate efforts, which Gordon will be talking about to some degree. We've got a meeting set up at NEI next week. We'll be working with David, and Warren with others, to come up with a right solution to this thing. And this is good input. I think we have the right people looking at this to come up with what is a difficult problem; because, as you're pointing out, there's all kinds of possibilities here. And what is a reasonable thing to do is an important end result of this thing. And we will be working on that with, what I expect to be the right people to come up with some answers.

MR. BEAULIEU: And, in fact, the rest of my slides, I've really covered everything, that information in the discussion, so at this point I can shift it over to -

MEMBER ARMIJO: Before you do that, let's ask if there are any additional questions to Mr. Beaulieu? If not, we'll move on to industry comments, and Mr. Clefton will make that presentation.

MR. CLEFTON: First, I'd like to thank you for giving us an opportunity today. In a different process, if you will, this is in infancy stage as far as recovery and response, and such, so the industry is mostly standing by to respond to the generic letter response that's out there. We've been addressing the issue on a case-by-case basis for 20 years, since plants started, as was identified earlier. We're not just limited to safety systems, we've got gas intrusion and line-up, and fill issues that have been in the problems from the time we started running the plants.

As has been described in the discussion today, it's an infinite number of possibilities of how you can get gas in, and complications of how you can test for it. As Jim pointed out, we've responded more on an industry-basis, on an individual basis, I'm sorry, not a collective basis, and what we're planning to do now, as I've worked with the pressurized water owners group, and the boiler water owners group, is to be able to bring the resources that we have, the industry experience we've gained from the plants that were used as identified items in the 60 examples. But what we're finding is that there's a need for classification, so we can address and fix things, perhaps in a more organized manner. We've got dynamic situations, we've got static situations, we've got cold situations, we've got hot situations, we've got examples that when I was in plants, we had field route event, and drain valves, PNIDs if you're familiar with them, they show them on the same side of the line. Well, a field operator looked at that one time, and he put the vent and the drain line side by side.

(Laughter.)

MR. CLEFTON: We found it in doing a walk-around in early construction. That was atrocious, that nobody even considered, and they never looked at a high rise point. These were folks that were not engineers, putting welders to work out there. They were putting weld dust, nut sets on the bottom side. It was atrocious. I spent some time at a utility where we put 21 vents into a high system. We assigned a system engineer, an opportunity to go out and walk down their system to identify the high point vents. We, as an industry, have struggled with a one-size-fits-all measure capability, because as soon as you decide you're going to use ultrasonic measuring, you have to have a clean attachment point shiny on there. Well, when you've got four inches of insulation out there, that's a problem. And you can't get to it, so we -- I think everybody in the room can recognize that we don't have a simple solution for anything that's out there.

We plan to gather the task force here. We talked about the operational challenges here. We've covered those. I'll talk a bit about the B and the Ps, and then the industry activities. We've collectively boxed ourselves in, painted ourselves into the corner of the room. If you look in the standard tech specs, it says, "ECCS system will be maintained full." That sounds pretty simple until you come up with a definition of what's full.

MEMBER CORRADINI: In the computer world when they say there's no void, they use 1 percent as the numerical void value.

MR. CLEFTON: Exactly. And so, if we open up the tech specs and go back to the basis, we'll find that the first opening sentences say, "Normal operation of fluids in pipes result in gases coming out of solution and that air voids are expected." Well, you go back to the thing and it says "full", it's unacceptable. So we've got to come back -

MEMBER SIEBER: Well, it's full. The gas will fill -

(Laughter.)

MR. CLEFTON: As mentioned, we've got the tech spec task force working on better words for the word "full". But, collectively, we're all sharing the fault when that was released, that we defined something that was not capable of doing, not possible, and so we need to fix that. But the basis says it's normally expected, as David has pointed out, we need to define what's acceptable, and what's not. The operability is a key item here. A little bit of belch or burp, or even a small void going through doesn't hurt us. But as Warren and I've talked, if it's in the suction line and there's multiple high points, and it's all going to collectively end up in the pump, we're going to air bind the pump. Now whether that's a positive displacement pump, as the case of Oconee, or whether we've got other styles of pumps, multiple stages, horizontal, vertical, any one of those can air bind to this degree. But as we've pointed out, you can get a lot of bubbles going through there without affecting performance. And when you go back to the original pump curves, they'll give you a percentage that's acceptable for pump operation, but that may not even approach what's operability limits. So we're challenged to decide what's full, and what is acceptable limit. Operability is our key aspect there.

As you pointed, we would declare it inoperable if we thought there was a question of it. Now we all know in reality, operators are going out, they're opening the valve until they see water spraying out, some hits the floor, and they turn it off, and that's for the ones they can get to. Now we've made conscious efforts in the industry to go out and find high point vents, and find what we can do there, but it's still open the valve, spray it on the ground, because unless you've watched an engineering lab technician go around and take a pressure temperature volume measured gas from the system and then record the temperature, the volume, the flow, and then bring it back to the lab and do the pressure volume molecular controls, that's a major effort. And, realistically, that's not going to happen out there. We're not going to be able to get that type of reconstruction. And that was only a snapshot at that moment, because if somebody went to a two-pump operation, or opened by the bypass, it just changed. So we've got to look at what we can use as a collective solution, a generic solution.

We're gathering the forces of the industry to bring resources that have solutions that have worked at sites, starting on the 11th, and then we'll be sharing that again with Warren and folks on the 12th.

Accessing, we talked about, we talked about the trending and the tracking. One of the concerns that came up in the generic letter is it said we needed to record. Well, an operator is going out and turning the valve until it opens, water hits the floor, he doesn't record how much gas came out of there, and tracking of it is -- that would be a major effort, and affect their operability.

MEMBER ARMIJO: But he could record the time it was venting in one of the -

MR. CLEFTON: And what we found is when the utilities came back to put in a ball valve with a known orifice size, and it was top notch. And he would open it with a ball valve, with a stop watch, and it was a better estimate, but it wasn't totally accurate.

MEMBER SIEBER: You still have to use the Perfect Gas Law to get to the answer. And usually the people who do surveillance tests are not mentally equipped to use the Perfect Gas Law.

MR. CLEFTON: That's true. Some of my students aren't equipped to use it.

(Laughter.)

MEMBER ARMIJO: I'm thinking of something that's a little more qualitative. And you go in there to vent the line, and your expectation, somebody should have an expectation that this thing should vent for no more than five minutes, and that's it. And if it goes on for half an hour, you know you've got a problem.

MR. CLEFTON: A burp or belch is questionable, and a void is bad. And if it's 30 seconds of venting, then you've got a problem. And I think our operators with their, what would you say, they're skilled craft recognize that, and that's when they would flag it.

MEMBER SIEBER: They can do that.

MR. CLEFTON: But we've had reports of inspectors who have gone out and questioned, followed an operator through his watch grounds, and found out that he didn't write down what was there, and he was venting two or three times a day, and it had always been that way, so he figured that was normal. Well, perhaps it was, but maybe that's not acceptable.

Our concern as an industry is, we don't know what was operable limits, where we put a warning in that we have to take action with corrective action program, or we put an alarm in that something is going wrong, we have to declare inoperable and have to shut the system down. Those are the categories that challenge us right now. And as you mentioned, it's a Perfect Gas Environment where we've got to do a lot of calculations on each scenario. The question is, what's the most bang for our buck? We've got to stop the problem, and work -

MEMBER SIEBER: On a system that's basically isolated, you may accumulate some gas, but you aren't accumulating big volumes.

MR. CLEFTON: Right.

MEMBER SIEBER: And so if you get more than just a little bit of gas, you probably have a problem that you ought to think about, and look into.

MR. CLEFTON: And that's the research project that Duke did a couple of years back.

MEMBER SIEBER: Right.

MR. CLEFTON: The water program that Mr. Powers referred to.

I guess, in opening, what I'd like to say with the Bs and the Ps, is both organizations have recognized that we have a problem. And in global perspective, we don't think the generic letter should spend or request too much time to go out and research and document how much of a problem we have out there. The same people that would be researching and documenting what was a historic problem are the ones that are going to be fixing the problem right now. And I guess what I'm saying overall is the industry recognizes we have a gas intrusion problem.

Now we challenge that there were 60 good examples of gas intrusion, is what we have as a good definition of gas intrusion, because some of those were line-up errors. I mean, if you keep a plant with a leg dry in a system for 22 years, that wasn't gas coming out with liquid in a pipe. That was a liner problem, so I have to challenge that that's a gas intrusion from dynamic or static situations. But it was a void in the flow path of the system, so, therefore, it needs to be under this category and addressed. It's not gas is coming out because we had cold water going into a hot environment burning up. Every time you have fluid in a pipe, you're going to have a void over at the top unless you have extreme pressure and a pressurizer standing alongside of it, so you don't get bubbles in the pressurizer.

MR. BLEY: And that was not a high point problem.

MR. CLEFTON: Right. All this concern about transferring the bubble from the pressurizer back to the top of the core, and so we can do that in pipes all along. We can generate it. You could have a vent valve that's leaking, and a negative pressure on it, be sucking valve air back into the system, and hurting ourselves, because valves are mechanical, they can break, their seals go away, and they're typically three-quarter, one inch size valves with small seats that are no easily polishable. You just replace the whole valve types.

MEMBER CORRADINI: Just one other thing, so to switch sides a bit, so I didn't know if you said it. Maybe you said it, and I missed it, you're not just interested about static conditions. You're also interested about dynamic conditions that would lead to gas intrusion, like vortexing.

MR. CLEFTON: Like vortexing.

MEMBER CORRADINI: Okay. Fine. I just wanted to make sure I didn't miss it.

MR. CLEFTON: When you get a pump and you run without an intense amount of suction pressure, you're going to get cavitation. That's bubbles that's coming out that's going to go into -

MEMBER CORRADINI: I'm also, though, thinking about any sort of usage of a tank where I can get to the level to the point that it would vortex from a low level.

MR. CLEFTON: And that was one of our examples in the generic letter that came out. They ran the tank dry and got air into the pump. Well, that's not gas intrusion, as it is, that was operator error, the low level alarm switch didn't go off and things like that.

MEMBER MAYNARD: You also have dynamic situations where you're changing the line-up. I mean, you may switching over to a different suction, or different discharge, and end up with -

MR. CLEFTON: And we get into a commercial interest here, not just on the pure safety systems. So you walk through the secondary plant, you've heard air hammer, water hammer when the supports are given inches of movement and stuff like that. I think that was referenced at one of the TVA plants, that there was a number of water hammers in a plant startup. Well, we've heard that because of the fill process can't get all the bubbles out that you'd like, and when you start the pump, you get an air slight, and you see pipes move three to four inches. It's pretty exciting in the industry to happen in a secondary site. Commercial interest, we don't want to crack or break the pipe, we're out of business. And we're all not there for any particular purpose.

MR. BLEY: You said one thing that interests me a little, because I was sitting here thinking all along, I know it's a real operational pain if you get a pump that won't run because of this, and figuring out how to clear it, and use it. So I'm kind of surprised things stay around a long time, but the idea that operationally there are guys out there who know they have a problem informally. They've venting the pipe routinely, and that's not tracked officially, and may get lost in the process. Have you gotten to the point you have a feel of how common that is?

MR. CLEFTON: No, I don't have real numbers on that. We encourage it, we encourage management by walking around, we want system engineers in the field, on safety systems more perusal than what you'd expect. And we find that when you go to talk to the operators when they're actually in the field, because on the watch logs they're not typically writing down that they vented six times.

MEMBER SIEBER: On the other hand, walking passed a pump suction, you're not going to know whether it's gas or liquid.

MR. CLEFTON: Right.

MEMBER SIEBER: You have to do something more than put your hand on it.

MR. CLEFTON: So I think what we've collectively agreed is that we have a problem out there. We're working on it. We've got some sites that have been successful at it. Indian Point's got a working system, Duke Energy has a research group that goes after the problems and troubles, the Perry Plant went after high point vents and modified with their system engineers input and stuff like that.

A concern we have is that we don't have confidence that we don't have an outlier out there, that we don't have people that are just getting by with operators opening until it's vented. So bringing together the resources of the power plants, we've got the Bs that have, you can see in the slide here. They funded planning, strategic planning for this year already. They've got a committee working on it. One of their aspects is to respond to the generic letter. The second is to put a solution and resolution together that will apply for creating processes, procedures, and guidelines for the sites that are out there. As we mentioned earlier, the Bs and Ps have separated enough on this issue; recognizing it was just a common one, we're bringing them back together to share some of the solutions. We're doing that through NEI.

The Ps, on the other hand, pressurized water reactors, have turned to Westinghouse. They've activated a group that's done a road map for the gas voiding concern. They've got action going out in Rowville right now. Some of the tasks that are listed here on this chart have already been completed. They've got folks working on determining gas voids in different systems.

We've had full-size mockups that the industry has used to be able to duplicate systems that were challenging, to figure out where the gas was coming. Sometimes it's an inlet flange, sometimes it's a leaking valve, sometimes it's, as you mentioned, three valves in a row that were a leaking issue. But we've got activity in both the Ps and the Bs. We're bringing them together at NEI. We've got a steering committee meeting on the 11th of October, next week, an all-day session. We expect to address the 60 items that were in the generic letter. We're going to share the industry experiences, because we've got a number of utility reps that have got successful programs going coming to our meeting. We've got a couple of vendor reps, what you're talking about, the ultrasonic measurement devices, and what limitations, and what capabilities we have with those. We're looking at a path forward. We expect to have a path towards resolution, a time schedule, the resources available, the costs that we'd have to put that together. And then on the following day, on the 12th of October, we expect to share that with NEI for a few hours, with a drop-in visit, if you will. We're just going to share what came out of our meetings quickly as it occurred so that we've got direction. Our hopes are -

MEMBER APOSTOLAKIS: NRC, you mean. You want to share it with NRC.

MR. CLEFTON: Yes. NEI sharing the industry meeting output with the NRC. Our intent there is that perhaps we can influence the content of the generic letter, so that we don't spend an immense amount of time just emotionally documenting that we have a problem out there. Let's go back to real root cause solutions that were true gas intrusion problems, and say these are examples. Now that you've seen it, what can you do in the future to recover, and resolve the issue?

I don't think, and Warren and I have talked about this, that the six-month period is going to be an appropriate length of time to resolve issues as complicated as what we've discussed this morning. It might be enough time to put a plan together, and to initiate action, and to get some responsible activities identified at each of the licensees, but a six-month period is not going to solve something that we've been working on for 40 to 50 years of problem generation. So we need to be a bit realistic on that.

MEMBER SIEBER: Yes, you've got a couple of problems. I don't think there are any two plants that are the same, even plants where you have one unit sitting next to another unit, they're different. And the only kind of drawings that you can get locations of vents, and drains, and fill valves, is isometrics, and they're tough to read, because they're written by room, and you can't -- you have to do a lot of thinking in order to associate system piping with the components that are in that system. It's not lot a schematic, and a schematic doesn't tell you anything about layout, or vent paths, or chance of accumulation, so this is not a simple job. And I think there is probably, the industry, each plant is going to have to go hand-over-hand over the vulnerable areas in order to be able to make any kind of determination as to where their vulnerabilities are.

MR. LYON: If I may make a couple of comments. One, on your drawings, isometrics typically don't indicate slopes in pipes, which are vitally important in some of these aspects. And in my personal experience, they're not always accurate with the as-built plant. And I have found that in side-by-side units where they were right in one plant, and not in the other one, for example.

MEMBER SIEBER: That's true.

MR. LYON: With respect to some of Gordon's concerns, we share effectively a picture of, we don't want to waste a whole lot of time with unnecessary documentation. We want to get at the problems, and our intent is that the generic letter responses will be correctly focused.

With respect to the six months, we fully realize we're not going to have a complete resolution in place in six months. We're talking typically years, and again, the generic letter would allow the flexibility for that kind of response.

MEMBER SIEBER: On the other hand, you don't want to wait until you get tech spec violations, plant incidents, and perhaps an accident to say gee, there's an air pocket there.

MR. LYON: And absolutely correct.

MEMBER SIEBER: You're better off -

MR. LYON: In that case, we would anticipate a feedback that says well, we haven't been able to handle all of these problems, but during the interim, how do we reasonably ensure operability?

MEMBER SIEBER: I agree with that.

MEMBER ARMIJO: So in the six months period do you expect to come up with some interim guidelines for licensees as to how to address this issue until you complete your research, and come up with a reliable solution that people can follow?

MR. CLEFTON: I think, as Warren implied, we're going to have to look at a short term to make sure we don't have an issue that's hurting us right away, so we have guidelines and what to go look for right now, in case you haven't gone out and seen the vent and drain lines are on the same side of the pipe. And then we have long-term solution of how you ensure that you've done a walk-down when it's available, because we can only get to a lot of these systems and points in certain modes of operation, if you will.

MEMBER SIEBER: So you're asking the industry to develop that, as opposed to dictating how they will develop it.

MR. CLEFTON: Yes. We'd prefer to develop it ourselves, and come back and give you status reports of the success that we're having, or the hardships, or the barriers, or whatever is in front of us, rather than to be regulatory driven by an artificial schedule that says well, we think it would be good nine months if we have this, and twelve months you have this, because we've got real-life situations. Every pump and every system is going to be different scenario that's going to need to be addressed, and realistically, staff resources, it's going to be a handful of people on each site that can do that, so if he's got eight systems to do, it's going to take eight times whatever -- we'll have a learning curve, but it will still take a duration. So what I propose is that we be asking for a time line of commitment of deliverables from the sites, from the individuals, perhaps. But we're going to try and work it as an industry with a short-term solution so we don't have a failure that's embarrassing, and a long-term solution that we can feel confident that we've identified what's an operability limit for each of the systems, and that there's a manner of measuring it so that it doesn't occur, and that there's a warning level before that, an alarm level before that, so that we can go into selective leak before failure type arrangement, where we start getting more bubbles than we expected, we've got a belch now, and tomorrow we've got a void, something happened, you need to do a root cause analysis on it. So those are the type of things that -- the brain trust that's coming to this meeting are going to put on the table in a one-day period.

The advantage that we have is we're not starting with a blank sheet of paper. We're bringing experience to the table to share which are the best points of each of those.

MEMBER CORRADINI: So let me just ask a different question. So why didn't you do this sooner? Was it the threat of the generic letter that got you going? I mean, I -- you seem very resolved to the fact that it's been around, et cetera, so why not 10 years ago?

MR. CLEFTON: Well, what I can say in answer to that is it's been done on an individual basis until now, because of the sites that gets violated has to resolve it to get their license back. You're not going to give the keys back unless they fix their -

MEMBER CORRADINI: But I'm talking about the NEI's efforts.

MR. CLEFTON: NEI's efforts on this now are turning to a collective effort to handle the resources and do a generic solution, if you will, on the guideline. As far as the timing, it just hasn't been high on the radar scope, and the generic letter identified it, but this generic took what, a couple of years to get to that level, too. But we've been documenting and reporting the history, so it's not one that's been ignored on an individual basis. It just hasn't developed to a task force level of importance where we are collectively going -

MEMBER MAYNARD: I don't think it's been ignored. I think it's been left up to the individual utilities more, rather than being a coordinated effort. And I think some have done a very good job, some probably haven't done as good a job, and this kind of brings it to a level of consistency that addresses it for all.

MR. CLEFTON: We'd like to raise the bar for everybody.

MEMBER SIEBER: People tend to solve the problem at-hand, as opposed to saying this same problem could exist in a lot of other systems.

MR. BLEY: Mostly, you think it's the other guy's problem. Until it happens to you, you don't -

MEMBER SIEBER: You don't think at all.

(Laughter.)

MR. BLEY: I have a really different question. It doesn't have to do with what you're focused on, getting the generic letter out, and the response to it. But from both sides, how -- from the NRC side, how is what you're learning here being reflected into the design certification process so we don't have the same thing later? Same thing for the industry, is the industry thinking of doing something to make sure the vendors don't give you plants without hot point vents next time around?

MR. BEAULIEU: I'm not aware of any big efforts at this point.

MR. BLEY: Is there a mechanism that connects the -

MR. LYON: There is in a sense a mechanism in which our organization, the office that's in charge of all of the new reactors, and our old-timers, so to speak, are communicating back and forth so that we don't run into a piece of one aspect of NRC doesn't know what the other one is doing.

MR. BLEY: I ask it because we've been looking at a new design yesterday, and I don't recall seeing any questions, or anything about this issue.

MR. LYON: Great point.

MEMBER CORRADINI: I'd even go further what Denny is saying, which is all the new systems developed are all dependent upon small delta Ps to move things around. And now I'm almost in the testing mode of the pump, where I can bind things up with a very little amount of gas. So I think that's an incredibly important point, to make sure that at least the industry, or the vendors in their design are thinking about it, and have considered it in how they're doing their detailed design, because I think one of the responses from yesterday for the ESBWR was a lot of this detail design is yet to be done.

MEMBER MAYNARD: And I agree, it's an important issue. I think that the regulatory tie, I think for any new design certification, the COL, you basically do have to go back through all the old existing generic letters, and other items. So I think this will get captured as part of the review. It's not something that is just going to be dropped. Now, as to how well it gets addressed may be a different issue, but it -- once the generic letter comes out, then it will be tied in.

MEMBER ARMIJO: It's particularly important because you're talking about gravity-driven systems.

MR. CLEFTON: Thermal-driven systems. One of the things in defense of the new designs is that they are -

MEMBER ARMIJO: Oh, yes. You know where the high points are.

MR. CLEFTON: And we put the systems together back in the 60s, 70s, and -

MEMBER CORRADINI: You don't really believe the computers, do you?

(Laughter.)

(Simultaneous speech.)

MR. RILEY: Jim Riley, again. Just a couple of thoughts. It swept beyond where I wanted to make my comment, but I'll take us back for a minute. You had asked about industry getting, and thinking about what we could do on this, and I agree with what you're saying, that it was done on an individual basis. But we, also, INPO has been doing things on this. INPO did an OER/SER several years ago. They have been following the thing, and as Gordon and I were kind of working this thing up on where we were, it was apparent that INPO was also kind of building this issue up, and we're going to help bring it to everybody's attention, if we didn't trip over it other ways. But there are other things that were ongoing.

Regarding the new plants, just a couple of thoughts on that. Because of the fact we have the Ps and the Bs involved in this, I'm hoping here, but you would think there would be more communication, since we got those owners groups involved in the resolution of this, they're feeding us information back to the folks that are designing the plants. We have a new plant working group within NEI that meets regularly and kind of talks about these design certs issues, and infrastructure, and that kind of stuff. And this has got to be something that we also have to do internal to NEI here, to kind of make these kinds of communications over to those guys.

Now I'm not telling you whether there's anything going on right now, but this is a good point.

There's things that come up from time to time, and we've just got to make sure that Gordon and I are working on that level of communication with our new plant working group and task forces. Thank you for the comment.

MEMBER MAYNARD: I believe that a couple of the more recently identified issues are related to going back looking as a result of some of these INPO and other initiatives, too. Some of these were not self-revealing, you had to go out and look for them. And I think that process has identified some of these, too.

MR. LYON: There's one other thing that I consider to be a real important contributor to what's going on. As you can tell from what Gordon is saying, they're off and running on this thing, and we're working together, so the intent here is there aren't going to be any surprises from one side or the other, and we'll be working together to ensure we get to where we need to be. And I'm a little bit excited that this process is ongoing successfully.

CHAIRMAN SHACK: That was sort of my question, the requested actions and information in the letter have been changed since the version you saw for public comment. I just wondered if you've seen the most recent version, and you still have a concern?

MR. CLEFTON: No, that's why we haven't addressed those today, because probably the first time I'll see those is on the 12^{th} or so of October. And recognizing that's a document under change, under development, we expect it to have most of what we're looking for. Warren shared with me the contents on the telephone as much as we can. There's been open communication back and forth. We're just concerned that we don't want to be regulatory-driven in a direction that none of us wanted to go, or to ask for something that's impossible to do, that we don't want to keep the pipes all full, by the definition of full.

MR. BLEY: One last one from me. I'm sitting here thinking about the guy who's going out crawling around, and he gets to his 43^{rd} vent and opens it, and for the 43^{rd} time he gets no air, start worrying about how thorough it's going to be after that. And I know we lay out plans that everybody will do, and there's no question about that, but I've been there, and after a while you start to worry.

The idea of being able to look at the pump response and having some clue sounds attractive in the beginning, but a pump that's been out there for 15 years running has a lot of things that will affect its response. And I'm not sure -- have you thought about how well you can learn anything from that, given a pump with a lot of hours on it?

MR. CLEFTON: Well, if you were using that type of qualitative analysis, you'd probably have tracking records on it, so you'd be able to -

MR. BLEY: Maybe it will -

MR. CLEFTON: Whereas, the venting with a different operator, you have 23 up on the scaffold, and just during startup, and never ever after. That's a difficult one to go for, but the qualitative ones I think we would be able to keep in the calculation realm, if you will, on the engineering -

MR. BLEY: At least you could track it into the future.

MR. CLEFTON: You could track it. You can see detectible changes in pump performance, and that's why if you had a normal startup and you watched the ramp, the curve of pressure build-up on it, for example, and all of a sudden it was significantly different, the rate came up different than what you expected, that's an alert, call the system engineer and get an analysis going here. But what we can do is raise the awareness, if you will, of the science routes available for the industry, and make that available. We don't have a lot of vendors out there right now spending time offering services to come out and measure voids. If this becomes a little pocket industry, we might have a whole bunch by this time next year.

MEMBER SIEBER: My experience with plants is that operators have a certain amount of professionalism, and that they go and do their job, if they've done it a thousand times before, they'll do it again, or at least the ones that work for me. And I could rely on that.

MEMBER MAYNARD: I agree. Rely upon that, not only for venting, but for system lineups, and everything else.

MEMBER SIEBER: And if a certain individual fails, it shows up someplace. And you take corrective action.

MR. BEAULIEU: One possibility is that if it's impossible to have gas at one point without also seeing it at another point, then you say well, we're only going to open them if we see gas here. That's a way of minimizing the burden, too. You have to properly justify that, but -

MEMBER ARMIJO: Well, are there any further questions to either Mr. Beaulieu or Mr.

Clefton?

MEMBER MAYNARD: I don't have any questions, but a comment. I'm really encouraged to see the NRC and the industry both in alignment on this. I was pleased to see that the NRC read and seemed to understand, and have attempted to accommodate public comments on the thing, where they were applicable. I think we've talked about a lot of things that this is an important issue, and I don't want my next comments to appear as though I'm saying this is a non-issue. But on the other side of the coin, these systems are very robustly designed. We've had a lot of operating experience. We've had plant transients where things have had to actuate stuff, so while this is an important issue, and we need to attack it, and we need to get on with it, there still is an adequate level of safety out there for protecting the health and safety of the public.

MEMBER ARMIJO: Thank you. Other comments or questions? Well, thank you, gentlemen.

MR. BEAULIEU: Thank you. I turn it back to you, Mr. Chairman.

CHAIRMAN SHACK: Again, we're a little bit ahead of schedule. Everybody has been running - I can't believe it.

(Off the record comments.)

CHAIRMAN SHACK: We'll break until 1:30 today.

(Whereupon, the proceedings went off the record at 12:10:15 p.m., and went back on the record at 1:34:11 p.m.)

CHAIRMAN SHACK: We can come back into session. Our next topic is the dissimilar metal weld issue. As members will recall, industry had a program to mitigate the similar metal welds on pressurizer nozzles. Then Wolf Creek found some circumferential indications and the staff was concerned that some of the plants would not be able to get their mitigation strategies in place as soon as was desirable. And so there was a question of whether an extension could be granted past December.

And the industry undertook a program to more accurately characterize and analyze the behavior of cracks in these kinds of welds. And staff has reviewed that and has granted the extension and we're here today to hear some of the technical work that formed the basis for essentially that decision to consider the extension on the mitigation deadline.

MEMBER POWERS: Didn't we go through this once with Davis-Besse?

CHAIRMAN SHACK: One of the reasons is this required an extensive analysis and an assessment and I guess Glenn White, David Steininger will start?

MR. STEININGER: Okay, my name is David Steininger. I'm the Senior Program Manager for the MRP and the SGMP. This work was done for the MRP by Dominion Engineering, Glenn White. I want to thank you for the invitation to allow us to provide to you a wrap up of all the work that we've done relative to this advanced finite element analysis to resolve the issue that we've had, as Bill indicated, with these plants that intended to inspect in 2008, first quarter of 2008. So I'll just hand the presentation over to Glenn.

MEMBER ARMIJO: Before you do that --

MR. STEININGER: Yes, Said.

MEMBER ARMIJO: Have you gotten any results from all the inspections that have been done so far? Have there been any other findings or any other indications or have they --

MR. STEININGER: Well, we haven't had any new indications domestically, but from what I understand there has been some actual, not linear indications, they've actually done dipenetrant tests on I believe it was a hot leg of Mihama 2. That came up in the last week or so.

If I remember correctly, what I saw were 13 linear indications of axial cracks in the --

MEMBER ARMIJO: Is this the hot leg --

MR. STEININGER: It's the hot leg to the steam generator.

MEMBER ARMIJO: Okay.

MR. STEININGER: Hot leg to the steam generator. I saw the dipenetrant tests. There were 13 indications of cracks. Whether they were called by SCC, I don't know.

MEMBER ARMIJO: Yes.

MR. STEININGER: I just recently heard that there may -- one of the indications may have some circumferential extent to it. I don't really know what means. UT was performed I think 12 of the cracks. They could not get a depth indication. One of the cracks they did have a depth indication, but I just don't know what that value was. I don't know what the percent through wide -- I don't think it was very large.

MEMBER ARMIJO: But as far as the U.S. inspections --

MR. STEININGER: About a half inch. They varied.

MEMBER ARMIJO: But as far as U.S. inspections that have been going on, there's been no indications of more circumferential cracks?

MEMBER ARMIJO: Not on the pressurizer.

MEMBER ARMIJO: Okay.

MEMBER SIEBER: Some of these plants went through mitigation, like filled overlays, so you don't know anything about those, right?

MR. STEININGER: Well, Farley actually inspected and then mitigated.

MEMBER SIEBER: Correct.

MR. STEININGER: They didn't pick up anything. They don't have to inspect.

MEMBER SIEBER: Right.

MR. STEININGER: If they don't want to. They can go directly to mitigation. Farley did. Farley and Southern did inspect and they didn't find anything.

MR. SULLIVAN: This is Ted Sullivan. Can I make a comment. We did talk about this a little bit at the last meeting. I'm sorry to contradict you, Dave. Farley actually did --

MR. STEININGER: They did find something?

MR. SULLIVAN: They did find a circ in an axial. And we talked about that, I believe, at the last meeting.

MEMBER ARMIJO: I forgot about it, that's why I asked again.

MR. STEININGER: Was I right on the Mihama?

MR. SULLIVAN: Yes, everything we know. You know, one comment is that after they apply the weld overlays, this is not worth a whole lot, but I think it's worth putting on the table that after they do the weld overlays, they do do an inspection. They do into the ordinal weld, at least the top 25 percent. And we haven't heard of any indications found from that inspection.

MEMBER SIEBER: Would they be obligated to tell you?

MR. SULLIVAN: I believe so. As Tim was saying, the reason that I said I believe so is because starting in I think about a year ago, we insisted with every relief request we granted which is part of the weld overlay process, that licensees tell us about all of the indications they find from their inspections. So we do get that information. We haven't heard of any indications, at least that deep.

MEMBER SIEBER: Now one of the things we learned from steam generator tubes or hot bi-metallic weldments, Alloy 82/182, is that it's temperature sensitive and it appears to have a knee in that curve, is that -- do I have that impression correctly at around 610 or 612 Fahrenheit? It's not linear, right?

MR. STEININGER: It is very temperature sensitive, you're correct about that. And most of the experience on steam generators has been on base metal, not weld metal.

MEMBER SIEBER: Okay.

MR. STEININGER: I would hazard to say that the weld metal, it isn't cracking as we expected it to crack, as fast, for reasons that we don't quite understand.

MEMBER SIEBER: But a plant, for example, might want to run at 618 or 620 or 1624. T-hot would be more vulnerable than the one that was running at 610?

MR. STEININGER: The higher the temperature, you're more vulnerable, that's correct.

MEMBER SIEBER: And it would be significantly more vulnerable, right?

MR. STEININGER: I don't know if I'd say that.

MEMBER SIEBER: We don't know what significantly means.

MR. STEININGER: I wouldn't say that.

MEMBER SIEBER: But I think there is a knee in the curve?

CHAIRMAN SHACK: Crack growth rates grow up pretty fast.

MR. STEININGER: But he's talking initiation and initiation is more of a mystery.

MEMBER MAYNARD: And the pressurizer, we're operating at higher temperatures than not.

MEMBER SIEBER: That always made me scratch my head.

MEMBER POWERS: We read in some of the literature that Argonne reported extremely high crack growth rates for the Alloy 600?

CHAIRMAN SHACK: It varies. Some of it's good, some of it's bad.

MEMBER SIEBER: Actually, the Wolf Creek anomalies that were found are in pressurizer nozzles and surge line, right?

MEMBER MAYNARD: The surge line and also the relief safety -- safety relief valves.

MEMBER SIEBER: Right.

CHAIRMAN SHACK: Glenn, do you want to start?

MR. WHITE: So here is our list of topics.

These topics parallel the final report which was released in August, so this is an EPRI report, but it's made available to the public, so it's a copyright only EPRI report that's available for free download on the EPRI website.

And Section 1 of the report covers objectives and approach, background. Section 2 covers inputs; 3 helping to find stress. Crack growth modeling is Section 4. Critical crack size calculations is in Section 5. Deep crack modeling in 6. And then the main matrix of crack growth results looking at time between detectable leakage and rupture is presented in Section 7 with conclusions in Section 8.

We're going to concentrate in this talk on the results, so we'll summarize the methodology. We covered that to a large extent in the previous presentation on July 11th.

The objective is the same as we've seen before and that's to evaluate detection of leakage from through wall flaws to preclude potential rupture for this group of 51 subject welds. And as Bill mentioned, the NRC has made a decision that there is sufficient confidence in detection if there were large circumferential flaws that they would be detected through leakage prior to rupture and therefore these plants have resumed their original plants to do either mitigation or PDI inspection in the spring.

We saw this slide before on the project team and the support of the expert panel, summed up by EPRI, so I won't go through the names again, but again, this was a team effort involving multiple organizations, plus we had ability in Boulder, Colorado supplied the software and codified their software to allow looking at arbitrary crack shapes. And that was the main advance that allowed these investigations.

So this slide summarizes the effect of the -- of looking at arbitrary crack shapes as opposed to semi-elliptical crack shapes.

MEMBER CORRADINI: Can you walk us through that?

(Laughter.)

MEMBER CORRADINI: It's not immediately obviously.

MR. WHITE: I am just trying to get the pointer options here.

Here we go. You can see my pointer now. So this first look at this red curve here and that is a semi-ellipse. So this is the previous analysis that was performed by NRC contractor and by Dominion Engineering back in December of last year. The first look at the Wolf Creek experience was to look at well, we start off with a crack that was 26 percent deep and an aspect ratio of about 21 to 1, that was the largest indication seeing that at Wolf Creek. It would have to be in the relief nozzle.

Now let's go that flaw, but let's assume that it stays a semi-ellipse where the aspect ratio of that semi-ellipse is allowed to change, but it remains that semi-elliptical shape. So that allows two degrees of freedom, one being the crack growth rate at the deepest point, that's the symmetry point here in the middle of the crack. And at the surface point here. So if we grow that semi-ellipse based on the stress intensity factor at each location, then we can simulate growth in both the depth direction and the circumferential direction.

At the point of through-wall penetration, what one gets through that exercise is this red curve here which takes up about 70 percent or so of the cross section of the weld. And when one does crack stability calculations under standard type assumptions, including considering the secondary loads from the thermal expansion piping stresses, giving them full consideration turns out that this flaw here is not stable, so it becomes unstable, causing rupture before it becomes through wall.

MEMBER CORRADINI: Can I say that back to you?

So you're doing a series of static evaluations of a crack shape and then with these series of evaluations of the static crack shape, you'll look at it at various positions as it might grow, and then at some point it becomes unstable and goes ripping through the structure?

MR. WHITE: Yes.

MEMBER CORRADINI: Given the potentially very boundary conditions of temperature, etcetera. Is that approximately right?

MR. WHITE: Yes.

MEMBER CORRADINI: So then from the first line which is some bloody color at the bottom to the red line, you're going, you're actually watching it under some stress field and temperature field. You're watching it grow?

MR. WHITE: We're not -- we're only showing the end points here when it comes through-wall under the semi-elliptical assumption. All the other profiles here are under an arbitrary crack shape assumption. So we're not longer just allowing two degrees of freedom for the crack growth at the deepest point in the surface --

MEMBER CORRADINI: But you described it to begin with as if you started the first analysis was that --

CHAIRMAN SHACK: If you did the elliptical analysis, that's what he would have is the series of ellipses that marches out until he get --

MEMBER CORRADINI: Right, that's what I was trying to understand.

MR. WHITE: Yes.

MEMBER CORRADINI: And then at some point it becomes unstable under the stress field and temperature field and away it goes.

And now you can go crazy with various shapes other than just elliptical.

MR. WHITE: When you look at the semi-elliptical shape, it actually has a negative stress intensity factors along a significant portion of its extent here.

MEMBER CORRADINI: Right.

MR. WHITE: What that means is there actually is partial crack to closure which is not physically meaningful, so what we've done is we've created a crack as a larger area than is physically possible and that is because we're growing it based on only two points along the crack profile.

MEMBER CORRADINI: To put it in structural language, the energy is not minimized. You've created something that is not possible to occur, right?

MR. WHITE: Yes.

MEMBER CORRADINI: Okay. Thank you.

MR. WHITE: So removing that artificial assumption, this is, in fact, the shape that the crack must take on, given that the crack growth at each point in the crack growth depends on the local loading there, the local stress intensity factor, once the crack begins to grow through the -- into the compressive part of the residual stress distribution, what occurs is that it's only at the top of the pipe where the bending stress is maximum that the crack continues to grow at a high rate. It slows down and approaches a rest along the section here where the bending does not produce enough force to go through-wall.

So the profile we end up with is this greenish shade, color here that comes across here. Now the crack does grow farther along in the circumferential direction than semi-ellipse is predicted to go, but overall the area is much smaller than the semi-elliptical area and this crack is stable under the critical cracks, the crack stability calculations.

Once that crack becomes through-wall, we continue the analysis to show how the through-wall portion of that flaw increases in size because that's tied to the leak rate and one has to have not just some leakage occurring, one has to show that we have detectable leakage occurring, in order to catch the cracking through leakage detection.

So this slide is intended to show that the motivation behind this project in removing this artificial assumption of the semi-elliptical crack shape which in the past was used for numerical convenience, a calculation of convenience. There's no physical reason for that assumption.

MEMBER ABDEL-KHALIK: What's the independent variable that goes from one line to the next? Is it time?

MR. WHITE: No, this is space, so this is unwrapping the weld into a flat box there. So we're looking, this is the ID --

MEMBER ABDEL-KHALIK: No, no, no, not the axes, but in going through one to the next.

MR. WHITE: Yes, time.

MEMBER ABDEL-KHALIK: Time.

MR. WHITE: So we're stepping ahead.

MEMBER ABDEL-KHALIK: What is time corresponding to the through-wall crack for both analyses?

MR. WHITE: In slide 14 we show the actual times that correspond to these steps. We'll just address that exact question. So you can see when we get to the through-wall penetration here, we are 5.7 years.

MEMBER ARMIJO: Once you have the penetration, how fast does it grow along the surface, opening up that crack?

MR. WHITE: It grows relatively rapidly because the -- we're in a high stress zone and the crack is fairly large. So those two things together give a relatively large driving force and you can see from this point here, from this yellow line, initially we have to assume that the -- we can't take credit for the initial think ligament.

A ligament that's less than 10 or 15 percent of the wall thickness may not be mechanically stable, so you get local rupture, local collapse, elastic collapse would be expected to be possible. So we don't take credit for that initial ligament, but we start off with an area here that is at least 15 percent of the wall thickness and that's zero days here. And to reach all the way around here is 178 days in this example. So whereas the -- to grow a through-wall that process from something was 26 percent deep, required 5.7 years; for process of a leak rate increasing is relatively faster, but still allows many opportunities to be detected.

MEMBER ARMIJO: But it's six years to get to penetration, but half a year to get to instability.

MR. WHITE: Even in some cases more like two months or so.

MEMBER ARMIJO: So you can't fool around.

MR. WHITE: No, but we are also calculating multiple gallons per minute of leakage often.

MEMBER ARMIJO: Should be detectable.

MEMBER CORRADINI: So you answered Sam on this plot, but on the one you were -- do you mind just going back to that and just to get an idea of -- so on this one we're through-wall with the green line?

MR. WHITE: Yes.

MEMBER CORRADINI: And now it's essentially propagating along the surface all the way through. And just with this unwrapped crack, can you say again what you just said to Sam, so to get to the green line is the matter of months and to --

MR. WHITE: No, years.

MEMBER ARMIJO: Six years to get to the green line, but to get to the point where it might become unstable and rupture the pipe, that was half a year, more or less.

MR. WHITE: Less.

MEMBER ARMIJO: Less.

MEMBER CORRADINI: And I remember back when you had the subcommittee meeting and the significant leakage was -- I've forgotten.

MEMBER ARMIJO: One gpm.

MEMBER CORRADINI: Is that what it was?

MR. WHITE: There are measures taken to be -- increase the sensitivity of leakage detection.

MEMBER CORRADINI: I understand that. But in terms of measurable amounts, my next question was since we're just performing this idealized calculation, where in the idealized calculation as it's opening up is the estimated leakage getting detectable?

MR. WHITE: For this example here, again, this is a common set of input assumptions, we call it the phase one inputs, but the answer is shown in this plot here on the right. The blue line is the increasing leak rate. So for that initial flaw, that initial flaw that this yellow line here -- well, we don't take credit for a surface ligament, the initial flaw is leaking on the order of a .4 gpm. And then you can see that that increases all the way to about 8 gpm after 150 days.

MEMBER CORRADINI: Thank you.

CHAIRMAN SHACK: And your tech spec limit is?

MEMBER ARMIJO: One gpm.

MEMBER SIEBER: That's pretty close to the detectables.

CHAIRMAN SHACK: You put in a compensating -- that was part of your compensation for doing this and that you lowered that to .3, .25?

MR. STEININGER: Point 25.

MR. RILEY: That was over a baseline, if I remember right and it was .1 increase in a day.

CHAIRMAN SHACK: Okay, so in theory, they're going to see that thing as soon as it pops through, that particular crack.

MR. WHITE: Now this is typical of the steam space nozzles. The surge nozzle where we actually had our most limiting results, the leak rates are considerably higher, typically over one gpm when they initially popped through them. Upstream we have the sub-cooled liquid whereas in the steam space we have saturated steam, so the mass, the density, developed the densities is significantly different. And so in terms of leak rates we're more limiting on top of the pressurizer.

MEMBER ABDEL-KHALIK: What happens to the thickness of the crack, once it breaks through? The width? Isn't that dependent on a whole lot of things?

MR. WHITE: We calculate, based on the crack stability model that a crack on the order of this size, approximately would become unstable. So this ligament would have a fish-mouth rupture that would occur. So there would be ductile overload and tearing that would occur along this region here.

MEMBER CORRADINI: I think what Said's asking is how well do you know the third dimension? You're showing us two dimensions. A third dimension --

MEMBER ABDEL-KHALIK: Prior to that point, the crack opening.

MR. WHITE: Oh, okay. So here's actually, this is a different case, so this is no longer the

Phase 1 case, but it's another case, Case 12. This is actually for a spray nozzle. We're covering all 51 subject welds and there's a variety of differences, some slight differences in dimensions and the spray nozzles are smaller than the safety release nozzles and of course, the surge nozzles are considerably larger on the order of 12 inches OD. But here's an example of crack opening displacements for a spray nozzle.

First, here on the left is when the leak rate is calculated to get to one gpm and on the right, when the stability margin factor is decreased to 1.2. So that means that this remaining cross section here can support 20 percent more load than is reported for that case.

And you can see that the contours show the crack opening displacement. In fact, it's half the displacement because we have a half symmetric model here and you can see that there is a variation in the opening in the through-wall direction and in the circumferential direction. So we considered those factors in our leak rate calculations.

CHAIRMAN SHACK: Those are inches, right in the units?

MR. WHITE: Yes.

CHAIRMAN SHACK: So it's three mils.

MEMBER ARMIJO: You can read those, Bill?

MEMBER CORRADINI: He's got his glasses on and he's squinting.

MR. WHITE: That plot is three mils, but on the right plot it's six mils.

And so for our base calculations we take the crack opening area at the outside diameter and then we plug that into the PICEP model to calculate a leak rate, but we also did sensitivity studies. PICEP also allows you to vary the ratio of the opening area from the ID to the OD and we did that sensitivity check to make sure that the fact that the opening can be somewhat smaller in the middle cross section to make sure that that does not have a significant effect on the results.

What tends to compensate that effect is that the crack length is longer as you approach the inside diameter.

MEMBER CORRADINI: You used some other software tool to estimate the flow through the crack?

MR. WHITE: That's right, so there are well-established codes in the industry. We've also applied the NRC code developed by Batelle called SQUIRT.

MEMBER CORRADINI: SQUIRT.

MR. WHITE: We've applied that code also. So this is a well-studied area where there have been experimental work with cracks within IGSEC type morphology, it recreates what's measured and so we can apply that tool, but be careful about how we're dealing with the crack roughness parameters, the tightness of the crack, the tortuosity of the crack, the crack opening area, how that varies through the thickness and the length of the crack.

And it turns out that this plot here shows results as the -- this is for an idealized through-wall crack, so these are scoping type calculations. What they show is that as a crack gets longer, one gets higher leak rates, but also as one increases the bending moment, if that bending moment is assumed to line up with the center of the crack, then one gets higher leak rates with higher bending load. That also tends to open the crack in addition to the other loads, the pressure load. And you can see the results here for a steam space type example, nozzle.

And what we see is that the SQUIRT code attempts to slightly over protect by 5 to 30 percent the leak rate that's predicted by the PICEP code. In terms of LOCAs, if one thinks about a Loss of Coolant

Accident, a higher leak rate may be a conservative number. For our purposes, it's the lower leak rates that are more conservative. We get a little worried about on-line detection.

MEMBER BANERJEE: Do these calculations indicate that there is vaporization and critical flow within the cracks or does sub-cooled water come out?

MR. WHITE: No, this is critical flow and so for the surge nozzles you would get a mixture of steam and liquid. In the steam space nozzles, it would be a super-heated steam.

But these codes are all non-equilibrium, a two-phase choke flow model that have been calibrated versus some experimental data. So it's non-equilibrium choke flow --

MEMBER BANERJEE: When you say it's calibrated versus experimental data through cracks or through what?

MR. WHITE: Through cracks, some the inter-granular stress-corrosion cracks.

MEMBER CORRADINI: But the very fact it's a tortuous path, the major uncertainty is what the area and the roughness of the pipe is. You essentially have a funny-looking pipe. So whether it's equilibrium or non-equilibrium, in some sense is immaterial. It's really the ugliness of the crack and the shape that's determining the flow rate.

MR. WHITE: There is a range of different morphologies you'd expect. And that's one of the sources of uncertainty. We addressed those uncertainties with a factor of four on the leak rate.

MEMBER ABDEL-KHALIK: How realistic are these values for the moment? The full moment is 275 --

MR. WHITE: There are some nozzles that do have a load reported to be that high. Perhaps they're conservatively high. But they are, in some cases there are some loads reported to be that high. And when we got into this work, it was not clear whether the most conservative case, the limiting case was the highest moment or the lower moment because moment has compensating effects. It tends to open up the cracks more and giving more leakage, but it also decreases the critical crack stability, so they go hand in hand. And what we saw through the matrix of results is that, in fact, the higher loads, the higher bending moment, the fact on crack stability is more important than the benefit on the leak rate.

There's also the third effect is that the crack is predicted to grow somewhat faster so there's less time, because of the higher moment. So there are three factors that tend to balance each other and that's why we were very careful to look at a full range of moments because they can be again design numbers. They can be higher than actual, but there are also -- in fact, there's one plant that had one nozzle that was capped, so there was no pipe attached to that nozzle, so we know the bending moment on that one is zero.

And so when the bending moment tends to push the crack through wall in a particular location, so in that sense it also helps getting a crack that's focused in one location that can give you leakage before rupture, but on the low end, what we saw was because the residual stresses under an axisymmetric assumption have to be self-balanced in through-wall, the cracks cannot make it all the way through-wall without a bending moment to assist it.

MEMBER BANERJEE: I have a question. Is there any effect of the flow on making the crack grow more rapidly? The critical flow is a very high velocity, very erosive. And what effect does it have on the cracks?

MR. WHITE: I think that would be conservative not to take credit for that effect.

MEMBER BANERJEE: No, I'm saying would it make the crack open up faster?

MR. WHITE: If it erodes some grains, Davis-Besse work showed that perhaps flow effects tend to open up the crack in the weld at Davis-Besse and in the Sierra-Leone nozzle. So that effect would tend to give a higher leak rate without affecting the crack stability.

Now the dynamic forces would both tend to affect the loading on the crack.

MEMBER BANERJEE: Then we have jets, for example, coming out and eroding things. This would be like internal erosion problem with very high speed flows. I mean if this is all liquid, the velocities would be about a thousand meters per second. They would be 300 meters per second. So what effect does that have?

MR. WHITE: Well --

MEMBER BANERJEE: Has any tests been done on that? Are you assuming that it has no effect?

MR. WHITE: We are not -- to be sure that they're shear forces, then there shouldn't be a significant effect on pushing the crack open more. What we did do was look at the sensitivity of the crack growth and the crack stability to whether we apply the full pressure on the crack base. So there is going to be a pressure drop across the crack and there are typical calculations according to PICEP. In SQUIRT, you get about a 50 percent drop on average, almost 50 percent.

MEMBER BANERJEE: I'm talking about electro-mechanical polishing effect, due to the flow which is also ionic, I presume. There's going to be a number of things there.

MR. WHITE: You mean sort of a steam cone effect to open up the --

MEMBER BANERJEE: I don't know. I'm just asking the question.

CHAIRMAN SHACK: It is steam cutting basically is what he's asking.

MEMBER ARMIJO: The answer would probably be different if you had carbon steels instead of the stainless steels. You might be thinking of flow accelerated corrosion zipping through that crack.

CHAIRMAN SHACK: This is a speed well beyond flow accelerated corrosion.

MEMBER CORRADINI: But so, if I could just ask the question a little bit differently. So you're saying if anything this, ignoring the fact that you had erosive effects of the fluid are conservative because you're not taking into account what would give you a higher leak to detect --

MR. WHITE: It would be non-conservative if it acts to make the crack bigger faster.

MEMBER CORRADINI: I was going to say fast. So let me ask the question about you went back and you said that these things have been tuned to experiments. So where have these experiments been done to tune these flows?

MR. WHITE: At Batelle Columbus, but those are leak rates attached and they did not try to grow cracks.

MEMBER CORRADINI: I was going to ask more did they do this over long periods of time to see if they actually caused erosion from their own idealized cracks.

MEMBER POWERS: The machine slots in pressure, that sort of thing.

MEMBER CORRADINI: Well, I don't know how they test, but my thought is if they ran it for extended periods of time.

MEMBER BANERJEE: As a follow-on, was it done with real cracks or was it done with simulated cracks?

MR. WHITE: They were done with stress

corrosion cracks.

MEMBER BANERJEE: Okay.

CHAIRMAN SHACK: I don't think they saw much in the way of erosion in those tests, but again, they didn't run them for months on end either. They ran them long enough to get a leak rate and then stopped.

We are running a little low on time. I will mention that we do see something in steam generator tubes that, in fact, the jet excites the steam generator tube and you get a fatigue driven crack that can grow extraordinarily rapidly in a steam generator tube. Once you get up to the fact when you have a true liquid jet coming out, but I suspect frequencies of these pipes are quite different.

MR. WHITE: We saw some in the VC summer experience which had a couple hundred pounds of boric acid deposits on the floor and there was still just a pinhole. So I think in general, these materials --

CHAIRMAN SHACK: But those leak rates are much smaller than the leak rates we're talking about here.

MR. WHITE: Well, if we are talking about those higher leak rates, they're going to be detected very quickly in three days at most.

MEMBER BANERJEE: My point of view here is that this may be negligible, but should be an effect that you really have looked at and said it's not important, not just ignore it because it doesn't have an effect otherwise. Flow does make things go faster.

MR. WHITE: We have plans to submit a paper to a refereed journal, so that's something that we can address in that paper.

MEMBER POWERS: If I look at your pink slide, pink blob slide, I'm going to abandon the assumption this elliptical crack indeed, I've never seen a crack that was elliptical, so that seems like a good thing to abandon. And I'm going to calculate this other kind of crack where I look at the growth at each stability point. And you get another kind of crack and I've never seen a crack that looks like that. Is there between the non-physical ellipse and your calculated curve a crack shape that's particularly obnoxious?

MR. WHITE: No. From what we see in the calculation is that we get crack arrest in this area because the crack is growing into the compressive part of the residual stress where there isn't a load to overcome that.

MR. STEININGER: You get penetration is

what we have seen in stress corrosion cracking.

MR. WHITE: We have the Duane Arnold experience that did show a shape that is not radically different from this.

CHAIRMAN SHACK: I mean, in these tough materials, it's basically loss of area that you're worried about, and so a particular shape isn't so important as just how much of the cross section you've chewed away.

MEMBER POWERS: In going from the ellipse to this peaked shape, it's a qualitatively different behavior.

CHAIRMAN SHACK: The shape is important.

MR. WHITE: The critical crack size you'll find you've chewed up just about as much area in either case.

You can go through-wall and have a through-wall crack out there, but until you chew up the right amount of area, it's going to sit there, roughly.

MEMBER POWERS: It's qualitatively different behavior between the two. I'm asking is there anything between that's particularly obnoxious?

MR. WHITE: We did look at the effect of the crack shape on the initial flaw. So we did explicitly look at flaws that were of more uniform depth to start off, parabola or a semi-ellipse to start off. Different shape. So we verified that that assumption was not important to the results.

MEMBER ARMIJO: Did you look at the multiple elliptical initiators that coalesced into a calculation cracking?

MR. WHITE: We addressed multiple cracks in a few different ways. This slide shows that we have -- we looked at enveloping initial flaws, 360 degree part-depth flaws and then multiple individual flaws and then combining them for crack stability calculations.

So for most cases we looked at a 360 -- in many cases looked at a 360 degree flaw, so that would assume initiation in many different points. But in other cases we looked at -- this one on the right, you can grasp it assumed initiation of two flaws or an initial condition of one flaw at the top of the cross section and one at the bottom and it grew, both at the same time. And the one on the top grows much more than the one on the bottom in that time period. So we looked at cases like this and looked at how this presence of this second flaw affects the stability of the cross section.

MEMBER BANERJEE: May I ask a question? How sensitive are these results to the stress intensity factor model that you use?

MR. WHITE: Numerically, this is just a math problem to calculate the stress intensity factor. So --

MEMBER BANERJEE: What you have, your finite element code, all it does is calculate stresses and stress intensities. Then you have to have a model for cracked growths, right?

MR. WHITE: That's right.

MEMBER BANERJEE: How sensitive is it to the crack growth model?

MR. WHITE: We especially looked at that question. We had several cases where we varied the crack growth rate equation. We changed the slope of that line from - -the nominal slope is 1.6 exponent, and we changed it to 1 and 2.2, based on the 95th percentile values from the regression analysis and came up with that sensitivity stress test factor. So we think we look at that and the fact of the crack growth rate equation. There's significant uncertainty there and --

MEMBER BANERJEE: What did you find for the more rapid crack growth? How long did it take?

MR. WHITE: There was a modest sensitivity. I can find the results. This is much too busy here, obviously, to -- but it's in Table 7.7 in the report and this is actually the NRC's suggestion was to show explicitly all the sensitivities to summarize. So there's two pages of them. And it was cases 44, I'm sorry, 42 through 47, looked at this. So 42 we changed the exponent from 1.6 to 1.0. And the time between detectable leakage and rupture with margin change from 41 days to 39 days. When we increased the exponent to 2.2, it went from 41 days to 47 days --

MEMBER CORRADINI: Ten percent effect.

MR. WHITE: Ten percent effect there. A little bit higher effect for some other geometries. Here it went from 35 days to 22 days, so that's more like a third effect, maybe.

MEMBER BANERJEE: So there's an exponent and there's a coefficient --

MR. WHITE: That's the exponent. So we calculate the 75 percentile magnitude crack growth the same because the exponent, you cannot vary the exponent independently of the coefficient and get sensible results. So we also -- it's simply, you don't need to re-run the analysis to look at the coefficient itself. That's just a scaling factor on time. And that's discussed --

MEMBER BANERJEE: Let me ask a more simple question. Imagine your crack growth model gave you crack growth that was three times as fast. Would this open up three times as fast?

MR. WHITE: Yes.

CHAIRMAN SHACK: It wouldn't change the crack shape. That's the critical thing. It's just scales and times. So the real thing is instead of five years, it's two years, but it still pops through and you still have a fair amount of growth along the surface. So these things are sensitive to the initial crack shape. They're sensitive to the weld residual stresses. They are in a sense almost independent of the crack growth law because that just scales in time.

MEMBER CORRADINI: But once you break through the crack growth law --

CHAIRMAN SHACK: Yes, at 2.5 gallons per minute, you're detecting this thing in a day or two.

MEMBER CORRADINI: But can I ask Sanjoy's question a little bit differently? So once you break through, then the crack growth effect is minimized because now you are essentially just -- you just have so much load-bearing area which is slowly getting away. Is that correct? Do I have this right?

CHAIRMAN SHACK: Yes, that cuts down that amount of time, but again, your time, you don't need much time.

MEMBER BANERJEE: It could be 20 days instead of 60 days.

MR. WHITE: If you look at the data from the laboratory, world-wide data that's available, the crack growth rate equation, coefficient we're assuming is not that different from the upper end that's ever been seen in the lab. So there is not a big difference between with the highest rates as seen in the lab, versus our normal function.

MEMBER ABDEL-KHALIK: Are any of the nine plants operating currently with an unidentified leak close to the tech spec limit?

MR. LUPHOLD: I am Tim Luphold. These facilities can generally detect a leak on the order of .05 gallons per minute, some even less depending on the sophistication of their instrumentation for their mass balances.

MEMBER ABDEL-KHALIK: So they're all near the detection limit, all nine plants?

MR. LUPHOLD: A lot of times these plants are running around like a .05 gpm to like a .1 gpm leak rate normally for unidentified leakage.

So yes, they can see increases above what their current leak rates are. I think that's what you're asking.

MR. RILEY: There may be another way to answer that, if I understood the question right is the -- all these plants are still operating under an enhanced leakage program which is significantly below the tech spec limits as it is.

MEMBER ABDEL-KHALIK: But I just want to find out where they are and how close are they to either the tech spec -- the new tech spec limit or the detection limit.

MEMBER MAYNARD: And I think the magnitude isn't quite as important as the change for this particular one. Somebody might be operating at .05. Somebody else may be at .2. That's not as important as do they see a change. That's part of the enhanced modeling, I think, for doing it. Do they see any upward trend.

MEMBER SIEBER: There's an occasional plant that will have a negative impact.

CHAIRMAN SHACK: Glenn, how fast do you think you can get through the rest of this.

(Laughter.)

MR. WHITE: These are very similar to July 11th. We had a handful of cases we're still finishing up. The final matrix was 119 cases. We call the main matrix of 109 cases. All those results either showed stable rest 60 cases or met our evaluation criteria that we covered last time that contain safety margins.

MEMBER BANERJEE: These cases, they included the parametric studies of crack growth model and the crack stability model as well?

MR. WHITE: That's correct. All the various sensitivities.

MEMBER BANERJEE: So you did sensitivity on the crack stability model as well?

MR. WHITE: That's right.

MEMBER BANERJEE: And you will tell us something about those?

MR. WHITE: Sure. The crack stability model, the big message there is for our main cases we considered 100 percent, we considered no reduction in the secondary load. However, we did detailed work that are explained in the Appendices B and C of our document to look at whether, in fact, there would be reduction in the secondary stresses. And what we conclude, let me step back to that slide. So this is slide 19. This introduces appendices B and C. And

Appendix B we looked at structural integrity associates, looked at two models, one of a Westinghouse surge line and one of a CE surge line and modeled the rotation that's produced if one releases the nodes at the location of the surge nozzle. And made conclusions regarding the degree of relaxation of those loads and that was complimented by the work in Appendix C by Quest Reliability and Ted Anderson who looked at elastic and elastic plastic models with idealized through-wall cracks.

And what you see here on the right is the normalized crack length goes from zero to one. So in the middle here we have a 50 percent of the cross section is cracked and this is the moment knock down factor. So if you look at the situation with an imposed rotation versus an applied load, one can look at for the imposed rotation case which is more like a secondary, which is a secondary load situation, one can look at how much the applied moment decreases and you can see you get about a 50 percent reduction in load when the crack becomes 40 percent long of the circumference.

And then you can take it and extend that to a J-integral, J theta over JM, so J is the crack driving force. J integral driving force for the imposed rotation case versus the applied moment case. And for the same crack length, and you can see that as that crack again approaches .4, 40 percent of the circumference, that driving force decays to a great extent compared to the applied moment, peer reply moment case.

So this supports at least a reduction in load of at least 40 to 50 percent or more occurring in the surge nozzles and in our main cases we always did not take credit for that. Slide 31 here looks at our most limiting case which we call S1b where we assumed a 360-degree flaw in the surge nozzle starting off 10 percent deep and if one assumes 40 percent or more reduction which is supported by the work in appendices B and C, then that result does satisfy the evaluation criteria. So that's a large source of conservatism and we evaluated that explicitly for our most limiting case.

The bottom of slide 30 here, this is the work I'm look at multiple flaws. Other than assuming a 360-degree flaw, we did look at different cases with multiple flaws. We based some of those cases on the Wolf Creek surge nozzle experience where three different indications were reported separated around the circumference. One of those indications was rather small, but we conservatively applied that experience to some of our cases.

The last two slides here, 32 and 33, just summarized the conclusions, so the assumption of the semi-elliptical flaw shape, that's an artificial assumption that shows the result in a large unnecessary over conservatism. And that was shown throughout the work. So preparing the work now from our work back in December with the semi-elliptical shape, there's a large change in the results.

We concluded that all 51 subject welds were adequately covered by cases that met our evaluation criteria and those safety factors. A couple other important conclusions that mentioned back in July 11th, but we're re-emphasizing here that circumferential cracks tend to show stable arrests. We saw many cases with stable arrest. If one assumes the axi-symmetric loading, then there has to be self-balancing at each point on the circumference and that means that one needs a large bending moment in order to overcome that compression in the wall's residual stress. And that's consistent with the Wolf Creek experience that all four of these five indications were found all between around 25 percent through-wall which is consistent with where you would expect the arrest to occur, based on our finite element residual stress calculations.

So -- and again, all the experience we've had in the world is that we've had through-wall axial cracks. We haven't seen through-wall circumferential cracks in these PWR configurations.

Another conclusion I already mentioned here was if you take credit for the relaxation secondary loads, that is supported by the detailed evaluations. That's a large source of conservatism and we concluded that the work supported the viability of leak detection here and again, just to mention that we are publishing -- putting together a paper for a scientific journal.

CHAIRMAN SHACK: I have a question, it's a little -- do you understand why your hoop stresses are lower than Dave Rudland's for the welding residual stresses?

MR. WHITE: Yes, we've done detailed comparisons and I think we understand most of the reasons for the differences. There are effects. We found that the fill-in weld is a key part of the surge nozzles. Not all the surge nozzles had fill-in welds, but the way that you simulate that fill-in weld, in a sense it's the ID where the whole process is most sensitive to the residual stresses near the ID, in that first third of the wall.

And that fill-in weld comes last, so how you simulate that fill-in weld, the results are sensitive to that and we took two different approaches to the simulation of the fill-in weld. The second major issue is how one simulates the stainless steel to field pipe rod and what kind of constraint one puts on that pipe. So that's an area of active study that we want to continue to work on.

The industry and the MRP plans to participate along with the NRC in work on improving the welding residual stresses and to build mock-ups typical of the PWR configurations. So that is going to be a significant effort to look at these questions.

One of the main conclusions here was that the results are sensitive to the welding residual stress, and so understanding them, understanding the uncertainties in these calculations is critical as we move forward and that's why that's the next major effort in this area.

CHAIRMAN SHACK: Back on schedule. Are there any additional questions from the Committee? Thank you. Thank you. I enjoyed reading the report. It was an impressive amount of work done under an extremely demanding time schedule. I'm sure your family missed your summer vacation because you certainly didn't have time to take on.

Staff is ready to go, I think?

(Pause.)

MR. SULLIVAN: Dr. Shack, I wanted to make an offer if you're interested. There is a video of that, an animation, that Al has that shows the corrosion of the crack with this elliptical, semi-elliptical restraint. It would take an extra few minutes to do it.

CHAIRMAN SHACK: Yes, I would like to see it.

MR. SULLIVAN: I think it's worth doing.

MEMBER POWERS: It would be far more valuable to actually see a crack growing than to see these computational fantasies.

MEMBER ARMIJO: They have them. They have them. It would be nice if they could shown them.

MEMBER POWERS: If they would show them, it would be useful. But right now we're not seeing them. We're seeing the computational fantasies.

(Pause.)

MEMBER POWERS: My point is is that we're doing computations on a continuum and something that actually has a grain structure with grain flaw, grain boundaries and unusual things that are just not modeled at all and we're attributing some reality to it that may or may not exist.

DR. CSONTOS: Okay, we did not include those different micro-structure features in there. This is an isotropic body. We understand that. We believe that there is actually some work that the industry did in one of the MRP documents that looked at, that promote that that kind of micro-structure promotes through-wall growth and not growth around. So what we're doing is conservative to that issue.

That's the part of why we went with this. It's also much more difficult in the time allotted to us to evaluate this.

CHAIRMAN SHACK: That's also why this is phenomenological model. We don't know what happens at the crack tip. All we do is describe what controls the deformation in that crack tip. We don't understand those processes at all, so this is all an analogy to something that we can simulate in the laboratory which is a cracked tip, and all we do is to say that the crack tip in the laboratory is subject to the same loads and deformations as the crack tip in the real world. We can't tell you any other way except experiment what happens to that crack tip. So this is not a first principles model.

MEMBER BANERJEE: I have a question on that. Has there been any validation of this approach that you are describing?

DR. CSONTOS: This approach is well-rooted in good fracture mechanics.

MEMBER BANERJEE: I'm just asking has there been an experiment and a calculation done and they agree with each other?

DR. CSONTOS: I don't --

CHAIRMAN SHACK: I think you can say that what we see in the real world is quite consistent with what we predict from these kind of finite element predictions of welding residual stresses and laboratory measurements of crack growth. I mean, we've been doing this for 30 years in a variety of circumstances.

MEMBER BANERJEE: But has there been a sort of a run-off? Let's say that you did a finite element calculation and then went and did an experiment in the lab and they agreed? Not after the fact, but before the fact.

DR. CSONTOS: The experiments in the lab are run with certain types of specimens that you get a crack growth rate from. From that, we take the finite models. We have a k-relationship with crack growth and we model it in that fashion, per se for the whole entire code and the entire kind of fraction mechanics in terms of validation, we do have some for fatigue cracks, but we do not have them for PWSCC cracks because this is the first time that we have really addressed this type of crack growth modeling in this fashion.

We haven't been able to make pipes in the last six months to test these and verify them. We are planning to do something along those lines of validation. Once we get this weld residual stress issue taken care of, what you heard Glenn alluding to at the end. Once we validate the weld residual stress is because that's pretty much one of the bottom lines from my clock is that weld residual stress is really governed how these cracks grow.

If we really get a handle on the weld residual stress aspect of it, we will then be able to validate the entire model. Without that, we are just shooting in the dark right now. I have some information here about a preliminary effort to validate, but we have a good sense of how this is going. But in terms of validation space, that's another maybe year or two off until we get the weld residual stress validation done.

MEMBER BANERJEE: So if you took the weld residual stress issue out, has the rest of these procedures ever been validated by some what I call integral tests?

DR. CSONTOS: In terms of dissimilar metal butt weld?

MEMBER ARMIJO: Fatigue or stress corrosion crack.

DR. CSONTOS: Yes, in terms of fatigue we've done a bunch of pipe tests back how long ago, Dave? That was in the first LPB program.

DR. RUDLAND: The tests were done in the '80s for fatigue and things like that, but in terms of cracks in pipes under SCC or monitoring the growth rates, those kind of tests really haven't been done. We use laboratory based-size specimens to predict the growth and assume --

MEMBER BANERJEE: You have to fit at the moment you save and take a crack growth model, take a crack stability model and predict anything --

DR. CSONTOS: I think that if you looked at Glenn's work back in July 11, ACRS meeting, he showed how our models predicted, is it Duane Arnold crack growth and that with this model. That's validation --

MEMBER BANERJEE: A post prediction, right?

DR. CSONTOS: Yes, that is a post prediction.

MEMBER BANERJEE: Has there ever been a pre-prediction of an experiment?

DR. CSONTOS: There hasn't been a pre-prediction of a weld residual stress model as well. But that's important, though.

MEMBER BANERJEE: I agree.

DR. CSONTOS: You can't do the second until you do the first.

MEMBER BANERJEE: But let's say taking that uncertainty out, has there been a well-controlled experiment which has been pre-predicted by this procedure and puts them together with a time element model?

DR. CSONTOS: In fatigue space yes. In crack growth and PWSCC, which is what we're worried about here, or on just SCC, we do have some for IGSCC, but not for PWSCC.

MEMBER ARMIJO: But there were pipe tests done for IGSCC.

DR. CSONTOS: There were IGSCC. But those were support.

DR. RUDLAND: There was leak rate, but there wasn't necessarily IGSS crack growth pipe experiments.

MEMBER ARMIJO: There were a huge number of experiments that GE did with what they called their pipe test lab, specifically, to test the crack initiation and growth basically tensile-loaded, four-inch diameter pipe tests. I'm sure they shared it with the NRC.

DR. RUDLAND: Environmental --

CHAIRMAN SHACK: They didn't try to do that as a comparison. I would argue that you have lots of field experience that says the predictions we make are what we see consistent with the field. I mean, we predict that core shrouds will grow to a certain depth and by and large, you know, you look at the kilometers of core shrouds that are cracked and they behave the way that they think they do. We predicted that large pipes and small pipes will behave differently under stress corrosion cracking.

Now again, the BWRs have given us lots of experimental evidence so that's a different kind of SCC, but it's still a k-controlled fracture mechanics phenomenological model that I think is a reasonable model for PWSCC.

DR. CSONTOS: If we are talking about stress corrosion cracking and then we're talking about fracture mechanics, this is right now the best that we can do. Validation space --

CHAIRMAN SHACK: But he's asking you is it good enough?

DR. CSONTOS: And a validation space, we have, we'll have to get to that in the next year or two.

DR. RUDLAND: I mean, Bill brought up a good point earlier about the welds aren't cracking the way that the base metals are cracking. And so our experience just with the experimental stuff on the base metals is telling us that the welds should be cracking a lot faster than they really are. So we really don't have a good handle on that because there have been no experiments that have really been done for PWSCC and welds.

DR. CSONTOS: I wanted to show you the video here, just to give you an idea. I know we're way behind time. Do we just want to bag this and go on?

What Glenn showed you early on was that

one graph that you were looking at, one was looking at semi-elliptical crack and the other ones were looking at an arbitrary crack as it grows through a stress field and all the nodes and full-on to cracked growth to whatever extent it wants. In this case, this is the scoping analysis result that we had where we keep the crack semi-elliptical. It grows at this point and at this point alone. So this is where we determine k. The k grows to the extent that is from the crack growth rate equations, and what you see here is it stays in a semi-ellipse and then right here it pops.

This is the rupture that occurs. This is because we, what Glenn showed in that pink area is the ligament that is remaining. When we change that model to this model, which is growing the crack along the entire crack front, along every node, k is calculated along the entire node and then the crack grows to whatever extent. This is showing how the crack is growing with a specific weld residual stress profile.

This is the crack in white and you can see that the bending moment that Glenn was talking about is coming out at you and the crack will then start to grow. Once the residual stress k, the driven ks, to grow the crack around, it then grows the crack through-wall. That is the amount of opening right there for leakage. That's what basically we're calculating. That's just a schematic of how this model is being developed.

With the presentation -- I'll just go ahead and use this.

MR. HAMMER: You have the wrong one?

DR. CSONTOS: I don't know.

CHAIRMAN SHACK: It's got the right title. October 4th.

(Pause.)

DR. CSONTOS: I just wanted to show this up here real quick. This is the scope of the work that we have done since October. What we broke it down through is the scoping, the phase one and phase two analysis. The scoping analysis we talked to. That was keeping the crack semi-elliptical. Phase one and we came back to you in March of 2007 and we gave you the results of the scoping study. We gave you some updates on the work, the advanced FEA proposal by the industry, and we gave you some initial, our initial comments in the regulatory activities.

In July, we gave you the phase one results, those videos I just showed you. We gave you two-thirds of the phase two result, and that's what we're going to be talking about mostly today. That is a sensitivity study and we're going to give you the rest of that.

My job in the Office of Research was to confirm the industry, confirm or deny the industry's model. We developed separate independent models based up on the sound scientific basis in fracture mechanics and structural mechanics that have been developed and the crack growth rates that have been developed over the past 20 years or more to develop this program and we both developed separate programs.

What you see here are, we broke it down, we had 31 cases that we evaluated. Thirty cases are for the phase two, and what I just showed you in those videos are for phase one results. What we have is 15 of those cases were to directly compare to industry cases. The other 15 were to evaluate certain conservatisms and certain other parameters that we were concerned with internally at NRC that were irrespective of what the industry did.

Industry could have provided those results if they wanted to, but we were going to evaluate those issues on their own.

MEMBER ARMIJO: Both groups used the same crack growth rate?

DR. CSONTOS: From MRP 115. Yes, that

crack growth rate, we've evaluated, we have been participating in looking through that report and reviewing the report, not officially but internally, and yes, we agree with those results of the crack growth rate.

MEMBER ARMIJO: There's no funny stuff going on that maybe the French have done similar crack growth rates and gotten ten times higher or you know, is there pretty much universal agreement that those rates are reliable?

DR. CSONTOS: Yes, there's been a real extensive effort in the past five or six years to go through and wash through all the data from all the crack growth rates.

MEMBER ARMIJO: Everybody in the world.

DR. CSONTOS: Yes. Everybody in the world. And those are usually test -- pardon?

MR. SULLIVAN: Including the Navy.

DR. CSONTOS: Including the Navy. And what, you know, they take these samples and they put a k and they drive a sometimes constant k and you can get these relationships that way. And so what we're showing here, I've broken it down between safety relief, the spray nozzles, and the surge nozzles. This is the phase two safety relief results, so I provided to you all the different parameters that we had in the past that we evaluated.

In this case, for these phase two results, for the safety and relief nozzles, we confirmed the industry's results. Between, well, I'll break it down here for you. So we've had here time at first leakage from the initial flow size to leakage, margins at 1 gpm leak and then time from 1 gpm leak to 1.2 safety margin. That 1.2 is an arbitrary number at the time to compare directly with the industry's results which you have saw. Glenn was using a DEI and the industry were using a 1.2 safety factor or I should say, what is it called, not a safety factor but assessment factor, margin.

Here are the spray line results. The spray line results again, we looked at the cases and we again confirm with the industry's cases. Now you will see here sometimes where we'll get a rest while they get 25 years. That's just the slight difference in the weld residual stress fits that we do as different from what the industry has done and what happens is when you get a k that gets to zero, you get crack arrest, and you don't get the crack to grow anymore because there is no energy to grow that crack any further.

And so the small differences can make a big difference in the final outcome of the prediction. So in the case of a spray line, we have confirmed the industry's results.

For the surge line, for the most part we have agreement on the industry and our evaluations. You will see here that we are usually about maybe 10 to 12, 10 to 15 percent higher in terms of the time to first leakage. We're a little bit lower in the time of first leakage to the margin at 1 gpm leak and that's because of our assumptions that are different in these two different analyses.

MEMBER POWERS: What are the units on margin?

DR. CSONTOS: Oh, on, these are just margins.

MR. SULLIVAN: It's dimensionless.

DR. CSONTOS: Yes, it's dimensionless. One is rupture.

MEMBER POWERS: You're going to have to point it for me. I don't understand.

DR. CSONTOS: This is a margin between leakage and rupture.

MEMBER POWERS: Margin is a difference to me.

DR. CSONTOS: Right, and --

MEMBER POWERS: Yes, but it's the difference in units.

DR. CSONTOS: It's dimensionless because what we're doing here is we are saying that one is let's say a safety factor of one where you do get rupture.

MEMBER POWERS: Safety factor on what?

DR. RUDLAND: It's a ratio on the loads or on the time, so in this particular case here the margins are 1 gpm are the ratio on the loads at critical crack size versus the loads at the crack size that equals 1 gpm.

MEMBER POWERS: Okay, tell me what the load is for the denominator?

MEMBER CORRADINI: I think he is looking for some dimensional numbers like time until something.

MEMBER POWERS: I'm just trying to figure out what the number is. I mean, 1.03 looks like a great number --

DR. RUDLAND: That is an actual load at that point.

MEMBER ARMIJO: That's why the times are zero.

MEMBER POWERS: I asked what the units on margin was. One person told me years, one person told me months. Now you told me they are ratios of loads, have nothing to do with time. Now I'm trying to find the loads on what?

DR. CSONTOS: If you look, let me show you, those plots that Glenn showed up earlier where you have the margin, it's a factor on loads.

DR. RUDLAND: Yes, it's the load at failure for that particular crack size. It's the load at that particular size divided by the load at critical crack size. It's the ratio of the loads --

MEMBER POWERS: Could you give me a table of the loads that were used to compute these ratios?

DR. RUDLAND: Yes, we could.

MEMBER POWERS: Please.

DR. CSONTOS: It is in the documentation that we provided.

MEMBER POWERS: What, by the way, is a load ratio titled arrest mean?

DR. CSONTOS: Arrest means that the crack will not grow, that the ks will get to a point where it is zero.

MEMBER POWERS: That mean that the margin, by your definition, is infinite at that point?

MR. BLEY: You never get to 1 gpm, is that what you're saying?

DR. CSONTOS: Yes, you never to get to a 1 gpm leak period. The crack stops growing through-wall and okay, and so for that matter, that's when we look at a lot of these flaws and how they grow. You have either a crack arrest or you have cracks coming through-wall and when we have cracks growing through-wall, this is the load margin that's available to us. If it is one, that means we have failure, okay?

Do you have something that you can show real quick?

DR. RUDLAND: I'm going to use Glenn's report. Here is case one, for instance.

MEMBER POWERS: Okay.

DR. RUDLAND: The loads that are on that.

MEMBER POWERS: 5.7 ksi.

DR. RUDLAND: And go back to here. For that particular case at that particular time, here is a supportable load on that particular crack.

MEMBER POWERS: 255.

DR. RUDLAND: Just so the total is 12.78. So in this particular case, the margin is 2.24.

MEMBER POWERS: So now if I total this up, I do not get to a .78.

DR. RUDLAND: If you look at 5.71.

MEMBER POWERS: 5.71.

DR. RUDLAND: By 12.78 is the total support bending point.

DR. CSONTOS: The bottom line for this is that when we have --

DR. RUDLAND: The ratio to total loads, applied loads, to the total load collapse for that particular crack size.

DR. CSONTOS: It's how much load can that pipe, after the crack grows, after the crack grows through-wall, so you have a crack and it goes through-wall, what is the remaining load that that pipe can withstand, it can hold, ok? When it is a ratio of one, that means that it is going to rupture. That's why we have this margin over here. This time, when this is one, the time from 1 gpm link to 1.2 margin is zero because it's already rupturing.

DR. RUDLAND: And so the supportable load equals the applied load.

DR. CSONTOS: And so basically whatever ligament is remaining on that pipe is not going to be able to withstand the load. So the margin is one. That's why I was trying to relate it back to safety margin. If your safety margin is one and you get to that load, you have rupture or you have failure.

DR. RUDLAND: If you have a margin of one and a half --

MR. SULLIVAN: It's really a ratio.

DR. CSONTOS: Does that answer your question?

MEMBER POWERS: I heard the explanation. When we looked at the tabled numbers here, we don't come up with those numbers.

DR. CSONTOS: We can provide more information. We're just confirming.

Basically, we're confirming the industry's work on this, so --

MEMBER CORRADINI: So let's just try it one last time with the top one which is easy. DEI and you both get the same number, approximately.

DR. CSONTOS: Correct.

MEMBER CORRADINI: So that means that the moment you get a through-wall, it starts leaking greater than a gallon per minute.

DR. CSONTOS: That's correct. At one gpm it's --

MR. SULLIVAN: No, it means the moment it starts to leak. Those are the ratios of the load. The load carrying capability versus the applied load.

Or divided by the applied load.

It can carry --

MEMBER CORRADINI: That's why I'm going -- I'm looking at line one, case 17-1. It says 1.03, 1.0. But if I understand, then I go to the next roll over, it says time since the leak is zero. That means that I interpret that to mean the moment it starts breaking it leaks at one gpm.

So do I have that right?

DR. CSONTOS: Yes.

MEMBER CORRADINI: Let's just go with that. So that means that it's leaking, but it doesn't mean that it's ripping open. It just means it is leaking greater than this criteria.

DR. CSONTOS: Greater than 1.0 -- yes, 1.0 gpm leak.

MEMBER CORRADINI: Okay, so that's line 17.1. I got that. Now let's go down line 17.11.

The numbers are the same once again. You guys agree, let's not worry about what 1.36 means. What is the .43 mean?

DR. CSONTOS: That's the number of months.

MEMBER CORRADINI: Aha!

DR. CSONTOS: Point 432 from a one gpm leak, so you have a crack that's gone through a wall.

It's leaking at one gpm.

MEMBER CORRADINI: Right.

DR. CSONTOS: And then it goes from that to a critical crack size and it takes .43 months to go from the one gpm leak to the critical leak or the critical crack size.

MEMBER CORRADINI: It just rips open.

DR. CSONTOS: That's right. And a 1.2 margin. That's the safety -- it's an evaluation margin that the industry was using. So we're trying to compare it to that number.

Ted will talk about what we use. It's a little different. But --

MEMBER CORRADINI: If the loads were 20 percent higher than they used in the calculations --

DR. CSONTOS: Exactly.

MEMBER CORRADINI: Okay, I got it.

DR. CSONTOS: So it's 20 percent higher and that basically drops the critical crack size down smaller.

MEMBER CORRADINI: Thank you. I get it --

MEMBER BANERJEE: Can I ask the question? In these comparisons, the difference between the NRC calculations and the industry calculations was what?

DR. CSONTOS: We haven't --

MEMBER BANERJEE: The same residual stress models, do you have the same K models? What was different?

DR. CSONTOS: Everything. We did everything independently. We -- the residual stress models were fit differently. And so most of the differences that you see here are -- for example, the arrests where it says 17-8 and 19-1, where the industry gets arrests and we get 6.15 and 9.5 years is a difference in the fit of the weld residual stress models. One.

Two, we also have differences, why you see a difference of about -- I don't even know how much percent.

MEMBER BANERJEE: That's okay.

DR. CSONTOS: But basically, there are certain assumptions. When you get a crack to go through-wall, how much can we allow for that crack or do we know the k? The k gets very high at the very tip of the crack, okay? And so once it goes through-wall, so how much do we allow, how much do we assess? Well, what we did is we conservatively said that it is going to be a certain larger extent rather than, you know, modeling it. That's a hard area to model.

We have certain different assumptions, and that's where the differences between the industry and our analysis lay. These aren't two of the same models. These are two independently developed models with different assumptions.

MEMBER BANERJEE: They are the same crack growth model, right?

DR. CSONTOS: The same crack growth rate expression that was developed in MRP-115.

MEMBER BANERJEE: But was it the same exactly or was it different?

DR. CSONTOS: The equation that is used is the same. In terms of the k relationship to crack growth.

MEMBER BANERJEE: That's fine. That's what I wanted. Was it also the same with regard to the z-factor in the crack stability model?

DR. RUDLAND: Yes, it was.

MEMBER BANERJEE: Okay, that's a straight answer. So what was the difference was the residuals stressers, the initial conditions, I take it?

DR. CSONTOS: Yes.

MEMBER BANERJEE: And the finite element code, was the nodalization the same or different?

DR. RUDLAND: That was totally unique, so those were done separately. The mesh size densities and all that kind of stuff was done independently.

MEMBER BANERJEE: And the constant equations were the same or not?

DR. RUDLAND: It's all elastic. So, yes. It was the same.

MEMBER BANERJEE: It's all elastic?

DR. RUDLAND: Yes.

MEMBER BANERJEE: All right, growth were all elastic?

DR. RUDLAND: Yes.

MEMBER BANERJEE: And you used the same constant equation?

DR. CSONTOS: Yes.

MEMBER BANERJEE: Why do you expect them to be different?

DR. CSONTOS: The main difference in the --

MEMBER BANERJEE: It's numerically different.

DR. CSONTOS: Again, remember, these are finite elements. So you've got to make some assumptions as the crack breaks through the wall and the behavior after it breaks through the wall and the assumptions that you make.

MEMBER BANERJEE: That's the only difference?

DR. CSONTOS: That's the difference. Yes, that's the main difference. And how you incorporate the residual stresses into the finite element model is the other difference. We didn't necessarily use the exact same curve fits, the exact same procedures and how we incorporated the weld residual stress in the finite element models.

MEMBER ARMIJO: But you can get some very different conclusions if I'm reading this right. Your case 19-1, the DEI calculates for the time, the month, the right-hand columns. They calculated rest and you calculate instability or rupture in a month. That's a big difference.

DR. CSONTOS: That's because you're getting very close to that, when you do a residual stress, the trough and the curve, it depends really on where that trough and that weld residual stress profile ends up. If it's just slightly higher, then you don't get a k of zero and the crack does not arrest. So these are the types of things, that's where actually you're going ahead a couple of slides why we did this validation exercise.

MEMBER ARMIJO: That's a huge, one guy

says, it will arrest. The other one says it is going to break.

DR. CSONTOS: It's because of the weld residual stresses.

DR. RUDLAND: And if you look at the complete, I think there were cases of opposite also where we said that it was going to arrest and they said that it wasn't going to. So it is very sensitive in that region.

DR. CSONTOS: And again, one month is quite a long time. That's 1.2 --

MEMBER ARMIJO: I understand.

DR. CSONTOS: I'll just briefly, we generally had good agreement between the NRC and industry. The biggest difference was this weld residual stress issue. We did 30 cases. You can read those cases. Because of this issue of the weld residual stresses, we did a validation exercise. On the weld residual stress to an EU report from a group over there that was doing a lot, a lot of study on the assessment of dissimilar metal weld integrity. Most of them were AREVA folks who were doing this work.

We dovetailed our modeling efforts to that actual, physical measure values for weld residual stresses and the dissimilar metal weld. They don't have a 82/182 dissimilar metal weld. They have a 309 L dissimilar stainless steel dissimilar metal weld. So it is a little different, but it's the same kind of concept in terms of fabrication effects. These are the results from including all of the EU participants, which you see there. The non-destructive measurement technique was neutron defraction that were done to model this, to measure the weld residual stresses here.

What you see here is the stresses on the actual stresses as a function from the OD to the ID of a pipe from here is the OD, here is the ID, and you can see that our, most of the modeling is fitting along a trend that is fairly good in agreement. Now these, just to let you know, these results, these measurements as you go through the thickness, the neutrons would have had to go from to to the OD to the ID, so that measurements probably better in this area than they are in this area. So that's just an FYI on that.

For the most part, we believe that these are in the --

MEMBER CORRADINI: So whenever you show an experiment, I actually get interested again. So the first three points I think I see what you're saying, so why would the neutron defraction cause essentially it looks like a bump in all the levels of stress up?

DR. CSONTOS: That's an interesting -- I met with the neutron defraction person who did the experimental -- who did this work. And there's a lot of issues with this particular study and the particular through thickness. You have an issue with the flux and a number of neutrons you can use to get your experimental values for the measurement.

He actually had to cut out holes out of the pipe to place the detectors into it and so when I was talking to him, he said that going down to about an inch is about right which is about 25.4 millimeters right there. After that, the neutron flux, the number of neutrons that they were using to calculate the weld residual stresses started getting pretty low.

MEMBER CORRADINI: So you have to count longer?

DR. CSONTOS: Yes, you have to count longer and also this is along the butter and there are issues of calibration as you keep on going down because butter is going along here, on this side and he was trying to get -- and this is where the Wolf Creek -- this is -- there are some results that aren't as nice as this and you can see that in our reports.

But along the butter is where the issue, where we were looking at for Wolf Creek in terms of the cracking and so this is the best one that we looked at. Now when you did that, the butter is at an angle and he has to go in there and he has to tweak the specimen over a little bit. But also, as you go deeper in, you have to get a larger sampling area.

MEMBER CORRADINI: So he's actually smearing what he's measuring?

DR. CSONTOS: Exactly. And so there are all these issues and that's one of the reasons why we're concerned with going to neutron defraction at greater than one inch.

MEMBER CORRADINI: Okay, thank you.

DR. RUDLAND: Quick comment about that. Also, if you look at the experimental results, the stresses don't quite balance through the wall thickness and all the analyses are done axisymetrically, assuming that everything is the same all around the circumference. Well, in reality, they're not. So in that particular case, you can see the stresses are a little high which means someplace else around the circumference are probably a little bit lower.

MEMBER ARMIJO: So you used a residual

stress profile that looks something like this, but the industry's residual stress profile look a lot different?

DR. CSONTOS: Yes, it's in -- if you look at our reports, it's different than this because you have to remember when we're looking at this whole issue here in front of us, there are certain welds in these plants that did this back-chipping. That - -on the ID will not let the crack -- that stress will not go down. It will go pop back up. And so what we see in our analysis is that we start off pencil in the ID. It drops off and then drives back up again on the OD.

So it's slightly different, but we use different residual stresses modeling than they did. And of course, the more I look into the measurement issue of residual stresses, the more I get more concerned with that there it's just as much error or associated with that than it is with the modeling itself. So be careful with these results. In fact, I was told to be careful with these results beyond one inch, by the actual experiments.

So I'll move on. You can read these. Basically, all I want to say is that our confirmatory research program reviewed the industry's work. Our cases that are tied to theirs, in general, show generally good agreement.

MR. SULLIVAN: Okay, there's a regulatory piece that we wanted to talk about also and basically what I wanted to do is try to answer the question how did we come to our decision based on all this information.

And we started out by developing some safety factors. They turned out to be a little different from industry's. We wanted to use the safety factors to address uncertainties in analysis methodology and assumptions, weld residual stress modeling differences and leakage calculations.

Our goals, we didn't say they were hard and fast, but our safety factor goals were to demonstrate a 1.5 factor on stability for a minimum of one week and with a leakage safety factor of five being satisfied during that time.

So I tried to reword that. I knew this would be a little bit of a tricky area. So I put down a second set of wording and that means that one week after the leakage was five times higher than the actual level of the CALs we wanted to still have the stability margin of 1.5 met. So that was another way of saying it.

MEMBER ARMIJO: Now the action level is --

MR. SULLIVAN: It's basically .25 gpm. So the slight difference from industry, they set it at 1 gpm which is a safety factor of 4. It's about the same. When you look at these curves, it's hard to tell the difference between one and a quarter gpm anyway.

And as I just alluded, we didn't really feel we had to show for every single sensitivity case that the safety factors would be met because some of the sensitivity cases don't really reflect realistic or expected conditions and that is what happened.

MEMBER ABDEL-KHALIK: And these leak rate measurements are done in the plant on a daily basis?

MR. SULLIVAN: They're done at least daily based on -- I think the CALs required that they be done daily. A lot of plants did them daily anyway. Not all. I think some plants actually do them more often than daily.

MEMBER MAYNARD: Some actually have an on-line system that is pretty much real time. But as far as for record, they will do it --

MEMBER SIEBER: You got to hold the plant steady for an hour in order to be able to do it the old fashioned way.

VICE CHAIR BONACA: So essentially it

would be 1.25 gpm. So one week after leakage was 1.25 gpm or more.

MR. SULLIVAN: In the analysis time frame. But in terms of the plant and based on the way the CALs were awarded, we would expect a plant to shut down in no more than about five days even at that high leak rate and probably the plant would shut down a lot sooner. That's what we've been seeing. We've been seeing plants shut down that haven't even had through-wall leakage, just to find out what's going on and some of them will shut down within a couple of days if they have this kind of leakage. They're very sensitive.

MEMBER MAYNARD: They also have other mechanisms besides just the leak rate and it does depend on the plant, where they have some of their instrumentation. But you have radiation monitors and you have temperature monitors and in some cases you can tell where the leak may or may not be.

MEMBER SIEBER: It shows up first as radiation, containment radiation.

MR. SULLIVAN: We have talked about this several times before and I think Glenn alluded to the fact that there was a set of base cases that were done. They were based on weld residual stresses calculated by finite element modeling. These calculations were done with and without the effect of the stainless steel safe into pipe weld. Now, that's not the weld we're talking about. That's the next weld outboard. That weld has an effect of, the same kind of effect as you would have by doing what they call a stress improvement operation that tends to make the ID a little bit more compressive.

So a lot of our analysis, we just disregarded that weld even though we knew it was there. I'll talk about this a little bit more in the next slide, but ASME weld residual stresses were also used for smaller nozzles. The base cases reflected a range of nozzle weld safety geometries and fabrication steps. They looked at the range of loads and a range of initial flaw assumptions and all of the base cases resulted in either arrest or hope this wording doesn't cause us problems, but substantial margins satisfying NRC's staff safety goals.

Basically what that meant is a long time, you can operate for a long time before you would start to challenge the stability margin and still have fairly high leakage. That's what that expression means. And as I think you know from previous presentations, the base cases were supplemented by a whole bunch of additional sensitivity studies.

So in the interest of time I could skip over the safety and relief and go right to the surge. That's where the most interest is. That will save up a few minutes. This is where things got a lot more interesting.

I will just say one thing about the safety and relief and spray nozzles and that is that all those cases where they used the calculated weld residual stress, they just got arrest. So what DEI did was they introduced the ASME weld residual stress, which is a more severe condition just to study the problem further. In those cases, they didn't all get arrest, but they didn't reflect what was calculated. I think we all felt that was a good thing to do rather than show the boring results that they all arrested.

It was also an appropriate thing because it reflected the fact that there are uncertainties in weld residual stress modeling. So now I'm going to go to this slide.

DR. CSONTOS: Operationally, we see the cracks about the same depth from our modeling. They are 20 by 33 percent through-wall. So that's where this seems to arrest.

MR. SULLIVAN: I know that we're getting

nervous about the time here. All of the surge line nozzles were done with finite element modeling. The way we addressed the conservatism that we just talked about from the smaller nozzles was we didn't consider the safe end to pipe weld even though that we knew it was there. As I said, all the base cases turned out with good results. All of the cases that were done, even the sensitivity cases that used single flaws like we saw at Wolf Creek, they turned out to have plenty of margin.

So now what I'm going to do is just talk about the limiting cases. In the limiting cases, there was the most unfavorable conditions, of course. The highest plant loading. I'm not going to make any thing out of that. They were the loads that were from a couple of the plants. They weren't artificially boosted up. They were the design loads we got from the plants. They reflected the ID back-chipping and welding, which we've talked about before. That does tend to introduce some tensile residual stresses on the ID. That actually was part of fabrication of five of the nine plants. The next bullet that I just said and the last condition was a 360 degree ten percent initial flaw, a fairly severe initial condition. That was the starting flaw. That resulted in essentially no margin, which is a case that I think we talked about a few minutes ago.

So we wanted to address that, of course, because that wasn't very good result. We looked at it, instead of trying to attack or whatever any of those initial conditions, we thought, well, we'll go to the methodology and just see what conservatisms are there that we think might be reasonable to look at.

The first conservatism that we looked at was the one that Glenn talked about having to do with what, I'm not sure he used the term knock-down factor, but I'll use the term knock-down factor to account for the drop in secondary pipe thermal loads with crack face rotation. And then we also used a more neutral assumption in terms of load stress by considering that the flaw is in the middle of the weld. We still think that is conservative because what we've seen is that the flaws tend to be towards the butter.

And this turned out leaving acceptable margins, if you will, or satisfied the safety factors that the staff came up with.

And then we looked at one more case. We thought if it was appropriate to look at the knock down factors, then we should probably look at limiting thermal loads, so we did that. All of the assumptions were the same then. We looked at the five plants, the limiting case of the five plants with the back chipping and the rewelding, the weld residual stress. Without that safe bend, to pipe weld, the same 360 degree, 10 percent initial flaw, the knock down factor, and the different flow stress. This resulted in a margin close to 1.5. As I say, they were about 10 percent lower. We thought that that was okay. It was pretty close to what we were setting as a goal and we do consider that 360, 10 percent initial flaw to be somewhat conservative.

So we considered that these results were acceptable and then the last slide is really just a conclusion slide which gets to the point of the whole exercise which was that after we finished reviewing these results, including our own results of course, which I've talked about a lot, and starting to write up the safety evaluation and finished our thought process on it, we thought it was reasonable to allow the nine plants to continue to operate until their outages in the spring which is what industry had requested.

VICE CHAIR BONACA: You speak of adequate margins. Yes. Compared to the criteria that you are using at the beginning, the one that --

MR. SULLIVAN: Right, the first slide.

VICE CHAIR BONACA: The first slide. Would you comment there on the margin?

MR. SULLIVAN: For which case?

VICE CHAIR BONACA: Well, I mean that presents for the surge line.

MR. SULLIVAN: For the surge line, I basically talked in some detail about two cases and I didn't give any numbers, you're right.

VICE CHAIR BONACA: Yes.

MR. SULLIVAN: For the surge line case where we looked at the plant with the maximum normal loads which was about three slides in from the end, we got approximately 1.57 when the leakage was just high enough to be about 1.25 leakage. In other words, when the leakage did increase enough to satisfy the safety factor of five that we were looking for, the stability margin was 1.57. Within a week, it had dropped to about 1.5.

So we considered that that fully met the margins or the safety factor goals that we were looking for.

On the next case that I talked about which had to do with including the limiting thermal loads, the margin when leakage got to 1.25 gpm was about 1.35

which is, like I said, about 10 percent less than 1.5. And within a week, it hadn't changed much. That curve is fairly flat. That -- I could show you that later if you want because I brought over Dave's report.

VICE CHAIR BONACA: I just want a sense of the margin that you gave to me.

MR. SULLIVAN: Yes.

MEMBER ABDEL-KHALIK: let's say that somebody comes to you in the spring of '08 and says well, gee, the analysis shows we have plenty of margin and we're continuing this enhanced leakage detection and for some reason or another I really can't do it this outage. Would you entertain that at all?

MR. SULLIVAN: I don't think we could. From a technical point of view, I would have a hard time answering why we sort of open the door on this occasion, but we wouldn't continue to open the door for your hypothetical question.

I don't think management is particularly disposed to a favorable answer to the type of question that you're asking. I think in part, it's because these are analyses. There's a lot of work that we've acknowledged, particularly in the technical report that EMC^2 wrote which is attached that shows a lot of the limitations of the technology. We've talked about a lot of them today, a lot of work still needs to be done, the validation work. And so we don't really want to try to stretch this any further than we think we already have.

MEMBER ABDEL-KHALIK: I appreciate the unambiguous answer.

(Laughter.)

MR. SULLIVAN: We have talked about this with industry. We talked about some similar questions at our meeting on August 20th. I think that there's an increased awareness that the NRC staff is sensitive to deviations taken from the industry's initiative schedule and I think industry is probably going to be more reluctant to take deviations.

I don't know if anybody here can really speak to that because we don't really have utility people, but the sense I've gotten from talking to some of the industry folks is that industry is probably going to be a bit more cautious about taking deviations from the schedules that they've laid out in MRP 139. Maybe I shouldn't go down that path because I'm speaking for industry, but --

VICE CHAIR BONACA: I would say that it would be speculative at this point.

MR. SULLIVAN: Yes.

VICE CHAIR BONACA: I would rather not --

MEMBER ABDEL-KHALIK: I was looking for a clear, unambiguous answer and I got it.

MR. SULLIVAN: Maybe Jim Riley may want to add or disagree.

MR. RILEY: This is Jim Riley. I wouldn't disagree with you, Ted.

I am not sure whether you guys are familiar or at all with the deviation process, but I'll say this going in, obviously, this whole issue is extremely sensitive to the industry. And I think deviating at this point probably would be a surprise to many of us.

There's some pretty, we think, good controls over how these deviations occur and how they're approved and how they're reviewed and how they're communicated and all that. In fact, we're going back and looking at that whole process once again for the second time in little over a year to make sure that it is doing what it needs to do and has the controls in it that it needs to have and I'll go into the details then if you want me to.

But an answer to Ted's question directly, I don't think there's been anything that's been put out there that says you can't deviate. But there is certainly a lot of sensitivity to this issue and like I said I would be surprised if anybody tried to deviate you further from your schedules.

MEMBER MAYNARD: I think Said's question was pointed to this specific item that we're dealing with here throughout the entire MRP program. I would be surprised if anybody came in and --

DR. CSONTOS: It is somewhat hard to --

(Simultaneous speakers.)

VICE CHAIR BONACA: The other thing is that this would really be management's decision to the point that our discussion here is highly speculative about what path that would take and certainly it is also speculative about what ACRS would suggest I mean based on what we have seen.

DR. CSONTOS: I want to just offer myself up here. If you have more questions about this, I am available all day tomorrow if you want to. It's really hard to consolidate six months worth of work into ten minutes of slides. So I can answer some of your questions if you need to.

MEMBER MAYNARD: Well, I appreciate all the work that has been done in this area. I think that's good. I don't believe that we should rely totally on this as any justification for how long we take to do so. There's other defense-in-depth measures and I think that one of the main things we need to feel comfortable with is that even if we were wrong on all of this and something did happen, are we still in an analyzed condition or do we create an analyzed accident or an analyzed situation. I kind of hate to make the whole decision based upon a calculation that says it can't happen or it won't happen. I think we need to go to the next step and say what if it did and does that put us outside of an analyzed --

MEMBER SIEBER: We're clearly in an analyzed condition. The problem is the condition that's analyzed, it's pretty severe.

MEMBER ARMIJO: Yes, you'd have a LOCA. Medium --

VICE CHAIR BONACA: Even if it isn't alive --

MEMBER SIEBER: It doesn't represent a risk to the public, but it certainly represents an economic loss to the owner/operator.

MEMBER MAYNARD: We need to make sure that it remains that as opposed to --

MEMBER SIEBER: You put all these margins and conservatisms and you have leak rate and radiation detection and all these other factors as the early warning that you've got to do something and that's no different than if you didn't know there was a flaw there.

MEMBER MAYNARD: Right.

MEMBER SIEBER: You're still relying on the same mechanism.

MEMBER MAYNARD: But sometimes you find something that you had never anticipated that you find out may or may not create a situation that wasn't analyzed. I don't think this does that. I think it keeps it within the analyzed.

VICE CHAIR BONACA: The fact that I have an analysis for a LOCA doesn't give me any comfort on a LOCA. I mean, I certainly don't want to get there. I mean, I think that's what we're trying to do. I think I actually I get some comfort from the fact that, you know, the early evaluations of the NRC was that there was no margin and you would go from not knowing anything about it to a break.

DR. CSONTOS: We have learned a lot in this process.

VICE CHAIR BONACA: That's right. I think it's convincing to me that you have learned something in between. I mean, there is some margin. And again, I am confident with the responsiveness of the units, I'm sure, that if there is a leakage of half a gpm they shut down. So that gives me the comfort --

DR. CSONTOS: I mean, we've gone from an unanalyzed situation -- the analyzed situation before this all got started was six to one ratio. What we found at Wolf Creek was 21 to 1. We analyzed it. We analyzed the first time. We got bad answers. We reduced the conservatisms and we reduced the uncertainties, but we kept a lot of conservatisms on this phase two work. We evaluated a lot of parameters to understand sensitivity, understand conservatisms, and you see there the base cases with the most realistic conditions with the 21 to 1 flaw and we use a 360 ten percent flaw. We showed safe margins.

VICE CHAIR BONACA: Good, I am going to wrap up now. Any additional questions --

MEMBER POWERS: What is the longest time that we're delaying action based on the --

MR. SULLIVAN: The longest time is about five months, and that means that the way the confirmatory action letters were written, I'm not sure if this is the answer to your question, but the way the confirmatory action letters were written was that we wanted plants to shut down to the end of 2007. So with these results and with the allowance that these plants could continue to operate until the spring, the longest time is to something like the end of May with sort of a schedule that falls out probably, you know, some in February, March, April, and May.

MEMBER POWERS: And we have no hierarchy of plants? You did not talk about any plant being particularly susceptible to this?

MEMBER SIEBER: Don't have the data.

MR. SULLIVAN: What industry did in the report is they labeled the plants by letters. So we really didn't get into which plant was which. Certainly that information is considered proprietary by industry, which plant is which because of plant specific information that is in the report, if it were disclosed which plant were which.

DR. CSONTOS: And those plants that have the back-shipping process are the plants, there's four of them with the surge nozzle. There are five of them. One of them has already been overlaid. So there are only four plants out of the nine that have that concern of an access of weld residual stress that drives a crack to this kind a of a potential situation. So those are the ones that I think are or the ones that we are the most concerned about.

VICE CHAIR BONACA: Thank you very much. With that, we will take a break until a quarter of four. Please come back at quarter of four so we can start and we can talk about the research report.

(Whereupon, at 3:29 p.m., the meeting was concluded.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Charles Morrison
Official Reporter
Neal R. Gross & Co., Inc.

Advanced Finite Element Analyses of Pressurizer Nozzle Weld Flaws: NRC Confirmatory Program

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Al Csontos, Ph.D
October 4, 2007

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Advanced FEA Project: Chronology

NRC Scoping Study

- WC Indications Reported to NRC
- NRC Scoping Study Initiated
- MRP 2006-041 Submitted to NRC
- Public Meeting: Implications of WC Indications
- NRC Scoping Study Completed
- Public Meeting: NRC Scoping Study
- Industry Evaluates NRC Scoping Study
- Public Meeting: NRC Safety Concerns

Phase I Analyses

- MRP 2007-003 Submitted to NRC
- Industry Proposes Advanced FEA Project
- Industry Advanced FEA Project Initiated
- NRC Advanced FEA Confirmatory Project Initiated
- Confirmatory Action Letters Submitted to NRC
- NRC Comments to Industry's Advanced FEA Project
- ACRS Meeting: NRC Scoping Study & MRP Evaluations
- Public Meeting: Advanced FEA Project Outline
- Public Meeting: Phase I Results

Phase II Analyses

- Public Meeting: Fabrication & WRS
- Public Meeting: Phase II Proposed Matrix Cases
- Public Meeting: Resolve Technical Issues & Updates
- Public Meeting: Project Updates & Phase II Results
- ACRS Meeting on Phase I & II Results
- Public Meeting: NRC Initial Comments on Industry Report
- Public Meeting: NRC Final Comments on Industry Report
- Public Meeting: Summary of Advanced FEA Projects

Oct-06 | Nov-06 | Dec-06 | Jan-07 | Feb-07 | Mar-07 | Apr-07 | May-07 | Jun-07 | Jul-07 | Aug-07

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Advanced FEA Project: Phase II Safety/Relief Results

Case #	DEI Case #	Time at first leakage (yr)		Margin at 1gpm leak		Time since 1gpm leak to 1.2 margin (Month)	
		DEI	Emc2	DEI	Emc2	DEI	Emc2
1	1c	17.4	20.16	2.24	2.46	3.63	2.18
1-1	1b	Arrest	Arrest	Arrest	Arrest	Arrest	Arrest
3	3c	26.3	29.40	2.40	2.55	4.17	2.42
6	6c	3.4	4.13	1.70	1.79	1.37	1.13
6-4	35c	2.9	3.26	1.62	1.81	1.07	0.70
9-1	9c	32.2	119.18	2.50	2.50	4.80	2.90

- In addition to the Phase I relief line results, the Phase II results for the safety/relief lines confirm the industry results that margins exist between leak and rupture

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Advanced FEA Project: Phase II Spray Line Results

Case #	DEI Case #	Time at first leakage (yr)		Margin at 1gpm leak		Time since 1gpm leak to 1.2 margin (Month)	
		DEI	Emc2	DEI	Emc2	DEI	Emc2
10	10c	21.2	51.36	2.07	2.48	2.43	1.85
11-1	11c	25.3	Arrest	2.08	Arrest	2.43	Arrest
15	15c	Arrest	Arrest	Arrest	Arrest	Arrest	Arrest

- Phase II results for the spray lines confirm the industry results that margins exist between leak and rupture
- Results also indicate significantly long times for leakage to occur or complete crack arrest

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Advanced FEA Project: Phase II Surge Line Results

Case #	DEI Case #	Time at first leakage (yr)		Margin at 1gpm leak		Time since 1gpm leak to 1.2 margin (Month)	
		DEI	Emc2	DEI	Emc2	DEI	Emc2
17-1	S1b	1.2	1.30	1.03	1.00	0.00	0.00
17-2	17b	1.2	1.36	1.71	1.80	1.17	N/A
17-8	17a	Arrest	6.15	Arrest	1.58	Arrest	N/A
19-1	19b	Arrest	9.50	Arrest	1.58	Arrest	1.18
20	20b	Arrest	Arrest	Arrest	Arrest	Arrest	Arrest
17-11	25b	0.50	0.86	1.36	1.37	0.43	0.31

- Surge lines results confirm industry results for cases 17-1/S1b, 17-2/17b, 20/20b, and 17-11/25b
- Some divergence occurred for cases 17-8/17a & 19-1/19b, but, substantial margins exist

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Advanced FEA Project: Phase II Results

- Generally good agreement between the NRC and industry advanced FEA benchmarked cases
- Of the 30 cases in the NRC confirmatory program:
  - All 11 safety/relief cases showed either arrest or substantial margin between leakage and rupture
  - 3 out of 4 spray cases showed crack arrest with the final case predicting >50 years to leakage with substantial margins between leakage and rupture
  - 9 out of 15 surge line cases show either arrest or adequate margin between leakage and rupture
  - 6 out of 15 surge line cases show little margin due to multiple conservatisms used in the analysis

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Advanced FEA Project: WRS Validation

- NRC & industry conducted a weld residual stress (WRS) validation exercise since the Phase II results were most affected by the assumed WRS profiles
- NRC & industry WRS models were validated to the European Union Network for Evaluating Structural Components-III round robin study on the assessment of dissimilar weld integrity
- NRC & industry WRS models were validated to physical measurements of dissimilar metal butt welds
- WRS benchmarking showed generally good agreement between the NRC and industry models

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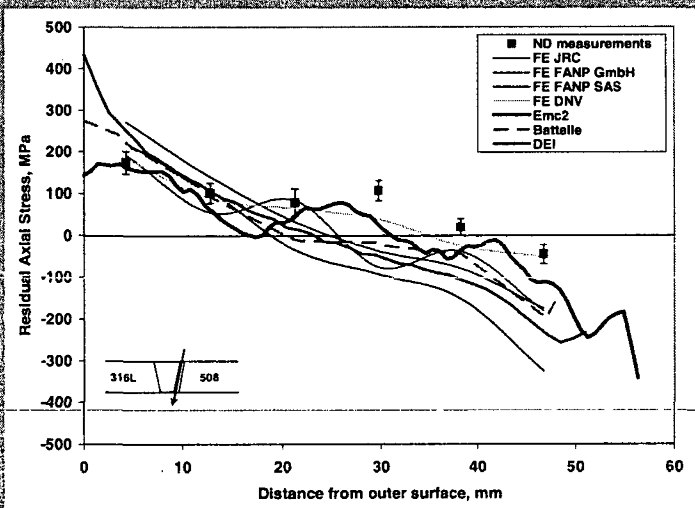
Advanced FEA Project: WRS Validation



Confirmatory Project Summary

- NRC confirmatory program developed to benchmark, verify, and evaluate industry's analyses and results
- Unlike the NRC Wolf Creek scoping study, Phase I results predict margins between leak and rupture
- Phase I & II results show good agreement between the industry & NRC advanced FEA model results
- Validation effort provided useful information for understanding the uncertainties in WRS distributions

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Advanced FEA Safety Assessment

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Ted Sullivan (NRR)
October 4, 2007

Safety Factors

- Safety factors (SFs) were used to cover uncertainties in the:
  - Fracture mechanics methodology and analytical assumptions
  - WRS caused by FE modeling differences
  - Leakage calculations
- NRC staff's goal was to satisfy SFs of:
  - 1.5 on stability for a minimum of 1 week and 5 on leakage
  - that is, 1 week after leakage was 5 X higher than action level of CALs, stability margin of 1.5 is to be met
- Staff did not consider it necessary to satisfy these SFs for sensitivity cases with highly conservative assumptions
  - Not all sensitivity cases reflect realistic or expected conditions

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Base Cases

- Base cases reflect:
  - WRSs calculated by finite element modeling for safety/relief and surge nozzles with and without effect of the stainless steel safe end to pipe weld
  - ASME WRS for safety/relief and spray
  - Nozzle, weld, safe end geometries and fabrication steps
  - Range of Loads
  - Range of initial flaw assumptions
- All base cases either resulted in crack arrest or substantial margin satisfying NRC staff SF goals
- Base cases supplemented by additional sensitivity cases to study additional conditions and assumptions

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Safety/Relief Nozzle Welds

- All cases with WRS calculated by finite element modeling with or without safe end to pipe weld resulted in crack arrest
- ASME WRS introduced to provide through wall crack results
  - conservatively addresses uncertainties in calculated WRSs
- DEI ran 12 sensitivity cases and Emc² ran 3 cases
  - Results of all cases satisfy staff SF goals except case DEI 42c

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Safety/Relief Nozzle Welds

- Limiting safety/relief nozzle case 42c:
  - Crack growth rate assumption is highly conservative for majority of crack growth
  - Stability SF falls below 1.5 within a couple of days of leakage SF being satisfied
- All cases with MRP-115 CGRs result in either arrest or satisfying NRC staff SF goals
- Staff concluded that analyses demonstrate reasonable assurance of safety

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Spray Nozzle Welds

- WRSs from safety/relief welds used for spray welds
  - Spray nozzle welds have configurations similar to safety/relief
- DEI and Emc^2 spray nozzle weld cases resulted in either arrest or substantial margin satisfying staff SF goals
- Staff concluded that analyses demonstrate reasonable assurance of safety

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Surge Nozzle Welds

- WRSs calculated by finite element modeling
- DEI & Emc^2 both ran numerous surge nozzle sensitivity cases
  - Majority of cases show either arrest or adequate margin between leakage and rupture
  - All cases with Wolf Creek-like flaws resulted in arrest or adequate margins
- Limiting cases combined most unfavorable conditions
  - Highest plant loading
  - ID back-chipping and welding
  - WRS from model without safe end weld even though weld is present – addresses uncertainties in calculated WRSs
  - 360° 10% initial flaw
- Limiting cases with these assumptions resulted in stability SF at first leakage of slightly larger than 1

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Surge Nozzle Welds

- Staff approach for assessing this limiting case retained previously stated assumptions but accounted for certain conservatisms in the analysis methodology
- Emc[2] case 17-10 was run with
  - A knock down factor of 0.6 (based on industry analyses) to account for drop in secondary pipe thermal loads with rotation of the crack and
  - Flow stress based on the more neutral assumption of a crack in the middle of the weld rather than close to the safe end
- Results of this analysis satisfied staff SF goals

Surge Nozzle Welds

- Staff also ran a sensitivity case with limiting thermal loads
  - ID back-chipping and welding
  - WRS of model without safe end weld
  - 360° 10% initial flaw
  - Knock down factor of 0.6 on secondary pipe thermal loads after crack leakage, and
  - Flow stress based on crack in middle of weld
- Results of this case were ~10% lower than SF goals
  - Staff considered results acceptable because of conservative initial flaw assumption
- Staff concluded that analyses demonstrate reasonable assurance of safety

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Advanced FEA Project: Summary

- Staff's evaluation of all sensitivity cases showed adequate margins between leak and rupture:
  - Majority of cases show either crack arrest or large margins
  - Balance of cases have adequate margins when conservatisms are considered
- Advanced FEA provided reasonable assurance that the 9 plants will continue to safely operate past the 12/31/07 industry imposed deadline to the next refueling outages in Spring 2008

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Pressurizer Nozzle Dissimilar Metal Weld Advanced Finite Element Analyses

ACRS Main Committee
October 4, 2007

Glenn White
Dominion Engineering, Inc.

Topics

- Objective and Approach
- Summary of Methodology
  - Plant Inputs
  - Welding Residual Stress
  - Crack Growth Modeling
  - Critical Crack Size Calculations
  - Leak Rate Modeling
- Analytical Results
- Conclusions

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Project Objective

- To evaluate the viability of detection of leakage from a through wall flaw to preclude the potential for rupture of pressurizer nozzle DM welds, given the potential concern about growing circumferential stress corrosion cracks.
- This study is specific to the group of nine PWRs originally scheduled for performance demonstration initiative (PDI) inspection or mitigation during the spring 2008 outage season.
- Commitments were made for these nine PWRs to accelerate refueling outages or take mid-cycle outages. These plants have now resumed plans to perform PDI inspection or mitigation during the spring 2008 outage season given NRC's conclusion regarding its review of the industry evaluations and its confirmatory analyses.

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Project Oversight

- Project Team
  - Dominion Engineering (DEI)
  - Quest Reliability – (FEACrack Software Developer)
- Expert Panel
  - Established to provide review, input, and oversight of the technical issues and approaches
  - Members well known in this industry were chosen
    - Ted Anderson, Quest Reliability, LLC
    - Warren Bamford, Westinghouse
    - Doug Killian, AREVA
    - Ken Yoon, AREVA
    - Pete Riccardella, Structural Integrity Associates
    - David Harris, Structural Integrity Associates
      - included specifically for his lack of recent involvement in Alloy 600 fracture mechanics applications to bring a fresh perspective
- Interacted with NRC Counterparts in ~7 NRC public meetings

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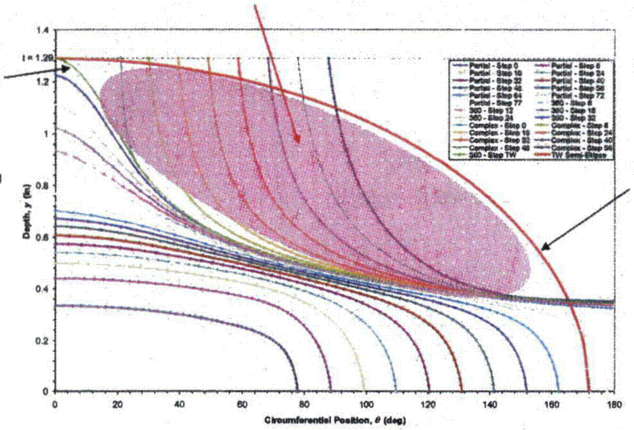
Project Approach
Artificial Conservatism of Semi-Elliptical Crack Assumption

Semi-ellipse assumption over predicted extent of cracked material in this zone vs. the arbitrary shape methodology for the Wolf Creek nozzle benchmark run

Arbitrary Crack Shape at Initial Through Wall

Growth at each point on the crack front as a function of the stress intensity factor calculated at that point



Semi-Ellipse Crack Shape at Initial Through Wall

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Project Approach
Key Project Activities

- Software capability development within FEACrack
- Develop and execute an analysis parametric sensitivity case matrix
  - Develop and apply a sensitivity matrix of welding residual stress (WRS) profiles, including weld repairs
  - Crack growth calculations for custom crack shape
- Critical crack size calculations to define the end point for the crack growth calculation
- Leak rate calculations - PICEP and SQUIRT models
- Software verification and benchmarking
- Validation
- Expert panel input and review throughout the project

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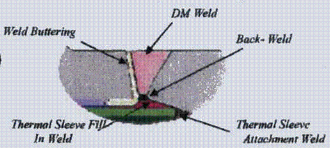
Plant Inputs
Weld Fabrication → Welding Residual Stresses

- Input obtained from design drawings & shop travelers
- Fabrication Steps affecting weld residual stress (WRS)
  - Fill-In Weld under thermal sleeve (Surge)
  - Fillet Welds (Safety/Relief)
  - Stainless steel field weld to pipe



- Repairs
  - Deep ID Repairs
- Either thermal strain applied to simulate WRS profile or WRS FEA results directly input to crack growth model

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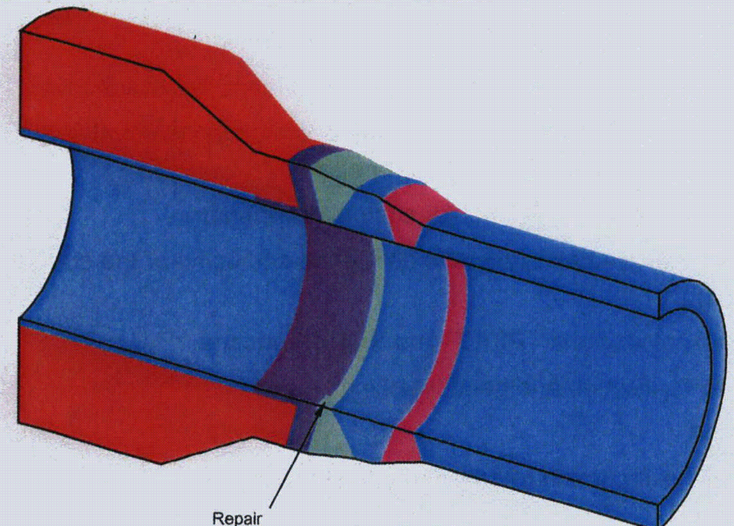
WRS Modeling
Safety/Relief Nozzle 3D Repair Model Geometry



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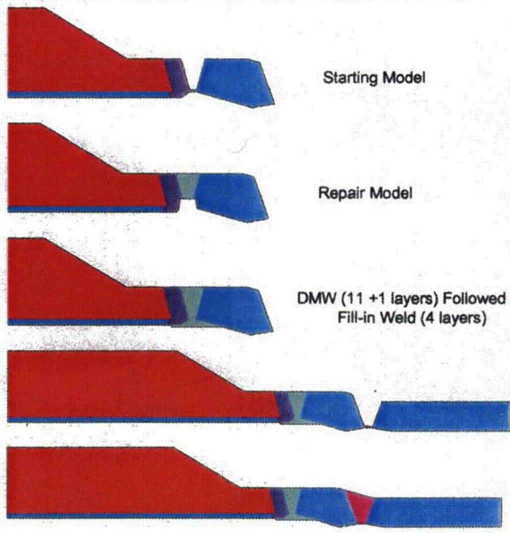
WRS Modeling

Type 8 Surge Nozzle Analysis Progression



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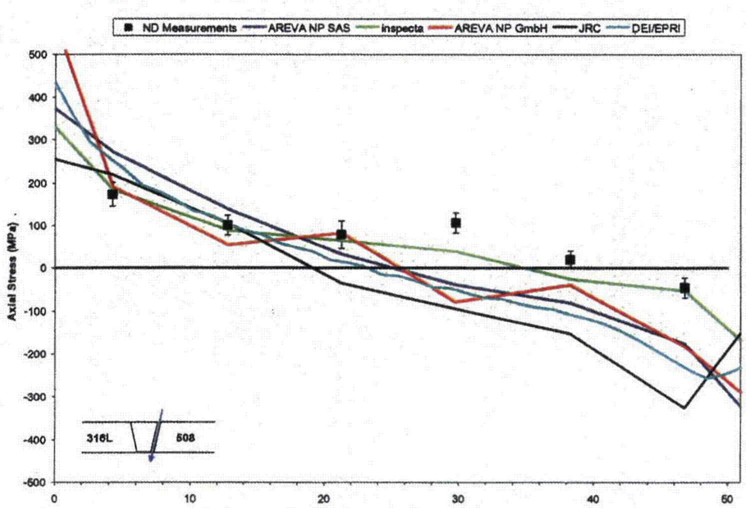
WRS Validation and Benchmarking

EU Mockup—DEI Butter Axial Stress
(Through-Wall Section at Butter Layer Center)



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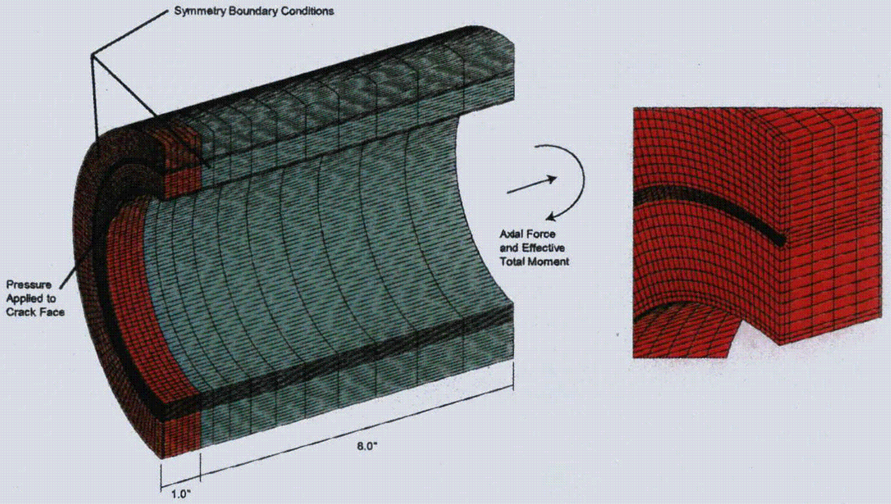
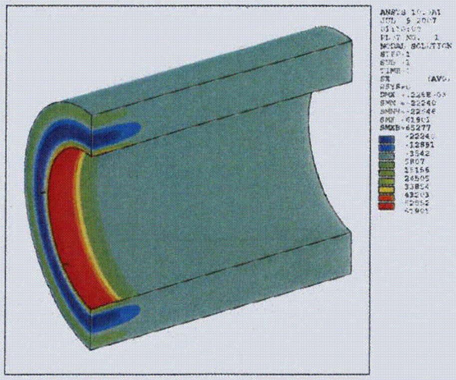
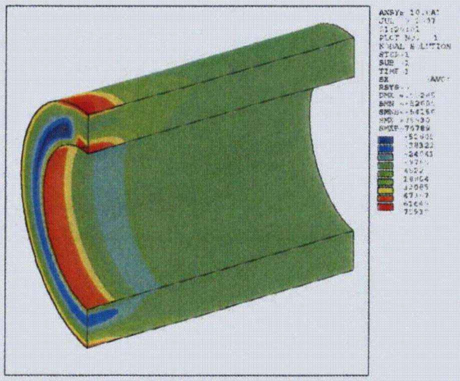
Crack Growth Modeling Approach
Cylindrical Model



Crack Growth Modeling Approach
Cylindrical Model: Temperature Simulation of WRS



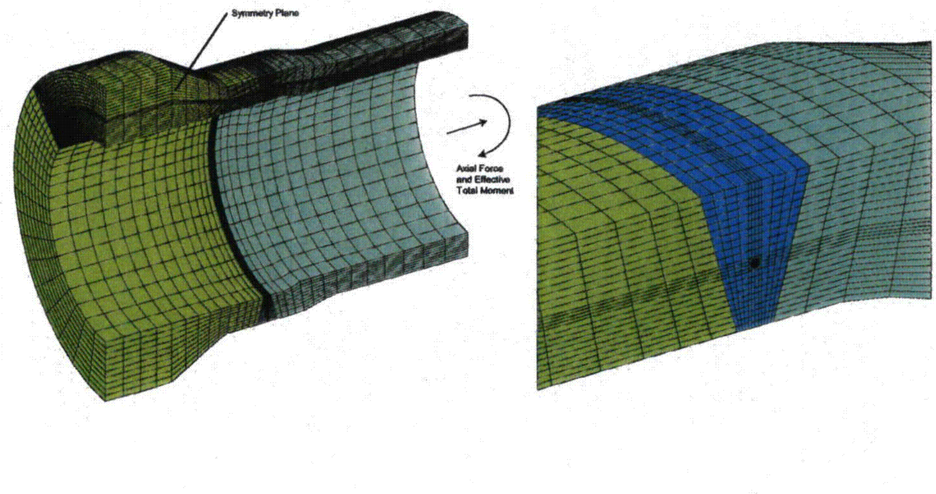
Example of Axisymmetric WRS Simulation



Example of Circumferentially Varying WRS Simulation

Crack Growth Modeling Approach

Nozzle-to-Safe-End Model (Type 8 Surge Nozzle)



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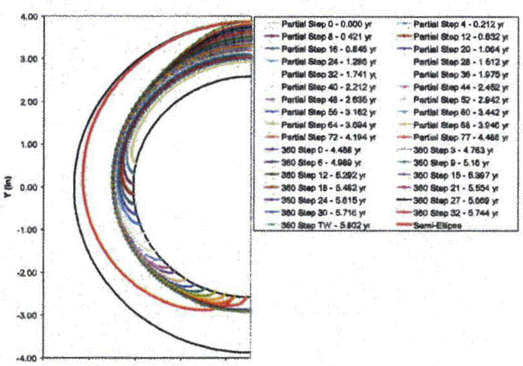
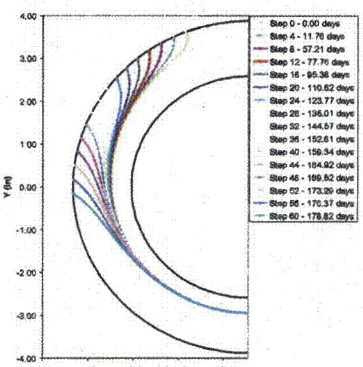
Phase I Crack Growth Calculations

Results for WC Relief Nozzle (December 2006 Inputs)



Surface Crack Progression



Complex Crack Progression

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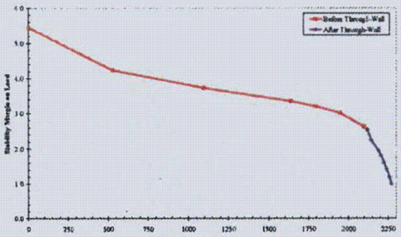
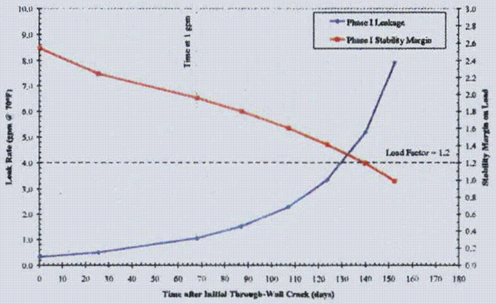
Phase I Crack Growth Calculations

Crack Stability and Leak Rate Results



Complete Crack Stability Development

Stability and Leak Rate Trends for Complex Crack



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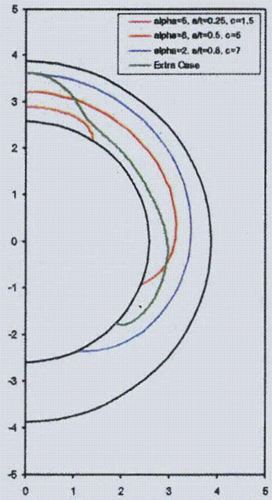
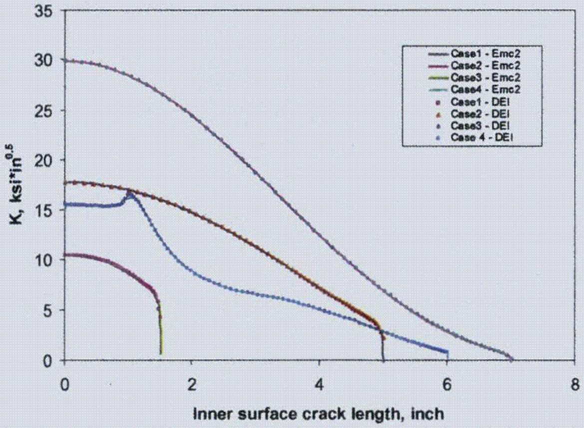
Stress Intensity Factor Verification

Comparison of DEI and EMC2 Results for Analytical Cracks



Assumed Nonstandard Crack Profiles



Comparison of DEI and EMC2 Results Showing Close Agreement Using Independent Software Models

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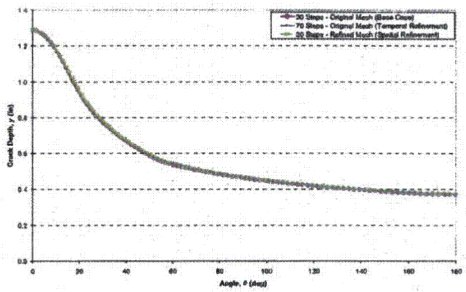
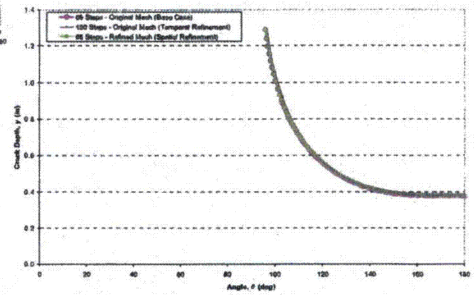
Crack Growth Convergence Checks

Temporal and Spatial Checks Demonstrating Convergence



Surface Crack Growth Progression Starting from Identical Initial Surface Flaw (Case 1c)

Complex Crack Growth Progression Starting from Identical Initial Complex Flaw (Case 1c)



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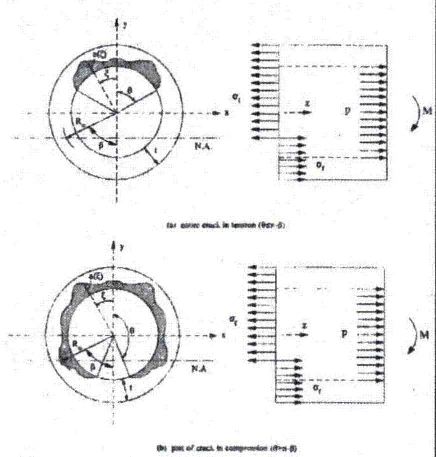
Critical Crack Size Calculations

Force and Moment Equilibrium for Arbitrary Crack

- Rahman and Wilkowski have published the thin-wall solution for axial force and applied moment equilibrium given a circumferential flaw with arbitrary depth profile
- DEI implemented this solution in spreadsheet form
- The solution was applied to crack profiles calculated by the FEACrack software
  - Case 1: Entire crack in tension
  - Case 2a: Part of crack in compression zone with crack taking compression
  - Case 2b: Part of crack in compression zone with crack not taking compression
- Arbitrary Net Section Collapse (ANSC) software by Structural Integrity Associates used to validate spreadsheet calculation
  - ANSC also allows arbitrary moment direction, unlike Rahman and Wilkowski



S. Rahman and G. Wilkowski, "Net-Section-Collapse Analysis of Circumferentially Cracked Cylinders—Part I: Arbitrary-Shaped Cracks and Generalized Equations," *Engineering Fracture Mechanics*, Vol. 61, pp. 191-211, 1998.

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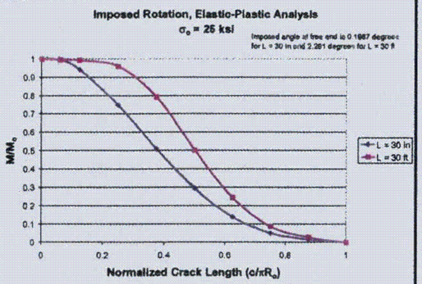
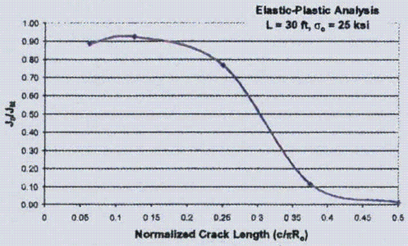
Critical Crack Size Calculations

Reduction of Secondary Load with Crack Extension

- Appendix B presents piping models developed for the surge lines of two representative plants to evaluate the maximum capacity of the secondary loads to produce rotation at a cracked surge nozzle, relative to the rotational tolerance of a nozzle weld containing a large complex crack
- Appendix C describes elastic and elastic-plastic finite element analyses of a pipe with an idealized through-thickness crack that were used to determine the effect on bending moment and crack driving force due to an imposed end rotation
  - Because of the finite amount of strain imposed by the rotation, the results (at right) show that the moment knock-down factor and crack driving force relative to the load controlled case decrease significantly as the crack length increases





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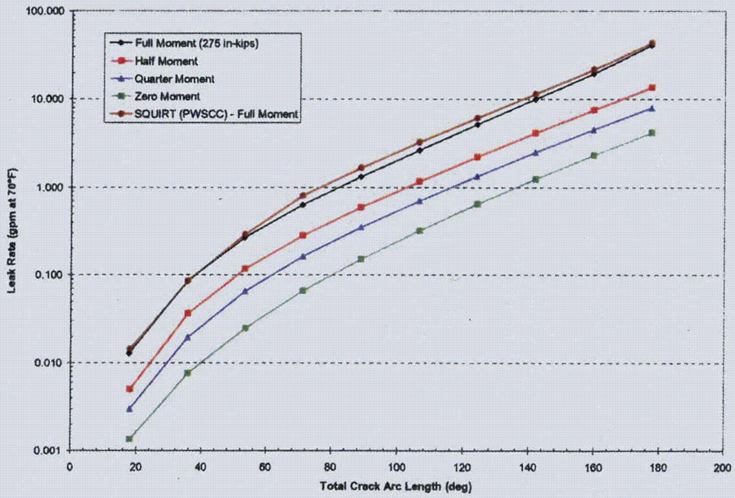
Leak Rate Modeling

Scoping Results Based on WC Relief Nozzle DM Weld Dimensions and COD Calculated by PICEP and SQUIRT



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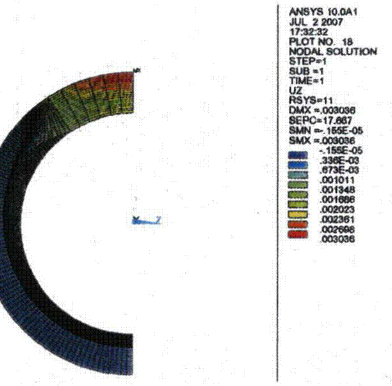
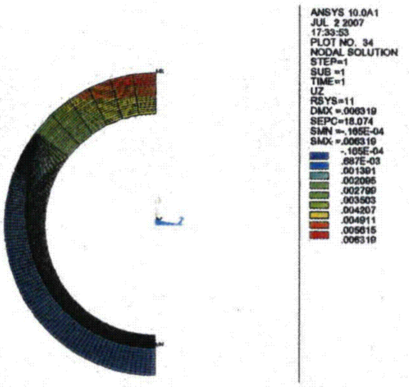
Leak Rate Modeling

Example Crack Opening Displacements (Half COD)



Case 12 – 1 gpm leak rate



Case 12 – Stability Load Margin Factor = 1.2

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Analysis Case Matrix

Evaluation Criteria

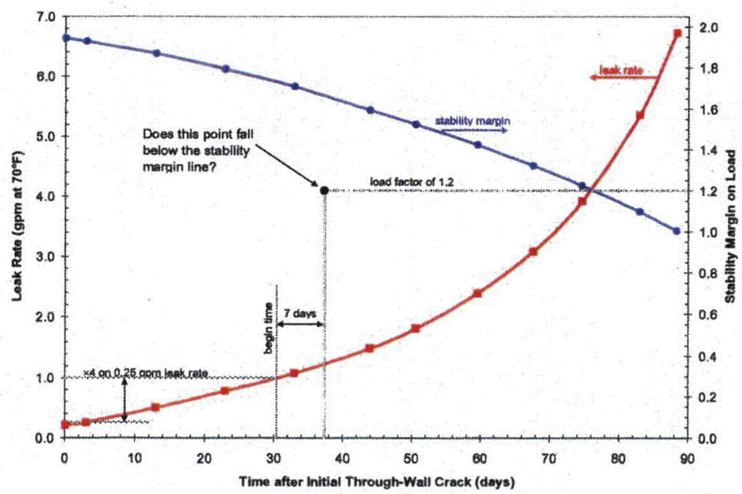

Illustration of Approach for Hypothetical Leakage and Stability Data

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Analysis Case Matrix
Sensitivity Parameters

- Fracture Mechanics Model Type
  - Cylindrical
  - Nozzle-to-Safe-End
- Plant Specific Geometries
- Plant Specific Piping Loads
- Welding Residual Stresses
  - Axisymmetric
  - ID Weld Repair
- Crack Growth Rate Equation
- Initial Flaw Geometry
- Effect of Multiple Crack Initiation Sites

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Analysis Case Matrix
Effect of Multiple Crack Initiation Sites

- Sensitivity cases investigate the effect of multiple crack initiation (e.g., Wolf Creek surge nozzle NDE results)
  - Enveloping of multiple initial flaws with one modeled flaw
  - Modeling of a part-depth 360° flaw
  - Growing multiple individual flaws and then combining on a single weld cross section for stability calculation

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Analysis Case Matrix
Definition of Case Matrix

- Up to three WRS profiles applied to each case
  - Geometry and load base cases (1-20)
    - Axisymmetric WRS
    - Moment load varied up to maximum reported for specific configuration
  - ID repair base cases (21-26)
    - Non-axisymmetric WRS based on ID repair WRS FEA
  - Further bending moment sensitivity cases (27-30)
  - Sensitivity cases to investigate potential uncertainty in as-built dimensions (31-32)
    - Hypothetical ±10% variation in weld thickness
  - Axial membrane load sensitivity cases (33-34)
    - Relatively narrow range in membrane load for each geometry
  - Effect of length over which thermal strain simulating WRS is applied (35)

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Analysis Case Matrix
Definition of Case Matrix (cont'd)

- Simulation of elastic-plastic redistribution of stress at ID (36)
- Effect of initial crack shape and depth (37-41)
- Effect of stress intensity factor dependence of crack growth rate equation (42-47)
  - 5th percentile exponent of 1.0 or 95th percentile exponent of 2.2 assumed
- Effect of pressure drop along leaking crack (48)
  - Other cases assume full primary pressure applies to leaking crack face
- Effect of relaxation of normal operating thermal load (49-51)
  - For through-wall portion of crack growth progression, the normal thermal load has been eliminated for these sensitivity cases (for crack growth, leak rate, and critical crack size calculations)
- Effect of nozzle-to-safe-end crack growth model vs. standard cylindrical crack growth model (52-53)
  - Investigate effect of detailed geometry
- Supplementary cases specific to effect of multiple flaws on limiting surge nozzles (S1-S9)

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Matrix Results
Sensitivity Summary

Case #	WRS Subcase	Base Case	Qualitative Sensitivity Description	Quantitative Sensitivity Description	Result Comparison: Time Interval from 1 gpm to a Stability Margin Factor of 1.2 [days] from	to	Stability Margin Factor at 1 gpm (or at initial leak rate if higher) from	to	Calculated Leak Rate (at 70°F) at a Stability Margin Factor of 1.2 [gpm] from	to
2	c	1c	Case 1c with intermediate bending moment	Pb from 5.71 ksi to 5.30 ksi	109	118	2.24	2.31	5.81	5.89
3	c	1c	Case 1c with low bending moment	Pb from 5.71 ksi to 4.88 ksi	109	125	2.24	2.40	5.81	6.22
5	c	4c	Case 4c with low bending moment	Pb from 5.74 ksi to 4.88 ksi	112	137	2.18	2.35	5.22	5.81
7	c	6c	Case 6c with low bending moment	Pb from 7.63 ksi to 4.78 ksi	41	71	1.70	2.01	4.04	5.44
9	c	8c	Case 8c with low bending moment	Pb from 6.70 ksi to 4.88 ksi	99	144	2.14	2.50	5.56	8.56
11	c	10c	Case 10c with low bending moment	Pb from 4.89 ksi to 4.50 ksi	73	73	2.07	2.08	3.81	3.70
13	c	12c	Case 12c with low bending moment	Pb from 4.76 ksi to 4.13 ksi	48	54	1.88	1.94	3.54	3.49
16	c	15c	Case 15c with low bending moment	Pb from 4.65 ksi to 4.13 ksi	arrest	arrest	arrest	arrest	arrest	arrest
17	b	17a	Case 17a with shifted weld residual stress	WRS from w/ SS weld to w/o SS weld	arrest	35	arrest	1.71	arrest	69.28
18	a	17a	Case 17a with low bending moment	Pb from 13.57 ksi to 4.88 ksi	arrest	arrest	arrest	arrest	arrest	arrest
18	b	17b	Case 17b with low bending moment	Pb from 13.57 ksi to 4.88 ksi	35	43	1.71	1.79	69.28	15.79
20	b	19b	Case 19b with low bending moment	Pb from 14.55 ksi to 6.65 ksi	arrest	arrest	arrest	arrest	arrest	arrest
21	a	1c	Case 1c with a 20° ID repair (WRS w/o SS weld)	WRS from ASME 3/30 fit to 20° ID repair w/o SS weld	109	>>21	2.24	4.42	5.81	1.28 (note 1)
22	a	3c	Case 3c with a 20° ID repair (WRS w/o SS weld)	WRS from ASME 3/30 fit to 20° ID repair w/o SS weld	125	>>17	2.40	4.78	6.22	1.25 (note 1)
23	a	6c	Case 6c with a 20° ID repair (WRS w/o SS weld)	WRS from ASME 3/30 fit to 20° ID repair w/o SS weld	41	>>37	1.70	3.36	4.04	1.67 (note 1)
23	b	6c	Case 6c with a 20° ID repair (modified ASME WRS)	WRS from ASME 3/30 fit to 20° ID repair modified ASME	41	173	1.70	2.96	4.04	6.44
23	c	6c	Case 6c with a 20° ID repair (WRS w/o SS weld) and multiple repairs	WRS from ASME 3/30 fit to 20° ID repair w/o SS weld; Number of Repairs from 1 to 3	41	>>21	1.70	2.99	4.04	1.22 (note 1)
24	a	7c	Case 7c with a 20° ID repair (WRS w/o SS weld)	WRS from ASME 3/30 fit to 20° ID repair w/o SS weld	71	>>21	2.01	4.24	5.44	1.31 (note 1)
25	a	17a	Case 17a with an ID repair (WRS w/ SS weld)	WRS from w/ SS weld to ID repair w/ SS weld	arrest	76	arrest	2.12	arrest	96.51
25	b	17b	Case 17b with an ID repair (WRS w/o SS weld)	WRS from w/o SS weld to ID repair w/o SS weld	35	88	1.71	2.06	69.28	91.86
26	a	18a	Case 18a with an ID repair (WRS w/ SS weld)	WRS from w/ SS weld to ID repair w/ SS weld	arrest	>>40	arrest	2.83	arrest	5.40 (note 1)
27	b	17b	Case 17b with intermediate bending moment	Pb from 13.57 ksi to 13.00 ksi	35	38	1.71	1.74	69.28	70.43
28	b	17b	Case 17b with low bending moment	Pb from 13.57 ksi to 10.00 ksi	35	27	1.71	1.67	69.28	28.75
29	b	18b	Case 18b with high bending moment	Pb from 4.88 ksi to 7.00 ksi	43	11	1.79	1.38	15.79	8.49
30	b	18b	Case 18b with low bending moment	Pb from 4.88 ksi to 4.03 ksi	43	arrest	1.79	arrest	15.79	arrest
31	c	1c	Case 1c with 10% greater thickness	Thickness from 1.29 in to 1.419 in	109	146	2.24	2.46	5.81	6.43
32	c	1c	Case 1c with 10% lesser thickness	Thickness from 1.29 in to 1.161 in	109	74	2.24	1.96	5.81	4.60
33	c	4c	Case 4c with low axial membrane stiffness	Pm from 1.90 ksi to 1.64 ksi	112	123	2.18	2.20	5.22	5.27
34	c	4c	Case 4c with high axial membrane stiffness	Pm from 1.90 ksi to 2.15 ksi	112	98	2.18	2.12	5.22	5.62
35	c	6c	Case 6c with shortened weld length	Weld Length from 1 in to 0.5 in	41	32	1.70	1.62	4.04	3.67

Note 1: Results not specific for a Stability Margin Factor of 1.2, case has Stability Margin Factor >> 1.2 when time > 40 days

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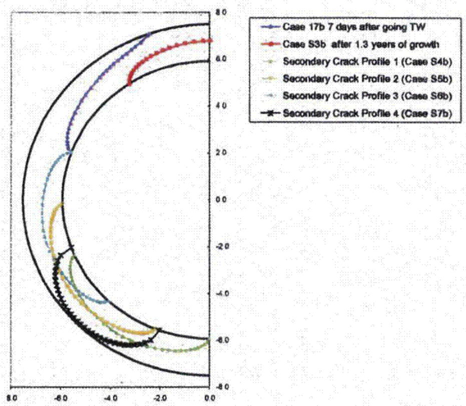
Matrix Results
Sensitivity Summary (cont'd)

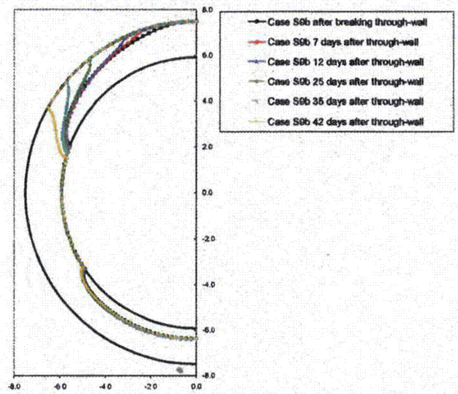
Case #	WRS Subcase	Base Case	Qualitative Sensitivity Description	Quantitative Sensitivity Description	Result Comparison: Time Interval from 1 gpm to a Stability Margin Factor of 1.2 [days] from	to	Stability Margin Factor at 1 gpm (or at initial leak rate if higher) from	to	Calculated Leak Rate (at 70°F) at a Stability Margin Factor of 1.2 [gpm] from	to
36	c	6c	Case 6c modeled with plastic redistribution (modified WRS)	WRS from ASME 3/30 fit to plastic redistribution	41	42	1.70	1.69	4.04	3.99
37	c	6c	Case 6c with natural shape initial surface flaw	Initial Surface Flaw from Uniform, 10% TW 360° to 21:1, 26% TW, natural shape partial-arc	41	49	1.70	1.83	4.04	4.97
38	c	6c	Case 6c with semi-ellipse initial surface flaw	Initial Surface Flaw from Uniform, 10% TW 360° to 21:1, 26% TW, semi-ellipse partial-arc	41	49	1.70	1.83	4.04	4.96
39	c	6c	Case 6c with constant depth initial surface flaw	Initial Surface Flaw from Uniform, 10% TW 360° to 21:1, 26% TW, constant depth partial-arc	41	47	1.70	1.81	4.04	4.87
40	c	6c	Case 6c with shallow initial surface flaw	Initial Surface Flaw from Uniform, 10% TW 360° to 21:1, 15% TW, natural shape partial-arc	41	53	1.70	1.89	4.04	5.18
41	c	6c	Case 6c with deep initial surface flaw	Initial Surface Flaw from Uniform, 10% TW 360° to 21:1, 40% TW, natural shape partial-arc	41	44	1.70	1.77	4.04	4.70
42	c	6c	Case 6c with low crack growth exponent	CGR Exponent from 1.6 to 1.0	41	39	1.70	1.67	4.04	2.97
43	c	6c	Case 6c with high crack growth exponent	CGR Exponent from 1.6 to 2.2	41	47	1.70	1.84	4.04	4.84
44	c	12c	Case 12c with low crack growth exponent	CGR Exponent from 1.6 to 1.0	48	37	1.88	1.69	3.54	2.64
45	c	12c	Case 12c with high crack growth exponent	CGR Exponent from 1.6 to 2.2	48	40	1.88	1.91	3.54	3.80
46	b	17b	Case 17b with low crack growth exponent	CGR Exponent from 1.6 to 1.0	36	73	1.71	1.71	69.28	73.56
47	b	17b	Case 17b with high crack growth exponent	CGR Exponent from 1.6 to 2.2	36	22	1.71	1.70	69.28	63.34
48	b	17b	Case 17b with reduced crack front pressure	Crack Front Pressure from 2235 psi to 1330 psi	35	39	1.71	1.73	69.28	70.05
49	c	6c	Case 6c without thermal loads for TW crack	Pm from 2.34 ksi to 2.48 ksi; Pb from 7.63 ksi to 0.94 ksi	41	145	1.70	2.85	4.04	8.57
50	b	17b	Case 17b without thermal loads for TW crack	Pm from 3.72 ksi to 3.71 ksi; Pb from 13.57 ksi to 0.79 ksi	36	293	1.71	4.33	69.28	191.43
51	b	19b	Case 19b without thermal loads for TW crack	Pm from 3.45 ksi to 3.36 ksi; Pb from 14.55 ksi to 0.90 ksi	arrest	arrest	arrest	arrest	arrest	arrest
52	c	1c	Case 1c with detailed nozzle-to-safe end geometry	Geometry from cylinder to detailed nozzle-to-safe end	109	94	2.24	2.26	5.81	6.61
52	d	1b	Case 1b with detailed nozzle-to-safe end geometry and direct FEA WRS interpolation	Geometry from cylinder to detailed nozzle-to-safe end, WRS from thermal simulation to direct FEA interpolation	arrest	arrest	arrest	arrest	arrest	arrest
53	b	17b	Case 17b with detailed nozzle-to-safe end geometry	Geometry from cylinder to detailed nozzle-to-safe end	35	49	1.71	1.69	69.28	42.36
S1	a	17a	Case 17a with 360° initial surface flaw	Initial Surface Flaw from 21:1, 26% TW, natural shape partial-arc to Uniform, 10% TW 360°	arrest	arrest	arrest	arrest	arrest	arrest
S1	b	17b	Case 17b with 360° initial surface flaw	Initial Surface Flaw from 21:1, 26% TW, natural shape partial-arc to Uniform, 10% TW 360°	35	not applicable	1.71	1.03	69.28	not applicable
S2	b	17b	Case 17b with 360° initial surface flaw and low bending moment	Initial Surface Flaw from 21:1, 26% TW, natural shape partial-arc to Uniform, 10% TW 360°; Pb from 13.57 ksi to 8.40 ksi	35	4	1.71	1.28	69.28	6.00
S3	b	17b	Case 17b with short crack length initial surface flaw	Initial Surface Flaw from 21:1, 26% TW, natural shape partial-arc to 5.6:1, 10% TW, natural shape partial-arc	35	74	1.71	2.03	69.28	87.49
S4	b	17b	Case 17b with additional crack flaw at position 1	after 7 days of leakage w/ additional 21:1 partial-arc crack at position 1 (Fig. 7-14)	35	not applicable	1.66 (note 2)	1.43 (note 2)	69.28	not applicable
S5	b	17b	Case 17b with additional crack flaw at position 2	after 7 days of leakage w/ additional 21:1 partial-arc crack at position 2 (Fig. 7-14)	35	not applicable	1.65 (note 2)	1.48 (note 2)	69.28	not applicable
S6	b	17b	Case 17b with additional crack flaw at position 3	after 7 days of leakage w/ additional 21:1 partial-arc crack at position 3 (Fig. 7-14)	35	not applicable	1.65 (note 2)	1.29 (note 2)	69.28	not applicable
S7	b	17b	Case 17b with additional limiting crack	after 7 days of leakage w/ additional limiting partial-arc crack at 95% TW (Fig. 7-14)	35	not applicable	1.66 (note 2)	1.44 (note 2)	69.28	not applicable
S8	b	19b	Case 19b with 360° initial surface flaw	Initial Surface Flaw from 21:1, 26% TW, natural shape partial-arc to Uniform, 10% TW 360°	arrest	arrest	arrest	arrest	arrest	arrest
S9	b	17b	Case 17b with additional crack flaw at bottom of weld	Number of Initial Flaws from single 21:1 partial-arc crack at top of weld to 21:1 partial-arc cracks at top and bottom of weld (Fig. 7-15)	36	29	1.71	1.60	69.28	69.28

Note 2: Stability Margin Factor after 7 days of leakage

Analysis Matrix Results
Multiple Crack Cases



Profiles of Pairs of Additional Cracks Applied in Stability Calculations for Cases S4b through S7b Based on Case 17b



Case S9b Growth Progression Based on Individual Growth of Initial 21:1 Aspect Ratio 26% through-wall Flaws Placed at Top and Bottom of Weld Cross Section

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Analysis Matrix Results
Summary

- All 109 completed cases in the main sensitivity matrix showed either
  - stable crack arrest (60 cases), or
  - crack leakage and crack stability results satisfying the evaluation criteria (49 cases)
  - generally considerable margins beyond evaluation criteria
- 10 supplemental cases further investigated the effect of multiple flaws on limiting surge nozzle cases
  - Conservative application of the three Wolf Creek surge nozzle indications with limiting surge nozzles (fill-in weld and relatively high moment load) gives results meeting the evaluation criteria with additional margin
  - A case with two long initial partial-arc flaws covering 46% of the ID circumference as opposed to a single initial flaw covering half this circumferential extent (and centered at the location of maximum axial bending stress) has only a modest effect on crack stability
  - On this basis, it is concluded that the concern for multiple flaws in the limiting surge nozzles is adequately addressed by cases that satisfy the evaluation criteria with additional margin

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Analysis Matrix Results
Summary (cont'd)

- Relaxation of secondary loads with crack extension is a significant source of conservatism in the most limiting matrix results
  - A reduction in the secondary load of 40% or more results in the most limiting case (S1b) satisfying the evaluation criteria, even given the assumption of an initial 360° 10%tw flaw
  - This degree of secondary load reduction is supported by the detailed secondary load studies performed (Appendices B and C)
  - Case S1b addresses the most limiting surge nozzles (relatively high secondary moment load and presence of thermal sleeve fill-in weld) and assumes an initial 360° 10%tw flaw (37 inches long)
- Other sources of conservatism for Case S1b:
  - Welding residual stresses (WRS) modeled as axisymmetric
  - WRS does not credit benefit of stainless steel field weld
  - Flow stress in crack stability model based on stainless steel safe end material even though worst case WRS is in the butter area

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Conclusions

- Assumption of semi-elliptical flaw shape shown to result in large unnecessary overconservatism
- All 51 subject welds are adequately covered by crack growth sensitivity cases that satisfy the evaluation criteria
- Results show tendency of circumferential surface cracks to show stable arrest
  - Axisymmetric welding residual stress profile must self-balance
  - Consistent with Wolf Creek experience given unlikeliness that four indications found in narrow depth band were growing rapidly at that time
- Sensitivity cases indicate a large beneficial effect of relaxation of secondary loads upon through-wall penetration
  - Detailed evaluations tend to support such a relaxation effect
  - Not fully credited in main cases

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Conclusions (cont'd)

- In summary, this study demonstrates the viability of leak detection to preclude the potential for rupture for the pressurizer nozzle DM welds in the group of subject PWRs
- DEI, Quest Reliability, and EPRI plan to submit a paper to a refereed scientific journal on this topic

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Managing Gas Intrusion

Gordon Clefton

Nuclear Energy Institute

October 04, 2007

NEI

NUCLEAR
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INSTITUTE

Managing Gas Intrusion

- Operational Challenges
- BWROG Activities
- PWROG Activities
- Industry Activities

NEI

Operational Challenges

- Implementing Technical Specifications
  - Words say 'full'
  - Basis says normally expect gas intrusion
- Accessing vent locations
- Tracking/trending of vent discharges
- Maintaining appropriate surveillance intervals

BWROG Activities

- BWROG General Meeting
  - Agenda item presentation on ECCS Gas Intrusion
  - Support / interest from Prime Representatives
- BWROG Chairman
  - Presented topic to BWROG Executive Officers
    - Recognized problem
    - Funded strategic planning in 2007
  - Staffed a Committee
    - ECCS Gas Intrusion Committee
    - Coordinating with BWROG & NEI
    - Prepared to respond to GL-xxxx action items

NEI

PWROG Activities

- PWROG using Westinghouse
  - Working Group
    - Monroeville PA
    - Staff and industry experts
- Draft road map for gas voiding concern
  - 1. Provide acceptance criteria
    - a. Acceptance criteria in piping (suction piping)
      - i. Amount of gas transport
      - ii. Pump Tolerance to gas void
      - iii. Issues of gas intrusion from tanks during accident
      - iv. Temperature effects on gas transport
    - b. Source and rate of gas intrusion
    - c. Criteria to characterize discharge piping pressure pulsations in systems with gas voids
    - d. Best practices to reduce gas in systems
    - e. Gas void detection
  - 2. Provide Technical Specifications revisions

Industry Activities

- NSSSOG
  - Agenda item at quarterly meeting
  - Resolution progress reported
- NEI
  - First steering committee meeting
    - On 11oct07 at NEI
    - Industry experts, BWROG, and PWROG
  - NEI-NRC 'drop-in' meeting
    - On 12Oct07 at NEI
    - Strategic information sharing

NEI

Managing Gas Intrusion

- Questions?
- Comments?
- Concerns?

NEI

ACRS Meeting on Draft Generic Letter on Managing Gas Intrusion in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems

October 4, 2007

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Warren C. Lyon,
Reactor Systems Branch
Division of Safety Systems

OUTLINE

- Background
- Purpose of Generic Letter
- Desired Outcome of Generic Letter
- Principal Concerns And Applicable Regulations
- Requested Actions and Information
- Public Comments
- Recommendation

Purpose of Generic Letter

- Request that licensees submit information that demonstrates that NRC regulations are being applied to ECCS, DHR, and containment spray system regarding licensing basis, design, testing, operability, and corrective actions to assure that gas intrusion is maintained less than the amount that challenges operability of these systems, and that appropriate action is taken when conditions adverse to quality are identified.

BACKGROUND

- **Gas intrusion events have occurred since the beginning of commercial nuclear power operation**
  - **Subject of many NRC generic communications**
  - **Following 1997 Oconee Unit 3 common-mode failure of high pressure injection, no NRC generic action taken based on industry actions**
  - **More than 60 gas intrusion events reported since the 1997 Oconee Unit 3 event**
  - **The number of identified gas intrusion problems and their significance at some facilities raise concerns about whether similar unrecognized design, configuration, and operability problems exist at other facilities.**

DESIRED OUTCOME OF GENERIC LETTER

- Periodic testing of the subject systems which includes:
  - measuring and recording the volume of gas voids at each high point in the subject systems that could impact operability
  - venting/removing identified gas voids of any volume to restore the subject systems to a filled condition which may necessitate installation of additional vent valves
  - if the location-dependent acceptance criteria for gas void volume exceeded, initiate corrective actions that provides reasonable assurance of operability until the next test
    - accelerated test frequency
    - identify and correct source of gas

PRINCIPAL CONCERNS AND APPLICABLE REGULATIONS

- **Licensing Basis**
  - FSAR – specifies that systems are filled with water
  - TS – surveillance to verify filled
    - May cover only portion of system
    - Operability not assessed
    - Some verifying some sections not possible/practical
- **Design**
  - 10 CFR 50, App B, Criterion III, Design Control
  - Inadequate provisions (e.g., vent valves) to satisfy design basis filled condition

PRINCIPAL CONCERNS AND APPLICABLE REGULATIONS - 2

- **Testing**
  - 10 CFR 50, App B, Criterion V, Instructions, Procedures, and Drawings
    - Instances of written test procedures do not incorporate the requirements and acceptance limits
  - 10 CFR 50, App B, Criterion XI, Test Control
    - Instances of not testing all segments to confirm acceptance limits and operability (excluded segments justified)
    - Required testing includes, but is not limited to, TS surveillances. TS Task Force to address TS later.
  - 10 CFR 50, App B, Criterion XVII, Quality Assurance Records
    - Instances of not recording test results (gas void volume), the acceptability, and the action taken for deficiencies

PRINCIPAL CONCERNS AND APPLICABLE REGULATIONS - 3

- **Operability**
  - **Technical Specifications**
    - **Instances of not maintaining operable due to gas instrusion**
- **Corrective Actions**
  - **10 CFR 50, App B, Criterion XVI, Corrective Actions**
    - **Gas treated as expected condition rather than a nonconforming condition**
    - **Substantial gas quantities not documented**
    - **Based on the as-found volume and location of gas, corrective actions beyond simply refilling a system may be necessary to provide reasonable assurance that the affected system will remain operable until the next surveillance.**

REQUESTED ACTIONS

- **Evaluate their ECCS, DHR system, and containment spray system licensing basis, design, testing, operability, and corrective actions to assure that gas intrusion is maintained less than the amount that challenges operability of these systems, and that appropriate action is taken when conditions adverse to quality are identified.**

REQUESTED INFORMATION

- **Results of the evaluations done pursuant to the REQUESTED ACTIONS**
- **Information to demonstrate compliance**
  - 10 CFR 50, Appendix B, Criteria III, V, XI, XVI, and XVII
  - Licensing basis
  - Operating license (Tech Specs)

PUBLIC COMMENTS - 1

- **Studies will have to be completed**
  - **In order to develop realistic criteria to determine the amount of gas that could impact operability**
  - **Gas detection techniques and the associated accuracies.**
    - **The GL provides technical considerations but leaves it to the industry to address these issues**

PUBLIC COMMENTS – 2

- **The draft Generic Letter does not consider ALARA, personnel safety, or accessibility**
  - **Testing of all segments of piping and components in the subject systems is necessary to confirm acceptance limits and operability unless it has been acceptability established that some items may be excluded.**

PUBLIC COMMENTS - 3

- **For BWRs, proposed GL does not demonstrate that a generic problem of high safety significance exists to justify costs**
  - staff reviews have clearly established the susceptibility of all plant designs
  - Potential to render redundant trains of one or more systems inoperable

- **Does venting that is preventive in nature need to be documented and quantified?**
  - Existence of gas is contrary to TS and the FSAR. The affect of this non-conforming condition on operability must be understood.

PUBLIC COMMENTS - 4

- **Systems are typically presumed operable when a surveillance is current and acceptance criteria are met and documented.**
  - **Based on the as found volume and location of gas, corrective actions beyond simply refilling a system may be necessary to provide reasonable assurance that the affected system will remain operable until the next surveillance.**

RECOMMENDATION

- **ACRS endorse issuance of draft generic letter**

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Presentation to the ACRS on Digital Instrumentation and Control (I&C)

October 4, 2007

Belkys Sosa
Digital I&C Task Working Group Director
Steven Arndt
Senior Technical Advisor for Digital I&C
NRR/DE

Agenda

- Digital I&C Project Plan
- Interim Staff Guidance
  - Cyber Security
  - Diversity and Defense-in-Depth (D3)
  - Highly-Integrated Control Rooms: Communications Issues
  - Highly-Integrated Control Rooms - Human Factors
- ACRS Recommendations Follow Up
  - Evaluation of Operating Experience
  - Inventory and Classification System
- Summary

2

Digital I&C Project

- Near-Term Activities
  - Develop interim staff guidance
- Long-Term Activities
  - Revise regulatory documents (RGs, SRP)
  - Continue interactions with industry to have ISG incorporated into industry standards
- Long-Term Focus of Project Plan
  - Risk Informed
  - Fuel Cycle Facilities
  - Remaining Human Factors Issues
  - Continue to refine and enhanced guidance as necessary

3

Interim Staff Guidance

- Status

– Diversity and Defense in Depth (D3)	9/28/07
– Highly Integrated Control Rooms – Communication	9/28/07
– Highly Integrated Control Rooms – Human Factors	9/28/07
– Cyber Security	10/31/07
– Licensing Process	11/30/07
– Risk Informed	03/31/08

4

ACRS Interactions

- ACRS provided recommendations to the NRC staff in the area of digital I&C
  - June 22, 2007 SRM – directed the staff to develop an inventory and classification of Digital I&C systems and to evaluate Operating Experience with Digital I&C failures
  - September 13, 2007 – ACRS Subcommittee on I&C
  - October 4, 2007 - ACRS Full Committee Meeting
  - Periodic updates to ACRS Subcommittee on I&C
  - December 31, 2007 - Complete assessment of operating experience and inventory and classification (ACRS Recommendations on D3)

5

Cyber Security

- Clarify the NRC staff's guidance with regard to implementation of cyber security requirements for nuclear power plant safety systems
- Interim Staff Guidance
  - Documents regulatory guidance in this area including a cross-correlation table that maps Regulatory Positions 2.1-2.9 from RG 1.152 Rev2 to draft NEI 04-04 Rev2.

6

Diversity and Defense-in-Depth (D3)

- In the Diversity and Defense-in-Depth area there are seven problem statements
  - Adequate Diversity
  - Manual Operator Actions
  - BTP-19 Position 4 Challenges
  - Effects of CCF
  - CCF Applicability
  - Echelons of Defense
  - Single Failure

Diversity and Defense-in-Depth (D3)

- Adequate Diversity
  - *Additional clarity is desired on what constitutes adequate D3. Determine how much D3 is enough.*
- Manual Operator Actions
  - *Clarification is desired on the use of operator action as a defensive measure and corresponding acceptable operator action times.*
- Interim Staff Guidance
  - There is no distinction in D3 guidance for digital Reactor Protection System (RPS) designs for new/future nuclear power plants and current operating plants.
  - While CCFs in digital systems are beyond design basis, the digital RPS should be protected against CCFs.
  - A D3 analysis should be performed to demonstrate that vulnerabilities to CCFs have been adequately addressed.

Diversity and Defense-in-Depth (D3)

- Interim Staff Guidance (cont.)
  - Where the protective action that should have been automatically performed by the system subject to CCF is required in less than 30 minutes to meet the BTP-19 acceptance criteria, an independent and diverse automated backup, achieving the same or equivalent function, should be provided.
  - This automated backup guidance does not apply to follow-on actions that are handled in a manual fashion.
  - In addition, a set of displays and controls (safety or non-safety) should be provided in the main control room for manual actuation and control of safety equipment to manage plant critical safety functions.
- Bases for 30-minute Operator Action Time
  - Minimizing operator burden under the conditions of a digital system CCF
  - Past regulatory decisions
  - Regulatory practices applied in the international community
  - Engineering judgment

9

Diversity and Defense-in-Depth (D3)

- Effects of CCF
  - *BTP-19 guidance recommends consideration of CCFs that "disable a safety function." Additional clarity is required regarding the effects that should be considered (e.g., fails to actuate and/or spurious actuation)*
  - *Industry also requested that the staff determine whether spurious actuations should be considered when evaluating software CCF*
- Interim Staff Guidance
  - In general, spurious trips and actuations are of lesser safety concern than failures to trip or actuate.
  - There may be plant and safety system challenges and stresses; however, these challenges are not as significant as failure to respond to a Chapter 15 event.
  - Software CCFs resulting in a spurious trip or actuation of a safety-related digital protection system do not need to be considered in the single failure analysis.

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Diversity and Defense-in-Depth (D3)

- CCF Applicability
  - *Clarification is required on identification of design attributes that are sufficient to eliminate consideration of CCFs (e.g., degree of simplicity)*
- Interim Staff Guidance
  - Diversity: If sufficient diversity exists in the reactor protection system such that CCFs within the channels are considered to be fully addressed, then no additional diversity would be required in the safety system.
  - Testability: If a system is sufficiently simple such that it is fully tested and found to produce only correct responses, then no additional diversity would be needed in the safety system.

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Diversity and Defense-in-Depth (D3)

- For Further Consideration
  - Work with industry to have ISG refined
    - Adequate diversity strategies
  - Staff assessment of ACRS recommendations on operating experience and inventory/classification
  - Revise the Standard Review Plan

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Highly-Integrated Control Rooms: Communications Issues

- Interdivisional Communications
  - *Communications among different safety divisions or between any safety division and any system or equipment that is not safety-related*

- Interim Staff Guidance
  - Acceptable ***provided*** the safety function processor is not encumbered by the communication process.
  - Separate processor & shared memory for communications
  - Limited to support of safety function
  - Communication failures & failures outside a division must not inhibit division's safety function
  - Division must not need input from other divisions to complete its safety function (other than voting logic)

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Highly-Integrated Control Rooms: Communications Issues

- Command Prioritization
  - *The process of selecting a particular command to forward to plant equipment when multiple commands exist*

- Interim Staff Guidance
  - Safety command from safety system always has priority
  - Hardware-based: physical device with inputs from safety and non-safety sources via hard wire and/or data link
    - Suitable for D3
    - May utilize software external to safety function processor
  - Software-based: safety-grade code executed by safety function processor
    - Not suitable for D3

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Highly-Integrated Control Rooms: Communications Issues

- Multidivisional Control and Display Stations
  - *Non-safety control station that can send commands to and/or receive information from equipment in multiple safety and non-safety divisions*
- Interim Staff Guidance
  - Must be supplemented by safety-grade stations for safety-related components & functions
    - Safety functions must be carried out using safety controls & indications (per IEEE603)
  - Cannot interfere with safety functions
    - No override except by priority module
    - No bypass initiation or removal except as explicitly permitted by safety system
  - Communications & prioritization should be as described on previous slides

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Highly-Integrated Control Rooms: Communications Issues

- For Further Consideration
  - Plant safety analyses must be consistent with possible failure modes
    - Spurious actuations could affect initial conditions
    - Spurious stoppages could affect event progress
  - Spurious events may be initiated by multidivisional stations, or may be initiated by failures in control processors
    - Safety analyses must accommodate what might happen, regardless of the source of the event

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Highly Integrated Control Room –Human Factors

- Minimum Inventory
  - *Better describe the process for developing the actual minimum inventory of alarms, controls, and displays needed to implement the emergency operating procedures, bring the plant to a safe condition, and to carry out those operator actions shown to be important by the applicant's PRA, both in the main control room and at the remote shutdown facility.*
- Interim Staff Guidance
  - Applicable only to new reactors
  - Identifies
    - Selection criteria
    - Process development considerations
    - Verification
  - Two step process consistent with the design acceptance criteria concept

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Highly Integrated Control Room –Human Factors

- Computer-Based Procedures
  - *Develop review guidance and acceptance criteria that are sufficiently detailed to adequately review computerized procedures and associated soft controls, to determine their effect on safety.*
- Interim Staff Guidance
  - The content of paper and computer-based procedures can be essentially the same
  - Computer-based procedures should not limit the control or situation awareness of the procedure user
  - Computer-based procedures can incorporate different levels of automation:
    - None (manual)
    - Advisory – Prompts for an action e.g. Start pump "A"
    - Shared – Monitor a process but be unable to access all necessary information about the system due to lack of instrumentation.
    - Automated – Performs the procedure step automatically

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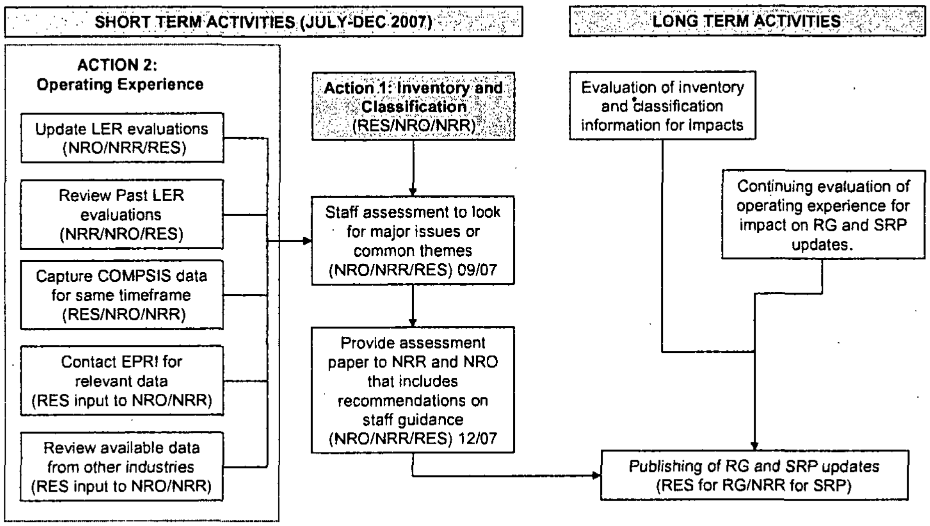
Operating Experience and Inventory/Classification



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Operating Experience and Inventory/Classification

- Assessment of operating experience in nuclear and other industries:
  - Internal assessment of operating experience and LER failure data ('87-'06)
  - I&C digital system failures in nuclear power plants ('94-'99)
  - COMPSIS database
  - Contacted EPRI and NEI for similar operating experience failure data
  - *Survey of Digital I&C Failures* (ORNL)
  - *Risk Informed Safety Assurance and PRA of Mission-Critical Software-Intensive Systems* (NASA)

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Operating Experience and Inventory/Classification

- Preliminary findings of review of operational experience
  - Availability of quality data is limited
  - Exact causal data is particularly difficult to locate
  - CCFs are credible
    - Other industries use diverse systems to mitigate the effects of CCFs
  - Ongoing NRC programs (e.g., operating experience program) are valuable in that they collect, analyze and distribute information providing lessons learned to staff, applicants, vendors, and licensees.

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Operating Experience and Inventory/Classification

- The inventory and classification research will provide
  - A framework for collecting operational data
  - Guidance for evaluating operational data
  - A process for translating operational data into D3 regulatory guidance
- Regulatory-based Classification systems
- Design-based Classification systems
- Operational-based Classification systems

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Operating Experience and Inventory/Classification

- NRC reviews of operational data have revealed that nuclear system failure classes are similar to failure classes in systems studied by Rashly, Perrow, and NASA
- A proposed failure-type classification expands on the work done by Rashly, Perrow, Aldemir, and NASA
- The proposed classification consists of three attributes
  - Complexity (including hardware and software complexity and testability of the system)
  - Interactions/inter-conductivity (including inter-system communications and the importance of timing and feedback with other systems)
  - Importance (including risk importance, how important the system is for maintaining defense-in-depth and the consequence of system failures)

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Operating Experience and Inventory/Classification

- Preliminary Conclusion
  - On the basis of an assessment of existing classification systems and operating experience data,
  - *No changes to the proposed D3 ISGs are required.*
- Future Plans
  - September 28, 2007
    - Complete short-term staff assessment
  - December 31, 2007
    - Provide white paper that details potential impact upon staff guidance
    - Capture assessment results of inventory/classification and operating experience
  - 2008 and beyond
    - Provide inputs for proposed long-term activities to refine guidance
    - Continue ongoing operating experience program reviews

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Overall Summary

- Steering committee is functioning effectively
- Project plan is in place
- Interim Staff Guidance is being developed
- Continuing interactions with ACRS Sub-committee on I&C
- Strong industry support
- Staff is on-schedule to complete near-term deliverables

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Digital Instrumentation & Control (I&C)

October 4, 2007

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NUCLEAR ENERGY INSTITUTE

Diversity and Defense-in-Depth (D3)

- Seven Problem Statements:
  - When is diversity needed?
  - How diverse is diverse enough?
- Remaining Challenges:
  - Credit for manual operator actions
  - Use of risk insights
  - Common cause failure applicability
  - Adequate diversity

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Diversity and Defense-in-Depth

- Path Forward:
  - Develop methodology for operator response time assumptions
  - Develop process for considering risk
  - Review operating experience data
  - Complete research on adequate diversity
  - Further refine interim guidance (ISG)
  - Revise BTP-19

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Operating Experience

- Obtain insights on failure modes
- Review and characterize 300+ events (NRC and INPO databases)
- Share information with NRC
- Document findings

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Communications

- Problem Statement:
  - Need better guidance for inter-divisional independence and data communication
- Remaining Challenge:
  - Implementation of interim guidance (ISG)
- Path Forward:
  - Further refine ISG, if appropriate
  - Revise IEEE 7-4.3.2 and RG 1.152

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Human Factors

- Problem Statements:
  - Minimum Inventory
  - Computer-based Procedures
  - Graded Approach to Human Factors
  - Safety Parameter Display System
- Remaining Challenges:
  - Implementation of interim guidance (ISG)
  - Completing longer-term actions

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Human Factors

- Path Forward:
  - Further refine ISG, if appropriate
  - NRC endorse industry reports
    - Minimum Inventory
    - Computer-based Procedures
    - Graded Approach
  - Develop or modify other guidance, as appropriate

NEI 7

Cyber Security

- Problem Statement:
  - NEI 04-04 and RG 1.152 have different guidance
- NEI 04-04, Rev. 1
  - Endorsed by NRC in December 2005
  - Contains programmatic guidance
- Regulatory Guide 1.152, Rev. 2
  - Issued in January 2006
  - Contains design guidance

NEI 8

Cyber Security

- **Desired Outcome:**
  - Allow either RG 1.152 or NEI 04-04
- **Path Forward:**
  - Perform gap analysis
  - Modify NEI 04-04, if appropriate
  - Develop interim guidance (ISG)
  - Revise IEEE 7-4.3.2, RG 1.152, and SRP

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