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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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596TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

OPEN SESSION

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WEDNESDAY

JULY 11, 2012

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:30 a.m., J. Sam Armijo, Chairman, presiding.

COMMITTEE MEMBERS:

J. SAM ARMIJO, Chairman

JOHN W. STETKAR, Vice Chairman

HAROLD B. RAY, Member-at-Large

SANJOY BANERJEE, Member

CHARLES H. BROWN, JR. Member

MICHAEL L. CORRADINI, Member

DANA A. POWERS, Member

JOY REMPE, Member
MICHAEL T. RYAN, Member
WILLIAM J. SHACK, Member
JOHN D. SIEBER, Member
GORDON R. SKILLMAN, Member

NRC STAFF PRESENT:
ANTONIO DIAS, Designated Federal Official
WEIDONG WANG, Designated Federal Official
ERIC BOWMAN, NRR
RICHARD CORREIA, RES
DARRELL DUNN, RES
BOB EINZIGER, NMSS
MICHELE EVANS, NRR
ROBERT FRETZ, JLD
MIRELA GAVRILAS, RES
CHRIS JACOBS, NMSS
TRACY J. ORF, NRR
LISA REGNER, JLD
JAMES RUBENSTONE, NMSS
MARK HENRY SALLEY, RES
DAVID STROUP, RES
ROBERT TAYLOR, JLD

ALSO PRESENT:

DAVE BROWN, FPL
RUDY GIL, FPL
STEVE HALE, FPL
JACK HOFFMAN, FPL
JOE JENSEN, FPL
FRANCISCO JOGLAR, Hughes Associates
JAY KABADI, FPL
MARK LEYSE*
ROD McCULLUM, NEI
KEVIN McGRATTAN, NIST
RICK WACHOWIAK, EPRI
CHRIS WASIK, FPL
JEFF WILLIAMS, US DOE/NE

*Present via telephone

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

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

(8:32 a.m.)

CHAIR ARMIJO: Okay, we're now all ready. Good morning. The meeting will now come to order. This is the first day of the 596th meeting of the Advisory Committee on Reactor Safeguards. During today's meeting the Committee will consider the following.

Development of Interim Staff Guidances, ISGs, supporting the Near-Term Task Force Tier 1 orders. Two, NUREG-1934, Nuclear Power Plant Fire Modeling Analysis Guidelines.

Three, Saint Lucie Unit 2 extended power uprate application. Four, technical basis for regulating extended storage and transportation of spent nuclear fuel. And fifth, preparation of ACRS reports.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mr. Antonio Diaz is the designated federal official for this initial portion of the meeting.

Mr. Mark Leyse has provided written comments and requested time to make an oral statement regarding the development of Interim Staff Guidances,

ISGs, supporting the Near-Term Task Force Tier 1 orders.

There will be a phone bridge line. To preclude interruption of the meeting, the phone will be placed in a listening mode during the presentation and Committee discussion.

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

The first topic today addresses the Interim Staff Guidances. And we will receive a briefing and hold discussions with NRC staff on the development of the guidance documents.

Dr. Steve Schultz was the subcommittee chairman of the ACRS Fukushima Subcommittee, is in Vienna this week. So I will take the lead in the briefing.

The three topics we'll cover are those including the ISG's supporting order EA-12-049, which addresses mitigation strategies for beyond-design-basis external events.

Order EA-12-050, which addresses reliable hardened vents for Mark 1 and Mark 2 containments.

And Order EA-12-051, which addresses spent fuel pool instrumentation.

The final versions of these ISGs are expected to be released by August 31st of this year. And I'd like to turn the briefing over to Mr. Robert Taylor from the Japan Lessons Learned Directorate, who will open the presentation. Mr. Taylor?

MR. TAYLOR: Thank you, Chairman. Good morning, Committee. My name is Rob Taylor and I'm the deputy director of the Japan Lessons Learned Project Directorate. It is a pleasure to meet with the ACRS today to discuss the staff's efforts to finalize the staff guidance for implementation of the Tier 1 Fukushima Orders.

With me today are Eric Bowman, Bob Fretz, and Lisa Regner, who will make the staff's presentation and answer your questions. They will be supported by staff experts who are in the audience today.

Since March of last year the NRC has moved at an exceptional pace to respond to, understand, and implement the lessons learned from Fukushima. That pace has challenged our ability to meet with ACRS as quickly and as frequently as we would've desired.

Nevertheless, the ACRS has provided

tremendous support and insights that have benefitted the Agency's activities on the lessons learned. We are grateful for your efforts on these important issues.

With this past spring's issuance of the Tier 1 Orders and Request for Information, staff now has the ability to reemphasize its normal processes, including frequent interactions with the ACRS.

We want to ensure, going forward, that we gain your insights and input as we move forward to implement the lessons learned. We greatly appreciated our recent meetings with the Committee on the Tier 3 recommendations.

The staff is currently finalizing that paper and is on schedule to provide it to the Commission by the end of the week. Your comments have aided our evaluation of those recommendations.

We look forward to your feedback today on the staff guidance documents that we will discuss. We remain committed to issuing those documents by the end of August to support licensees' development of integrated plans by February of next year.

Our public comment period on the staff guidance documents closed on July 7. We have received a limited number of submissions of comments from

stakeholders. I attribute that to the staff's efforts to engage stakeholders during the development of the guidance documents, including holding public meetings during the comment period.

In fact, to-date, the staff has held over 50 public meetings on Fukushima, including those with the ACRS. The insights from those meetings have led to the development of thorough and comprehensive documents that the staff will discuss today. With that, I'd like to turn the presentation over to Eric Bowman, who will start us off.

MR. BOWMAN: Thank you, Rob. Good morning. As Rob mentioned, I'm Eric Bowman. I'm the staff lead in the Office of Nuclear Reactor Regulation for the mitigating strategies under Order EA-12-049, as well as the mitigating strategies required by 10 CFR 50.54(hh)(2).

The things I'll be covering, the guidance that has been proposed by industry for the development and implementation of the mitigating strategies and their document, NEI 12-06.

The draft of the Interim Staff Guidance that we published for comment and a little bit of additional information on comments and changes that have been made to NEI 12-06 since we last met. Next

slide?

NEI 12-06, the diverse and flexible coping strategies implementation guide, the Revision B1 of NEI 12-06 is the revision that we had based the draft ISG we published in June upon, the document goes through and establishes a methodology and framework for developing the mitigating strategies, laying out initial conditions to be considered.

And how to develop the boundary conditions and the baseline coping capability of the individual licensees for the beyond-design-basis external OMATs.

It goes further into a assessment of external hazards that would be specific to a site, and implementation of a further guidance and strategies for those sorts of site-specific external hazards.

Defines what the site-specific FLEX capability should be and lays out what the programmatic controls for the equipment will be.

In addition, the guidance includes the requirements for the Phase 3 of the order, strategies and guidance, which is the maintenance or restoration of spent fuel pool coolant, core cooling, and containment capabilities indefinitely using offsite resources. Next slide?

CHAIR ARMIJO: Eric, before you do that,

that chart, from the June subcommittee meetings, there may be some confusion or misunderstanding of the sequence of the activities envisioned in this order.

And the concern was raised that the hazards, the definition, the determination of the applicable extreme external hazards was done later in the program, where in the mean time, a number of things were being done which might have to be redone later.

And so could you clarify that? Is that really the fact? Is the external hazard really going to be determined after a lot of other stuff has been done that should've been deferred until the hazards were -

MR. BOWMAN: There are a couple of different aspects to it that need to be brought to mind. A lot of the information in the guidance document that NEI provided is not sequential.

However, the way they've laid out and they've got a flow chart in here to show specifically how they see the process working. There's reasonable protection of the equipment and so forth to the design-basis or slightly beyond it, depending on the design-basis of adjacent sites, in order to establish a baseline coping capability.

The baseline coping capability in the FLEX Guidelines relies on an assumption that offsite power has been lost, onsite sources of power such as emergency diesel generators and alternate AC sources are lost. But keeps availability of the AC distribution system, to the extent that it's provided by station batteries through invertors for a baseline capability.

The mitigating strategies include workarounds if that internal power distribution system is not available. For example, restoration of core cooling through the black start of RCIC or a manual start of turbine-driven or diesel-driven AFW, et cetera, or local powering of equipment that survived the casualty by bringing in cables or by other means that doesn't use the internal power distribution system.

The evaluation of external hazards in this document is not intended to reset what the design-basis should be. It's intended to provide the licensees with a methodology to look at what are other things that could be hazards that are beyond the design-basis but were not included in the design-basis because of the low probabilities.

So that's what the intent is for that. It

doesn't really change the design-basis. It gives them a review -

CHAIR ARMIJO: But does it make the FLEX plan less, would a FLEX plan be capable of addressing these newly defined extreme external hazards? That's really the -

MR. BOWMAN: Well, we also have the effort that's underway under recommendation 2.1 for reevaluation of the external hazards that may lead to a reset of the design-basis later down the road.

MEMBER SHACK: Since it's for beyond-design-basis accidents -

MR. BOWMAN: Yes.

MEMBER SHACK: -- then clearly it's beyond the current design-basis. But there are a lot of references in it to, you know, you're going to store this stuff in a building that survives the safe shutdown earthquake.

MR. BOWMAN: Right.

MEMBER SHACK: So that safe shutdown earthquake though, is the current design-basis SSE.

MR. BOWMAN: Right.

MR. TAYLOR: Eric, if I could? And that's an important point. It's a very good question. And it's one that the staff and the Steering Committee

recognized early on as we were developing the list of Tier 1 activities that we were going to undertake, and attempting to maximize the integration.

We recognize that in a perfect world we could integrate them fully and we take one regulatory action. But we realized that the reevaluations that we're talking about for external hazards, seismic, flooding, and other external hazards would take time to be performed.

The Steering Committee didn't believe it was prudent to wait to require actions for plants to protect against potential beyond-design-basis events.

So recognizing that, we decided it was important to move out with imposing requirements and take the risk that there was a potential that some rework might have to be done. Both the NRC and the industry recognized this and believed it was a prudent first step to take these actions.

So when we complete the reevaluations, you'll still have an order in place that requires the protection of that equipment, right? So if rework needs to be done, there's still a regulatory requirement that the licensees adequately protect that equipment.

As well as if we pursue a rule make, as we

develop rule making on this, and put the requirements in officially into the regulations, then you'll have that as a regulatory mechanism to require the protection of the equipment that is being put in place in accordance with FLEX.

CHAIR ARMIJO: So just to follow-up on Bill's comment and to make sure I get it straight. Let's assume some FLEX equipment is stored in a location that meets the current design-basis hazards.

But the evaluation of the extreme external hazards, which is done later, determines that you could have a flood that would flood the storage area for all this FLEX equipment.

Then both industry and the staff would say sorry guys, we've got to move that equipment to a different location. Is that the current thinking?

MR. BOWMAN: That is the current thinking. The operative words in the order are develop, implement, and maintain. And understanding that your external hazard for the equipment, that you are providing reasonable protection of it, should that change, would impact what would be reasonable protection.

In addition, part of it is the use of the offsite resources, which includes other pieces of

equipment that will have standardized connectors and preplanned methodologies for bringing that equipment onsite.

For the case of the offsite equipment, protection of it from whatever happens on the site would be provided by the distance from the site essentially.

CHAIR ARMIJO: Okay. That's all I had. Thank you.

MEMBER SIEBER: Question?

CHAIR ARMIJO: Yes.

MEMBER SIEBER: In your review of FLEX, I doubt very much that you got an opportunity to include any of the changes that were in Revision C, that I also presume you've seen it, does it make a difference or can you go ahead with your work without incorporating changes from B1 to C?

MR. BOWMAN: The changes in Revision C were, for the most part, an effort by industry to address what we had published as exceptions and clarifications in the Interim Staff Guidance.

MEMBER SIEBER: Yes -

MR. BOWMAN: Our intention is to modify the Interim Staff Guidance to recognize things that have been included in the NEI guidance. And I expect

that we will get a Revision 0 when we come to a final agreement as opposed to, Revision C currently is in a redline markup state to show where the changes are -

MEMBER SIEBER: That's what I see.

MR. BOWMAN: There are a number of things, like in our Interim Staff Guidance we had included the requirement for reliable backup power to the hydrogen igniters for Mark III and ice condenser containments.

It's now been included in Revision C, so we no longer need to take that as an exception to the industry guidance. So we'll be deleting that from the industry, the markups.

MEMBER SIEBER: So all the NEI documents, the FLEX document is a work in progress and you will match to the current version?

MR. BOWMAN: We will match to the current version. We will, of course, take into account other stakeholder inputs that we've received. We had six formal comments and one additional comment that hasn't been added formally. I haven't finished -

MEMBER SIEBER: Okay.

MR. BOWMAN: -- working with the admin staff to determine what are formal comments that need to be addressed.

MEMBER SIEBER: Yes, I see things moving

very fast and an opportunity for a jumble.

MR. TAYLOR: Of course. And we do, a very important point is our goal and we will meet that goal, is to get the guidance out on August 31st because we believe it's prudent and necessary. So that the industry can move forward with some certainty in developing their integrative plans that they need the time for, between then and February.

So we do need to stop the evolution of the document, freeze it. And if it ends up with us still having exceptions, that's okay. We'll issue a final ISG with exceptions that we deem appropriate to the document.

MR. BOWMAN: And if it means that we refer to the Revision C of NEI 12-06 in the redline markup state, then so be it. We'll do that. And we can make a Revision 1 to the Interim Staff Guidance at a later point. But we will have the guidance out for the industry to implement the requirements.

MEMBER SIEBER: Things are moving fast enough that the opportunity for a jumble is there?

MR. BOWMAN: Oh, yes.

MEMBER SIEBER: But I'm glad to see that you're on top of it.

MR. BOWMAN: Well, thank you.

CHAIR ARMIJO: Is it the goal of the staff and the industry to converge and wind up with a minimum number of exceptions to the NEI guidance?

MR. TAYLOR: In a perfect world, yes, absolutely.

CHAIR ARMIJO: Yes.

MR. TAYLOR: I think there's a time constraint that will limit our success, or challenge our success is a better way to put it. If we can get a document whereby we're perfectly aligned, fine. If not, there will be exceptions within our ISG as to what we find acceptable.

CHAIR ARMIJO: That's really a timing issue, not a policy issue?

MR. TAYLOR: It is. It's a timing issue.

CHAIR ARMIJO: Okay.

MR. TAYLOR: And if you take more time, you can certainly resolve your differences and reach resolution. But there might be a point where we actually recognize the difference and we're in agreement. We just haven't had time to get a clean version -

CHAIR ARMIJO: Right.

MR. TAYLOR: -- that everybody agrees to done. So it'll just end up being a version that has

an exception to it.

CHAIR ARMIJO: Yes.

MR. TAYLOR: Yes, where there's no objection to the exception.

CHAIR ARMIJO: Okay. Because that addresses one of the concerns that we had in the subcommittee meeting of this is changing so fast -

MR. TAYLOR: Yes.

CHAIR ARMIJO: There's a lot of exceptions and comments. And if that's the guidance the industry winds up using it could lead to confusion, and rework, and problems.

MR. BOWMAN: In addition, industry is planning on having a series of workshops, led by NEI, on how to meet the guidance. The first one will be the week of September 3rd. And then they have two or three additional ones.

CHAIR ARMIJO: Okay.

MR. BOWMAN: And we've been discussing with them participating in part in the workshops.

CHAIR ARMIJO: Okay. Yes that helps a lot.

MR. BOWMAN: So we're working to stay on the same page.

CHAIR ARMIJO: Good.

MR. BOWMAN: For the definition of site-specific FLEX capabilities, on the slide here are a listing of the types of things that will be in the capabilities.

The reasonable protection of the equipment means to deploy the equipment from where it is being stored to the site where it will have to be used. Interfaces with the emergency operating procedures, abnormal operating procedures, and even the severe accident of management guidelines, and so forth.

The N+1 sets of equipment are what is, the guidance specifies will be maintained by the licensees onsite and being the number of units on a particular licensed site. The N+1, the intention is to have an extra set with programmatic controls on outage times for the sets of equipment. Next slide?

Our Interim Staff Guidances, I mentioned, the draft 1 that was published was a proposed endorsement of Revision B1 of NEI 12-06, with some exceptions and clarifications.

In the draft Interim Staff Guidance that we published we included a section on the reporting requirements, to lay out the types of things that we intended to look for in the reports that are, the integrated plans, and the pre-audit reporting, and the

final reporting. That particular section has been incorporated in Revision C in NEI 12-06.

The only other things I would add were a lot closer to being in alignment on the programmatic controls running towards consensus standards. NEI has proposed reliance on the INPO document that's listed here. We're looking at it, as well as our relationship with INPO, as to whether it's something that we want to approve.

We've also received a -- and it's not on the slide because I just got it this morning -- comment from the American Nuclear Society proposing the development of consensus standards, with them leading the effort for the programmatic controls for this equipment.

CHAIR ARMIJO: Right.

MR. BOWMAN: And that concludes my portion of the briefing. Have you got any further questions for me?

CHAIR ARMIJO: Yes, related to the standards, there's a term of rugged design or something that needs to be defined. Let's see, a seismically rugged design. Is there a clear understanding in the staff and industry on what that means? Is that terminology still used in the ISG?

MR. BOWMAN: Was that in the ISG for this order or for the hardened vents order because I -

CHAIR ARMIJO: No, it's in the hardened vents. I jumped ahead. I'm just trying to keep track. I'll wait.

MR. BOWMAN: I'll leave that for Bob Fretz to address.

CHAIR ARMIJO: Yes, right, okay.

MEMBER CORRADINI: Just for clarification because I don't remember. I wasn't at the subcommittee meeting. INPO AP-913, that is for equipment qualification for safety-related equipment?

MR. BOWMAN: NEI, in the Revision C to NEI 12-06, is proposed use of the deadlines of that INPO document for the portable equipment.

MEMBER CORRADINI: Right, but I don't remember what INPO, I don't remember. I don't know what INPO AP-913 is. Is it safety-related equipment?

MR. BOWMAN: It's not limited to safety-related equipment, per se, it appears. I've glanced at the document. I haven't had an opportunity to read it in depth. And I would defer, of course, to the appropriate technical experts in that particular portion.

MEMBER CORRADINI: I'm just trying to

understand if that's where you're pointing, what are the requirements there? That's what I just don't remember.

MR. BOWMAN: They have proposed the use of that methodology for the screening and development of the maintenance and testing procedures for the equipment, as well as a development of standard templates.

MEMBER CORRADINI: Okay. Thank you.

MR. BOWMAN: But we also have the ANS proposal for a difference of standards.

MEMBER CORRADINI: Or just simply a review of these.

MR. BOWMAN: Could be, right. Could be, yes.

MR. TAYLOR: This is a recent development.

MEMBER CORRADINI: I just didn't remember what it was, that's all.

CHAIR ARMIJO: That was not discussed in the June subcommittee -

MR. TAYLOR: No. And I think it is part of an outgrowth of that subcommittee discussion, as we continue to -

CHAIR ARMIJO: Yes.

MR. TAYLOR: -- look at this issue and how

do we do it. And one of the questions is, it's not typical to staff to endorse INPO guidelines or documents.

So the question becomes, how would we do this, how would we? And that's something ongoing within the staff to look at the appropriate use of the standard or to have the standard -

CHAIR ARMIJO: Converted into something.

MR. TAYLOR: -- converted into something else that we can use.

MEMBER SKILLMAN: Yes, throughout the fleet, when the units go through their annual, or their biannual E&A, evaluation and the review -

MEMBER CORRADINI: For qualification?

MEMBER SKILLMAN: Well, they're every two-year E&A. One of the primary processes is equipment reliability. And the industry is subtle on the AP-913 as an acceptable process for equipment. And so it is a consensus standard, all of those, particularly plan engineering design folks at the stations understand this very very well.

And since it is recognized as an industry standard, what appears to me is occurring is, industry is saying you know what, we can use 913 for the FLEX equipment because it works for all the other equipment

in the plant.

MR. TAYLOR: Okay -

MEMBER SKILLMAN: But this is part of the -

MR. TAYLOR: That helps, thank you.

MEMBER SKILLMAN: -- review by INPO of the licensees on their every two-year E&A.

MR. TAYLOR: Okay, thank you. Thanks, Dick.

MEMBER SKILLMAN: Yes.

MEMBER STETKAR: Eric, on the N+1 capability, we had a little bit of discussion about that -

MR. BOWMAN: We did.

MEMBER STETKAR: -- in the subcommittee meeting. And I noticed that Rev C of NEI 12-06 doesn't have any change. The concern that we had is nominally the N+1, if you have a two-unit site, would have a pump for Unit 1, a pump for Unit 2, and a third pump.

So that you have essentially redundant capability for failures. But NEI allows you to have a single pump with enough capability to supply both units and one other.

So that in the first case if you had two

pumps failing, you would need to bring in offsite resources to help one unit. And in that option that's allowed under the NEI guidance, if you had two pumps fail, you now have two units in jeopardy that you need to mobilize equipment for.

Does the final ISG address that issue at all? We had some discussion, you said you were going to take it back and think about it.

MR. BOWMAN: We haven't come to a conclusion on that yet.

MEMBER STETKAR: And I noticed that they didn't change anything in the NEI document with regards to that.

MR. BOWMAN: Okay. Thank you. If that's all the questions for me, I'll turn it over to Bob Fretz for the hardened reliable vent system.

MR. FRETZ: Good morning. My name is Bob Fretz and I am the project manager for the reliable hardened vents order. And on the screen you'll see some of the topics we'll discuss this morning in our prepared presentation, as well as answer any of the questions you have regarding the Interim Staff Guidance. Go ahead, Lisa, next slide.

Now the reliable hardened vent order that was issued in March of this year essentially applies

to the BWR facilities with Mark I and Mark II containment designs.

Now the primary focus of the order is to provide a reliable means to protect the containment from overpressure failures, as well as to support strategies associated with the prevention of core damage by assisting in the use of low pressure water sources to ensure that the reactor core remains covered.

And again, in a lot of our discussion we've had internally we've been using the words, I guess prevention, to essentially just describe those strategies that were taken prior to core damage.

And then we used the word mitigation to describe those strategies that are applied after core damage occurs. So if I mention any of that, that's how I'm using those terms today. Next slide?

The reliable hardened venting system shall be able to operate under a prolonged station blackout condition, that is a loss of all AC power, while there is also inadequate containment cooling. So sometimes we refer to this as the TW sequence, sequences regarding these conditions.

Now because the order assumes that there is no core damage present, it does not provide any

specific requirements relating to severe accident service, such as being able to withstand the presence of hydrogen, or even requiring licensees to consider a severe accident source term in its assumptions.

Now that does not mean we have forgotten those concerns or even those lessons learned from Fukushima. The whole issue of severe accident service is including whether or not to install external filtration or additional filtration on these hardened venting systems will be the subject of an upcoming Commission paper.

So it's one of those things that we have not forgotten but essentially the purpose of the order is to really assist in those strategies related to prevention of core damage. Okay, next slide?

Now the order includes three basic design objectives. That is licensee shall design the system to minimize the reliance on operator actions. The system shall also be designed to minimize personal exposure to occupational hazards while operating the system.

And the system shall be designed to minimize plant personnel exposure to any radiological additions that might be present in responding to the event.

Now the second bullet there, large bullet, is that also the order essentially adopted the venting capacity requirement that was similar to what was recommended in the generic letter 89-16, you know, more than 20 years ago. So we essentially adopted the same thing. We felt that the basis for that was still valid.

MEMBER CORRADINI: This is the second bullet?

MR. FRETZ: The second bullet, yes, the capacity is.

MEMBER CORRADINI: And in referencing that, is there an analysis that's attached to that, that one understands why one percent makes sense from a timing standpoint?

MR. FRETZ: Well, we're essentially pulling from the analysis that was done in relationship to generic letter 89-16, in that the suppression pool has the capacity to accept decay heat during, essentially the first three hours of the accident before the pool itself becomes saturated.

And further analysis has shown that any kind of decay heat, following that point, is less than one percent. So we have essentially adopted that same analysis.

MEMBER CORRADINI: If I might just ask, so then is that the limiting case, that is with the range of Mark I designs and Mark II designs, it's either that or longer? That is, I don't have a situation. I don't have a potential licensee that just because of the design of a torus, of the wetwell, excuse me, and their power, three is really two. Do you know what I'm asking?

I'm asking is the three-hour one percent, which actually are consistent, the minimum for all the population of plants, given some past -- you said 89-16 analysis. You know what I'm asking now?

MR. TAYLOR: You're asking is there's a two-hour -

MEMBER CORRADINI: Yes, I'm asking is -

MR. TAYLOR: Is there a plant out there with a two-hour -

MEMBER CORRADINI: I'm asking if there was an outlier.

MR. TAYLOR: Yes.

MEMBER CORRADINI: That's what I'm asking.

MEMBER STETKAR: You can have a different scenario. For example, if ADS doesn't work, for example, and you can't depressurize, you only have the SRVs blowing down. Is there any scenario where you

might want to open a vent to depressurize, which could occur earlier?

CHAIR ARMIJO: Sure.

MALE PARTICIPANT: At a higher power level.

MEMBER CORRADINI: Right, but I guess, but at a higher, as a shutdown power.

MEMBER STETKAR: As a shutdown power.

MEMBER CORRADINI: In all intensive purposes -- I don't to answer for them.

MR. TAYLOR: I think it's a really good question. I think when we looked at this we still felt the basis was valid. But we'll take that back and take a look as we develop the final ISG is, are there any outliers out there --

MEMBER CORRADINI: Right.

MR. TAYLOR: -- that we need to specifically address relative because we are writing a generic guidance document, as opposed to a plant-specific one. But if there's a potential outlier out there where the guidance wouldn't fit or meet, we would also expect that outlier, that plant, to identify that the guidance isn't applicable to it and recognize it.

So we have a responsibility but so does

the licensee. They shouldn't take a guidance threshold and apply it when they know it doesn't fit to their plant.

MEMBER CORRADINI: Okay, that's fine. And the outlier I was thinking of besides system design is not different times of putting stuff into the wetwell but an ATWS event. So that I have some sort of full power event which shortens the time, that gives me less margin to saturation. So that's the one that I guess I wanted to ask about.

MR. TAYLOR: ATWSes are very difficult events to deal with. They are very challenging events from a pressure. And our Steering Committee considered ATWS events as part of the initial conditions for it and said, you're taking a very extreme event, a very low probability initiating event, an external event that causes something of this nature and then you're adding an ATWS on top of it.

MEMBER CORRADINI: That's fine.

MR. TAYLOR: You're complicating the probabilities or you're -

MEMBER CORRADINI: If there's a risk argument, that's fine. I just wanted to make sure that, what was going through my mind was the consistent connection of time with power and outliers

to that.

MR. TAYLOR: It does presume a shutdown of the reactor.

MEMBER CORRADINI: Right.

MR. FRETZ: That's the assumption, that we would have an ATWS.

CHAIR ARMIJO: This came up in the subcommittee and I want to make sure the full committee members hear it.

And that is there was an opinion by one or more members that there are a lot of hardened containment vents out there right now, a lot of variety depending on who designed it, who built them.

And the feeling was that there must be some that are close to, or actually meeting, the requirements of a reliable hardened containment vent but you won't know that until you get the submittals back from the order.

And it was suggested that the staff review those things with enough detail to say hey, there's some best practices out here that we can endorse, or encourage, or something.

Is that the staff's plan, to review the submittals and say hey, this is a state of the industry as far as the existing hardened vents and

this is a best practice? This is a good way to do it. Or is it just, you know, what's going to happen with those submittals, I guess?

MR. TAYLOR: That's a really good question. The plan right now for all the submittals, when we get the integrated plants, is the staff will complete safety evaluations on those plants. So that there is a clear basis for what we accepted and what we approved, as part of the compliance with each of the orders.

It would not be a difficult, or challenging next step, to say that if a plant came in and demonstrated that they had a design that met the intent of the order and we agreed to point to the rest of the industry and say hey, here's a model that you can follow as an acceptable.

We haven't heard a plant come forward yet, to my knowledge, Bob, to say hey, based on the draft of the guidance document here's our checklist and we obviously meet it. Now that doesn't mean it doesn't exist. It just means we haven't heard it yet.

CHAIR ARMIJO: Okay, right, okay. And the other question that came up was a definition of seismically rugged design.

MR. TAYLOR: Sure.

CHAIR ARMIJO: And Bob, maybe you can help us on that?

MR. FRETZ: Well, sure, the seismically rugged design, essentially we're defining that as essentially that the system needs to be designed to withstand the design-basis earthquake, or the current seismic requirements of the plant.

With that said, we are not requiring that the system meet all the requirements of Appendix B, you know, post or downstream of the second containment isolation valve. So therefore, it doesn't meet any of the, let's say Cat 1 requirements for, we inspected the quality control matters.

And so that's why we are trying to use the term seismically rugged design to essentially say, design a system to be able to withstand the earthquake and that it remain functional following the earthquake. But that the system not necessarily meet the safety-related design.

And I think you had a question earlier regarding whether or not the industry understands that.

I guess I can only answer that by the, I guess the absence of a lot of questions on the definition of that during our public meetings, and our

dialogue we've had with the various stakeholders, at least from the industry stakeholders. They seem to understand what the staff's intent is on that.

MEMBER SIEBER: I think that it would be a departure, the Agency's practice to choose a design and say this is superior to these others, that it either meets the requirements or it doesn't.

MR. TAYLOR: That's correct.

MEMBER SIEBER: On the other hand, you might see somebody in the hall and say this is a pretty good one. And the somebody might be NEI.

MR. TAYLOR: Of course, we don't discourage best practices. So you're absolutely correct. We try to promulgate a performance-based requirements and let the licensees propose how to meet those requirements. And then we judge those proposals or we evaluate those proposals.

MEMBER SIEBER: Whether they comply or do not?

MR. TAYLOR: Yes. That's exactly right.

MEMBER SIEBER: As opposed to whether one is better than another?

MR. TAYLOR: But the industry is, I give them some credit. They are good at learning lessons from each other. And if they see somebody who's got

a good design and a good way to do it, that has already been found acceptable by the staff, they try not to reinvent the wheel too often.

MEMBER SIEBER: Right. And they're getting better at that as time goes on.

MR. FRETZ: Yes, right. And then as far as our dialogue with the BWR Owners Group, they are sharing information amongst each other.

MEMBER SIEBER: Yes.

MR. FRETZ: And as it turns out, one licensee has about one-third of all the, you know, that being Exelon, has about one-third of the plants either needing a new system or existing system. So I'm sure there will be no problem with them sharing information on -

MEMBER POWERS: Maybe.

MR. FRETZ: And I just made a commonality of designs, you know, we know say even among licensees in that one.

MEMBER SIEBER: I do have a question that involves some speculation. But obviously the current designs, and the design requirements for hardened vents, does not include its ability to be able to vent hydrogen.

MR. FRETZ: Right.

MEMBER SIEBER: Because that's beyond the design-basis. On the other hand, there have been concerns about hydrogen explosions in the vent systems and examples of where that's happened.

And it is not beyond my personal dream of the future that some day somebody is going to say, you ought to do that and make them hard enough to withstand detonation or deflagration.

And under those circumstances, the work that's being done now and the requirements that are laid on that, are wasted because current vent systems won't meet the severe accident requirement.

Do you see any pathway to resolving that to avoid back pedaling twice? Or what is your vision at how this will all pan out?

MR. TAYLOR: I think it's a very good question. Of course, we want to minimize rework, right, the potential for rework. That's why we're moving as expeditiously as possible on the severe accident aspects of the venting system.

MEMBER SIEBER: Right.

MR. TAYLOR: That activity that we deferred, we do not believe we had enough work done, by the time we had completed the orders in March, to make a recommendation to the Commission on both the

severe accidents and the filtered aspects of what the requirements of the vents should be.

So the staff is working very diligently on the analyses and the assessment of those issues so that we can make a comprehensive recommendation to the Commission on those issues.

We're hoping to complete that in a sufficient, timely manner so that the industry can factor that into the design of the vents that they're putting in. If they're making upgrades and enhancements to those capabilities, they could include what needs to be done, relative to that, to minimize the work.

MEMBER SIEBER: Yes, that will be a challenge because you're changing the regulatory space in which the design must fit. I would hope that it would work out that we could avoid rework and really cover some aspects, some of the more probabilistic aspects of severe accidents. But it's not clear to me that we can do that under the current framework.

MR. TAYLOR: We share your concern. We share your interest in that.

MEMBER SIEBER: Great.

MR. TAYLOR: Absolutely.

MEMBER SIEBER: I figured you would. But

I thought I would put it out on the table anyway.

MR. TAYLOR: We appreciate it. We do, we appreciate that.

MEMBER SKILLMAN: I'd like to go back to Dr. Armijo's comment on seismically rugged. I'm reminded of 30 and 40 years ago when we battled our way through seismic design before we had the regulatory guides that provided guidance, Reg Guides 1.26, 1.29, 1.48, 1.51.

Words matter and seismically rugged will probably be interpreted by many different people, many different ways. It would seem that it might be helpful for the staff to simply say, design-basis earthquake commercial quality. The industry understands that.

MR. TAYLOR: Okay.

MEMBER SKILLMAN: And the industry knows how to build strong robust systems independent from Appendix B to 10 CFR 50. They know how to do it. Most of the fire systems are like that.

MR. TAYLOR: Okay.

MEMBER SKILLMAN: So it might be advantageous to consider what you mean in terms of seismically rugged. And there are probably some words that the bulk of the design engineering teams at the

sites could say, we know how to do that.

And we can make it at least as good, or even maybe better, than what would've come with an Appendix B seismic one system using commercial quality.

MR. FRETZ: Right.

MEMBER SKILLMAN: That might save a whole lot of time and a lot of words.

MR. FRETZ: Thank you, okay. And I appreciate that. That was essentially the staff's intent. Sam, is that -

CHAIR ARMIJO: Yes, that's really helps.

MR. FRETZ: Thank you.

MR. TAYLOR: Thank you.

MR. FRETZ: Yes, I appreciate that. Okay, just turning to the next slide, I guess on Slide 12 is a listing of some of the other major features of the reliable hardened vent.

Again, the order allows remote or manual operation. It does not preclude either. Also, because no core damage is assumed, the order also allows venting from either the drywell or the wetwell currently, as written.

So the system must also include design features to prevent the loss of containment integrity

as a result of inadvertent operator action.

The system must be designed to minimize cross flow. That's even cross flow between units, as well as amongst themselves, such as a standby gas treatment system.

The system must be designed to discharge the effluent at a point above adjacent plant structures. Licensees must be able to monitor that effluent, at least the overall radioactivity of that effluent, that could be released.

And again, like we talked about earlier, the system must be capable of functioning following a seismic event. However, it's not safety-related but again, we could clarify that a little bit better and maybe look at the term used.

MEMBER SHACK: Yes, I guess -- I'm sorry -- like I said, the last time you looked at this with GL-89-16, and the BWR Containment Performance Program, a drywell event was not one of the suggestions.

CHAIR ARMIJO: Yes.

MEMBER SHACK: And what did we learn since then that says a drywell vent is a good idea. I know you've now got this strict separation between prevention and mitigation. But what is the real purpose of, as I say, once you start to think about

severe accidents --

CHAIR ARMIJO: You don't want it.

MEMBER SHACK: Just even if it's in the back of your mind, why not stick with 89-16?

MR. FRETZ: Well, the order itself is nonspecific. It does not say either drywell or wetwell. But it does not preclude the use of either the drywell. That said --

MEMBER SHACK: The Guidance seems to. I mean it permits both. It certainly doesn't --

MR. FRETZ: Right. Like I was saying, we're stating in the negative that the order is essentially is silent on whether or not a drywell or wetwell vent is used.

Because we understand that some plants do have, in their existing systems, drywell venting as well as wetwell venting. Usually many of them have both locations. Some have only the wetwell venting.

CHAIR ARMIJO: The question is, is that still a good idea to have both? Have we really looked at that whole idea of venting, now that we're thinking in terms of mitigation as well as prevention?

MR. FRETZ: Well, under the current framework of the order, the order assumes that no core damage is present. So therefore, there is no, I guess

essential harsh, radiological consequences associated with that. So as of right now, without any kind of severe accident service required under this order, the drywell is satisfactory.

MEMBER CORRADINI: But -- Bill was going to ask the same question. Just from an analysis step, can you give me an example where you'd prefer to do it through the drywell? I might be missing something. So can you give me an example? I understand you want to provide flexibility but I'm looking for an example.

MALE PARTICIPANT: I'm sure Mr. Stetgar would give you an example.

MEMBER STETKAR: No, I don't have an example. But my concern would be the pragmatism of somebody saying well, it's easier for me to meet the requirements for my drywell vent, so this is now my hardened vent to meet these requirements. Because it's easier for me to declare that to be the case. And therefore --

MR. FRETZ: You're right.

MEMBER STETKAR: -- that is what I'm taking credit for.

MR. TAYLOR: And they would meet the requirements of the order. Our order is performance-based in that respect because it's about containment

pressure.

CHAIR ARMIJO: But that would put them on the path to put in the filter.

MR. TAYLOR: Well, if we go there. If the Commission decides that that's the appropriate thing. So a licensee who takes that risk and goes with a drywell vent and makes it meet the requirements of the order.

If we ultimately decide later, that when you conclude the mitigation, it requires you to go to a wetwell vent to meet the requirements of that, then they run a risk. So the licensees have a responsibility to think ahead and plan as well as we move forward with this.

MEMBER CORRADINI: Well, I guess I'm asking, maybe I'm just too naive about this. Technically, why would I do a drywell vent when I have a suppression pool sitting there with the ability to condense, remove --

CHAIR ARMIJO: Scrub.

MEMBER CORRADINI: -- scrub, you pick the verb, I'm just struggling.

MR. TAYLOR: Okay. Bob, go ahead.

MR. DENNIG: This is Bob Dennig. The staff certainly doesn't prefer it. It's just not

concluded by the requirements. And we can't write something in the guidance --

MEMBER SHACK: But you guys set the requirements.

MEMBER BROWN: You set the requirements.

CHAIR ARMIJO: I suspect.

MR. DENNIG: We can't write something into the guidance that's not based on the requirements. As far as the engineering concern, that the drywell vent is a better location for heat removal purposes.

MEMBER POWERS: I suspect that as we sort out Fukushima, in severe accident space, and we look at what's going on up at the drywell head, and the thermal and radiological insult that an even sealing material faces up there, there may evolve some interest in drywell venting.

CHAIR ARMIJO: Some advantage there?

MEMBER POWERS: Well, some interest. I persist in believing it to be misguided but I --

MEMBER CORRADINI: I guess I'm with your judgment, that it is misguided. So I guess I want to get back to -- I didn't mean to interrupt you, Dana -- but I think you're right, it is misguided. So I wouldn't want to encourage them to think in a misguided fashion.

CHAIR ARMIJO: Well, I think you get the sense of concern from --

MEMBER CORRADINI: But I guess I don't understand -- the gentleman that was standing up there disappeared on. The order says, thou shalt go do a hardened vent. So that's the order. It's up to the staff to technically decide what makes sense. And I'm trying to understand, technically, why does a drywell vent makes sense.

MR. DENNIG: The original draft of the order contained a wetwell language and that was struck. And we were told to be non-specific about the location of the vent.

MEMBER CORRADINI: Told by private guidance from commissions?

MR. DENNIG: No.

MEMBER BROWN: By whom?

MEMBER CORRADINI: By whom?

MR. TAYLOR: It was discussed extensively by the Steering Committee, as to whether to be prescriptive in picking the location of the vent and there wasn't a clear basis to prescribe a particular vent location, one over the other. It was to let the licensees make a argument for where they wanted to put the vent for their particular design.

MEMBER CORRADINI: Would the staff welcome some suggestions as to where to put the vent from others?

MR. TAYLOR: We would, of course, welcome --

MEMBER CORRADINI: I'll stop.

CHAIR ARMIJO: Okay. I just had a comment on your chart there about minimizing cross flow between units. Why don't we just say prevent instead of minimize?

MR. TAYLOR: Prevent is a hard thing to prove.

CHAIR ARMIJO: What?

MR. TAYLOR: Prevent is a hard thing to prove.

CHAIR ARMIJO: Well, and what, no connection. I'm reminded of Unit 3 and 4 at Fukushima, a common stack. And that's what destroyed Unit 4. And why can't we be more --

MEMBER POWERS: And the trouble is you run into the same problem with minimize, minimize with the respect to what. The only minimum that you have specified there is zero.

CHAIR ARMIJO: Yes.

MR. FRETZ: That's the language of the

order so that's where we -

MEMBER CORRADINI: I have a question about your seventh bullet when we're done with your third bullet. I didn't appreciate where that, not required to be safely beyond second isolation valve means. Does that mean inside the reactor building or outside the reactor building?

MR. FRETZ: Okay. Essentially, that was my shorthand essentially summarizing the quality requirements. Whereas, the quality requirements, you essentially have to adopt the current design-basis of the plant for, up to, and including the second containment isolation barrier.

Then downstream of the second containment isolation barrier, it's not necessarily have to be Category 1 seismic, or the current design-basis.

MEMBER CORRADINI: But where does that reside, geometrically? Where would it reside geometrically? Or is that up to the licensee again?

I mean, so here's what's going through my mind. I guess I'm thinking outside of the realm of said design-basis. But if I have some sort of event that chops off everything above the second isolation valve, and it's inside the reactor building, that would give me pause.

MEMBER SKILLMAN: Well, this is General Design Criteria at 57. This is why the wording is as it is -

MEMBER CORRADINI: Okay.

MEMBER SKILLMAN: -- causes the way the Appendix A to 10 CFR 50 -

MEMBER CORRADINI: Oh, okay.

MEMBER SKILLMAN: The General Design requirements are written. And this is General Design Criteria.

MEMBER CORRADINI: Right.

MEMBER SKILLMAN: So what it says is, including the second isolation valve is ASME 3103, it's seismic one and all QA and after that second valve it can be something different.

MEMBER CORRADINI: Okay.

MEMBER SKILLMAN: And that's what their telling us.

MEMBER CORRADINI: Okay.

MR. FRETZ: Yes, that's what we're trying to communicate there. Any other questions? Thank you. I guess, Lisa, we'll go to the last slide.

With respect to the draft Interim Staff Guidance, I guess the order for reliable hardened vents, this Interim Staff Guidance differs from the

other two orders that you'll hear this morning, in that we are not endorsing any industry guidance. The staff, and essentially the draft ISG was prepared by the staff with that in mind.

So we've had three public meetings with industry and public stakeholders regarding the draft ISG. And the interaction has been quite helpful. The number of insights we've gained, not only from the industry but as well as public interest groups, has been helpful.

We've just received about five comments from members of the public during our public comment period. And a number of them did ask that the suggested language changes to some of the various elements of the ISG.

Such as, for example, some wanted us to help clarify what instrumentation was required for monitoring the system status. And so we're going to take a look at that.

But again, we feel that the interaction with the stakeholders has been very key in the development of this ISG. And it has been a very helpful process along with it.

Now again, although, the order for the mitigating strategies order that we heard earlier,

provides move performance-based approach. The staff believes that there is general idea among the ISGs with respect to the orders.

The NEI 12-06 dose of .2, this order in its document, as far as requiring the licensees meet the requirements of this order. The ISG does state though, that the reliable hardened vent should be able to function with permanently installed equipment for the first 24 hours of the event.

The staff reasoning is that during the first 24 hours plant operators will be focused on restoring cooling to the reactor core. And the possibility of even installing what many are calling the FLEX equipment at that time, in order to attempt to restore cooling to the core.

Therefore, consistent with the order's requirements, to design a reliable hardened venting system that minimized the reliance on operator actions, the staff believes that plant personnel should not have to focus on restoring the containment system during this time.

But that their efforts be more aligned with and focused on restoring cooling to the core. That's obviously the most important thing that they have to focus on.

So again, the staff's intent on having the system being able to operate during the first 24 hours, relatively free of installing, let's say additional equipment to help it work, was that it would allow plant operators the ability to focus on restoring core cooling, which is really the most important thing that they have to worry about.

And then they would not have to worry about the containment venting system having to work during this time while their focus was on these efforts. So again, that was the staff's intent in putting this 24-hour requirement.

Again, that said, the ISG does not preclude times less than 24 hours if justified by licensee's analysis. So we do recognize that the FLEX program and the guidance, and so we just want to make sure that licensees, their strategies remain focused on restoring the core cooling.

And that they be able to, at least, demonstrate that at any times less than 24 hours, that they would be able to handle both at once. So again, that was the staff's intent.

MEMBER SKILLMAN: Let me ask this, please?

MR. FRETZ: Sure.

MEMBER SKILLMAN: Permanently installed

equipment, does that mean station batteries? Or could that mean permanently installed, another set of batteries dedicated to this purpose?

What I'm really asking about is the philosophy of your use of those words. Were you really thinking about 125-volt DC safety grade? Or were you thinking, if they permanently installed a dedicated set of batteries for this, that would also be okay?

MR. FRETZ: I think if the licensee responded with either one of those, that would satisfy the staff's intent.

MEMBER SKILLMAN: So it was not necessarily pointing towards the originally installed equipment -

MR. FRETZ: No.

MEMBER SKILLMAN: -- or presently -

MR. FRETZ: No.

MEMBER SKILLMAN: -- installed equipment.

MR. FRETZ: Again, much of the thought was essentially dedicated batteries -

MEMBER SKILLMAN: Okay, thank you.

MR. FRETZ: -- for that, as well as even installed nitrogen bottles at strategic locations to provide the mode of force for, well, most of the time

they use air operated valves in many of these systems. And so that will at least provide the mode of force for that, to operate those valves. So that was the staff's intent.

MEMBER SKILLMAN: Thank you.

MEMBER STETKAR: Bob? Something that, and I'm trying to skim through, quickly, the ISG here to see and maybe you can help me. And I didn't think about this in the subcommittee meeting.

The term manual operation is used an awful lot. And does the guidance indicate that the valves need to have capability for low cold, and I'll call it mechanical operation to avoid this term manually?

You talk an awful lot about alternate power supplies, alternate pneumatic supplies, alternate means of moving the thing that is other than a mechanical crank, let me use that term.

And if the valves are motor-operated valves, okay, they typically will have some sort of mechanical device to operate the valve. Whether or not you can physically touch the device, given the location of the valve, is a different issue.

And often time air-operated valves don't have those devices. So is the intent to also, have local mechanic capability to operate these valves?

MR. FRETZ: Essentially, we would allow local manual operation of valves and maybe --

MEMBER STETKAR: That's not what I'm asking. Certainly you would allow it. The question is, do you require it? So for example, I can't hook up the nitrogen bottle to it.

MR. FRETZ: Bob, do you want to talk about -
-

MR. DENNIG: Yes. I believe and I don't think we raised during the subcommittee simply because I believe the answer is no, we're not requiring that they have, in addition to some way of operating it standoff to have a manual wheel.

MEMBER STETKAR: Okay.

MR. TAYLOR: We'll take it back for consideration. Thank you. Any other questions?

MS. REGNER: The last Interim Staff Guidance we'll discuss is associated with the spent fuel pool instrumentation order. My name is Lisa Regner. I'm the project manager for this order.

I'm going to provide a short overview of the standards required by the order. I'll talk about the key features of the proposed guidance document submitted by the Nuclear Energy Institute.

And I'll also cover the exceptions to the

NEI document. And I do want to specify that's Revision B. We have recently received a new revision from NEI submitted as a comment. The staff is still reviewing that revision.

But the purpose, as Eric said, is to try to align what the staff wants and NEI guidance as closely as possible. So this Revision 0 was submitted to incorporate the staff's exceptions. But what I will talk about here is Revision B exceptions.

So this is a summary of the key performance criteria from the order. The purpose of the order is to require reliable instruments to monitor the level of the spent fuel pool to enable emergency responders to make appropriate event response decisions.

Specifically, the order requires one permanent primary level instrument and one backup instrument, that may be permanent, portable, or a combination of permanent and portable.

The display may be located in the control room or at another easily accessible and protected location. Indication is to be continuously available but may provide on-demand monitoring.

MEMBER BROWN: What does that mean again?

MS. REGNER: Basically, it means they can

take, for instance, they can take a battery-powered monitoring device, an operator can go locally to a hookup. Hook up the battery power and get a reading, get an instantaneous reading.

MEMBER BROWN: Is that as an alternative to a continuous?

MS. REGNER: Yes.

MEMBER BROWN: Then how come you have the words, "continuously available," but then you can do it noncontinuously?

MS. REGNER: It's continuously available in that they can get a reading at any time. They don't have to install the entire instrument but they may have to send, we do allow them to send an operator to obtain a reading.

And the whole purpose of that is so that they're not draining a battery. It will allow a battery to last much longer so that they can obtain that. They can monitor for a longer period of time.

MEMBER BROWN: If the system is simple enough, and I've already looked at, still retained the second slides, that we had a late discussion on in the subcommittee meeting. And in simple systems, you can have a battery-operated, it will last for months.

CHAIR ARMIJO: Yes.

MEMBER BROWN: Okay, as opposed, so you don't have to worry about draining the battery if it's an independent set up to do that.

MS. REGNER: Yes.

MEMBER BROWN: So go ahead. I'm just trying to make the point that it seems like nothing changed subsequent to the subcommittee meeting.

MS. REGNER: Right.

MEMBER BROWN: And the continuously available is kind of mushy. If it's continuously available to me, it says I can read it all the time.

CHAIR ARMIJO: Right.

MEMBER BROWN: And it could be normally powered from your normal sources. And then if you lose those sources, you've lost all power, whatever it is. The battery takes over.

And if you don't have a complicated, microwave, x-ray, radio controlled, wireless thing that consumes five million megawatts just to get a little signal out of the spent fuel pool, it'll last for months.

MS. REGNER: Yes.

CHAIR ARMIJO: If it's simple.

MEMBER BROWN: And yet we just allow anything to come in, as opposed to forcing it in the

direction where it is number one, simple and reliable.

MS. REGNER: Right.

MEMBER BROWN: And continuously monitorable.

MEMBER CORRADINI: So you want to help them.

MEMBER BROWN: I'm trying to help them. But we tried to help them in the subcommittee --

MR. TAYLOR: And we understand. We heard all the comments in the subcommittee. We haven't changed anything yet.

MEMBER BROWN: I noticed that.

MR. TAYLOR: And that's on purpose. Because the comment period was progressing. We didn't want to come in here with a bunch of changes as we get comments from all the stakeholders who are giving us comments. We'll take all of the comments we get and look at what changes should be made to the ISGs collectively.

So you're absolutely correct, we haven't changed anything since the subcommittee meeting. But that was on purpose so we could collect all the comments. Because we might get a comment quite to the contrary and we want to be able to make sure we hear what is --

MEMBER BROWN: These are contrary to what we suggested.

MR. TAYLOR: Somebody might say this is a perfectly good answer, who heard the subcommittee, and might have provided a comment that said, we disagree with the ACRS on that. But that's a hypothetical. So your point is very valid, very important. And we'll take it back and we'll take a look at it.

CHAIR ARMIJO: In this permanent backup instrumentation, is there any kind of requirement or expectation that they're diverse? Or assuming you had an installed instrument, would it be okay to come in with a backup instrument that's exactly the same instrument?

MS. REGNER: There's no requirement.

CHAIR ARMIJO: Okay, there's no requirement --

MS. REGNER: They can have the same exact instrument.

CHAIR ARMIJO: It can be the same or they can be different?

MS. REGNER: Yes, sir.

CHAIR ARMIJO: Okay.

MEMBER REMPE: I missed the subcommittee meeting. But during the events at Fukushima, they

relied on an indirect water level indicator. But they also relied on the thermocouples in the cool cleanup system as a method for when you have a bunch of junk in your pool, to understand what's going on, where a water level indicator might not help.

If all of the U.S. plants have such thermocouples in their cool cleanup systems, then maybe this isn't an issue. But it was sure nice, the thermal imaging didn't help a whole lot. And so those thermocouples were useful.

Other countries are saying let's put a temperature indicator in. And I believe, when it was discussed originally in the Near-Term Task Force, that was going to be included along with the water level indicator. And I just am wondering what the logic was for taking it out.

MS. REGNER: The staff did discuss, at length, the recommendation, the three recommendations. For example, the parameters were temperature, radiation, and level.

The staff did conclude that level would be, again, we're talking extreme events, low probability events, the staff felt that in keeping with a simple instrumentation, again, performance-based criteria for this order, the staff determined

that level would, in fact, provide the most vital information on condition of the pool.

MEMBER REMPE: Did the staff go through and verify that all the U.S. plants have thermocouples in their pool cleanup system as part of that decision process?

MS. REGNER: Go ahead, Steve.

MR. JONES: This is Steve Jones in the Balance of Plant Branch in NRR. We considered what would be available to operators under beyond-design-basis conditions.

For most of the plants the cleanup system requires operation of the cooling system and power that may or may not be from a safety-related source in order to provide that as a valid indication of what's going on in the pool.

We also considered that the conditions in the pool, temperature wise, we were only talking of a 60 degree or so variation between normal operating temperature and boiling.

And it really doesn't, under the high-heat load conditions we're most concerned with, that doesn't take a long time to transit through that.

MEMBER REMPE: And when you have a lot of junk in your pool it's just nice having something else

to think about, to give you an insight of what's going on.

MEMBER BROWN: Wouldn't you like to know it's boiling?

MEMBER REMPE: Or that it's heating up a lot?

MEMBER BROWN: Here's another example. Thermocouples, RTDs, whatever, you can sprinkle temperature devices all over the place to a little panel where you take the multi-meter, a 9-volt battery, it will last for months, months.

And you can go monitor the temperatures and see what ever they're doing. It's simple. It's wires, blacksmith technology. And it's so easy it just boggles my mind.

I'm sorry to be emphatic but that's just part of my personality. It boggles my mind that something can be so simple to do and yet we're making, and allowing, the potential for extreme complexity or rejecting certain things.

Well, gee there's only 60 degrees to boiling. Well, I think I'd like to know if the spent fuel pool is boiling. I think. I don't know. Is it kind of important if you know it's boiling? You've got all kinds of crap coming off of it.

CHAIR ARMIJO: You have no cooling. The pool isn't draining down. The level is fine, stays fine, except it's going to boil off. Okay, so it would be nice to know if it was a temperature we see increasing in the pool.

MEMBER BROWN: Yes.

CHAIR ARMIJO: But again, it doesn't need to be a Taj Mahal. It just has to be a simple thermocouple. I'm surprised they don't exist right now.

MR. JONES: Licensees would be free to go ahead and install additional instrumentation. The level provided the minimum set of data that we considered important for the decision making we were looking at in response to a beyond-design-basis external event.

CHAIR ARMIJO: But, you know, it would take a long time before you had a temperature indication of a problem compared to a water level indication of a problem. Those are big, deep pools. It takes a long time to heat them.

MEMBER REMPE: But you've got junk in your pool.

CHAIR ARMIJO: Haven't had a hydrogen explosion yet in this scenario.

MEMBER REMPE: It just would be nice to know, do we have thermocouples in the cleanup system.

CHAIR ARMIJO: I think it would be nice to do.

MEMBER BROWN: I don't think it's a matter of being nice, is it? I think it's a matter of considering what our lessons learned, our experience to-date, in a fairly severe environment and the lack of information, and the compromise of actions that were taken by operators, or they didn't take, because they didn't know what was going on.

MR. TAYLOR: We believe the level indication will give them the information necessary to make those decisions. The Steering Committee heavily discussed this and focused on the level indication.

That you're absolutely correct, in an event where loss of cooling of the pool occurs, the pool will heat up and will eventually boil if cooling is not restored.

And that will be indicated by a change in the level of the pool. So we will get an indication. And these are spent fuel pool events, like Fukushima demonstrated, that it's a slow progressing event.

CHAIR ARMIJO: Sure.

MR. TAYLOR: We want to make sure that

the operators have the information so they can understand what's going on. But we don't want them distracted and responding to a spent fuel pool condition if they have an ongoing condition with the reactor core.

I think it could be done. We decided it was not necessary at this time to require enhanced temperature indication, doesn't mean we can't require it in the future if we determine it's necessary.

MEMBER STETKAR: The only thing I've run into, and I've done some risk assessment work with utilities, spent fuel pool things. Most people who run power plants tell me they're not going to send anybody into the fuel building if the pool is boiling, in terms of dose.

So for example, once it starts to boil, if it's a lost cooling event and then you start to lose level. If some of your mitigation functions require people to go take either local level indications in the fuel building, or local makeup to the hoses or something like that, there could be a substantial reluctance to send people in there with the knowledge that the pool as started to boil.

MR. JONES: That's something I've run into just in terms of the reluctance of plant owners. They

typically will look at conditions of boiling in terms of guidance to send people to the pool edge, if you will.

MR. BOWMAN: Understand the industry guidance for the mitigating strategies orders includes a specification of a permanently installed connection to the spent fuel pool --

MEMBER STETKAR: Right.

MR. BOWMAN: -- makeup system that diverts flow from the deck to be able -

MEMBER STETKAR: Yes, I'm aware of that.

MR. BOWMAN: -- to refuel the pool without accessing the deck refill.

MEMBER STETKAR: Okay. Thank you.

MEMBER POWERS: In the aftermath of Fukushima, there was quite a lot of discussion in the Japanese popular press, not so much here in the United States, about the level of whether the spent fuel pool was, in fact, distorted, or shifted, or something like that.

MS. REGNER: The sloshing you mean?

MEMBER POWERS: What.

MS. REGNER: The sloshing of the pool --

MR. TAYLOR: You're talking about the actual building structure?

MEMBER POWERS: Yes, the building structure --

MS. REGNER: Oh, okay.

MEMBER POWERS: -- distorted away from. Did that enter into your thinking on this instrumentation business at all?

MS. REGNER: We did consider say catastrophic failure of the structure --

MEMBER POWERS: That would be pretty obvious.

MS. REGNER: Yes, right. And then that was exactly, and since that didn't, in fact, that the structure was sound at Fukushima, we decided not to address --

MEMBER POWERS: Well, I think --

MS. REGNER: The answer is yes. We did consider the structure soundness of the spent fuel pool.

MEMBER POWERS: Well, I think what I'm asking about, I think what was being discussed at the time was much more modest than that, shifting and whatnot. And I think people were interested in whether racks has slid and moved against each other or something had changed within the pool.

MS. REGNER: Yes.

MEMBER POWERS: So I'm just asking. Did that kind of thing get discussed? And what was the nature of that discussion?

MS. REGNER: We did not assume severe structural damage such as that for this order.

MR. JONES: This is Steve Jones, Balance of Plant Branch again. We're looking at this, I guess in a margins perspective and anticipating that the pool would have relatively large seismic margins often to other components in the plant.

And from that regard, recognizing we can't design for every eventuality, the level instrument would provide the best and broadest indication what was going on in the pool for an extended period of time. That was really our decision.

MEMBER POWERS: Well, for some reason people were concerned about that. And then maybe it's not the huge margins that you might be willing to exist.

What I'm coming from, in raising the issue, is a fundamental lack of faith, that we can anticipate with our instrumentation the questions that will be asked at the next accident we have.

Since having gone through several of these now, and everyone of them have been followed by, we

need better instrumentation because the operators need to know what's going on and they didn't have it here.

No matter what instrumentation you put in, you're going to have other kinds of questions. And that seems to be one of the questions that come up somewhat periphery.

There was no problem at Fukushima. And there probably is no problem at our plant. I just wondered what kind of discussions you had on that. Because presumably you're not designing against severe accidents. But you are designing against design-basis seismic events.

And seismic events change things away from absolutely horizontal or vertical. And that may be something that people want to know about in responding to a design-basis accident. Though, quite frankly, the easiest thing to do with a spent fuel pool is to look at it.

CHAIR ARMIJO: I think we had one other issue that we did talk about in the subcommittee, and that was a resolution with kind of a strange set of resolutions, one put at the top level --

MEMBER BROWN: I told you I'd already read ahead.

CHAIR ARMIJO: Oh, you did?

MEMBER BROWN: And they didn't -- and then he answered the question, they've done nothing to anything.

CHAIR ARMIJO: And that hasn't changed so --

MEMBER BROWN: Don't take my emphasis on the nothing.

MR. TAYLOR: I understand.

MEMBER BROWN: I wasn't trying to --

CHAIR ARMIJO: We had a lot of discussion on it.

MR. TAYLOR: We will take the comments from the subcommittee meeting, as well as from this meeting --

CHAIR ARMIJO: Yes.

MR. TAYLOR: -- and consider that.

CHAIR ARMIJO: You'll address that.

MR. TAYLOR: It's just we haven't made a change yet. We haven't decided to make an explicit change yet. If we do, we'll take it back to our Steering Committee, discuss it with the Steering Committee, make an informed decision.

If we need to take an exception to the guidance document that the industry proposed and refine what our expectations are, we will do so. But

we just have not reached the conclusion that we need to make the change yet. And it's not because we don't agree with it. It's because we haven't fully vetted and discussed it internally yet.

CHAIR ARMIJO: Okay. All right, please, go on. We're running a little late and we do have some comments from a member of the public that I'd like to get in. So let's --

MR. TAYLOR: Okay.

CHAIR ARMIJO: -- try and wrap it up.

MS. REGNER: Okay. In developing the guidance associated with the order, the staff initially wrote its own guidance to assist and promote discussions during stakeholder interactions. I think this was key in a resulting NEI guidance, that was very very aligned with the staff.

They did submit Revision B on May 11th, as I stated earlier. They have since submitted Revision 0 on July 5th. And the staff is currently evaluating that.

The comment period ended on Monday, this past Monday. We have received six comments. Some of those comments are in-scope, some are out-of-scope. I can discuss those if you'd like. But if not, I'd like to just go on and briefly talk about the

exceptions, if you'd like to hear those in the ISG.

CHAIR ARMIJO: Sure.

MS. REGNER: They're basically the same as discussed during the subcommittee. Primarily, the staff and these are the staff's disagreements with the, not disagreements but clarifications that the staff would like in the final NEI guidance.

MEMBER BROWN: These are things you want put in. In other words, in the present one, just to calibrate me, specify that instruments must be able to resist beyond-design-basis external events. Right now it doesn't say that and you want that thought process in the document?

MS. REGNER: Correct.

MEMBER BROWN: Okay, all right. I was just trying to get what we mean by exceptions here.

MS. REGNER: Right, right.

MEMBER BROWN: Thank you.

MS. REGNER: And again, this Revision 0, they did attempt to address every one of our exceptions. Okay, the ISG describes acceptable criteria for instrumentation readout indications.

The use of sets of instruments. In other words, more than one instrument should read the full range from normal to the top of the fuel racks. And

acceptability of continuous or discreet instrument indications to meet the minimum criteria for resolution and accuracy.

The ISG clarifies the personnel-based dose criteria for Level 2, and that the readings are to be available to appropriate plant staff and decision makers promptly when required.

The staff also provided a detailed integrated plan template so that licensees will understand the level of detail required by the staff, so that they can write a safety evaluation. Any questions?

CHAIR ARMIJO: Okay. Just very quickly comments, questions from the staff. We do have comments submitted by Mr. Mark Leyse and I think I'd like to open it up and have his comments heard.

He's on the bridge line and he also submitted some documents which we've distributed. And he asked us to project a couple of slides from his documents, which we're going to do shortly.

MR. LEYSE: Yes, this is Mark Leyse, can you hear me?

CHAIR ARMIJO: Yes we can, please, go ahead.

MR. LEYSE: Oh, okay, great. Yes, my name

is Mark Leyse. I want to thank the ACRS for giving me the opportunity to speak today. I am speaking about a short paper I wrote for NRDC, post-Fukushima hardened vents with high capacity filters for BWR Mark Is and Mark IIs.

But I want to clarify that I'm speaking on my own behalf and not for NRDC. May I have the first slide projected, please?

CHAIR ARMIJO: It's on the screen. I believe it's a text on total quantity of hydrogen that could be produced in a severe accident.

MR. LEYSE: Yes, thank you so much. On this slide is, as you just said, information about the total quantity of hydrogen that could be produced in a severe accident.

And it is generally estimated that a total of 500 kilograms of hydrogen was produced in the Three-Mile Island accident. Yet, in a BWR severe accident a total of over 3,000 kilograms of hydrogen could be produced from the oxidation of the zirconium.

What we see is a quote from a 1988 Oak Ridge National Laboratory report, that spells that out, that the entire zircaloy inventory of the reactor would eventually oxidize, if there were a complete meltdown.

And then there's another quote from an IAEA paper, which spells out the difference in the quantity that could be produced from a PWR core and also, from a BWR core. And we see that it's significantly greater for a BWR core.

In fact, if we factor in the steel and also boron carbide, up to perhaps 4,000 kilograms of hydrogen could be produced in a BWR complete meltdown.

Also, in a severe accident if there were a re-flooding of an overheated core, over 300 kilograms of hydrogen could be produced in one minute.

The NRC's Near-Term Task Force reports on the Fukushima accident does not mention anything about the total quantity of hydrogen that could be produced in a BWR severe accident.

Nor does it discuss hydrogen production rates. I think those are two of the key issues if you want to address the hydrogen that is produced in a BWR severe accident and attempt to mitigate it. May I please have the second slide projected?

CHAIR ARMIJO: Okay, it's up.

MR. LEYSE: Thank you. On this slide is a quote that says, "Filtered venting is less feasible for those sequences resulting in early over-temperature or over-pressure condition. This is

because the relatively early, rapid increase in containment pressure requires large containment penetrations for successful venting."

So I hope you keep that in mind because there could be scenarios in which there was re-flooding of an overheated core, which would rapidly produce hydrogen and cause a rapid containment pressure increase.

Also, on this slide as Sal Levy stated in a 2011 article, there could be scenarios in which early venting would be necessary.

The NRC should also consider that not all severe accidents would be like the Fukushima accident, slow moving, if you will, accidents, station blackout, accident caused by natural disasters.

Fast moving accidents could also occur. For example, a large-break loss of coolant accident could rapidly transition into a severe accident. A meltdown could commence within ten minutes after an accident initiated.

Early venting might be necessary in a fast moving accident scenario. A high-capacity filter would help protect the surrounding population, who would not have time to evacuate, and prevent becoming exposed to radioactive releases.

This is discussed in more detail in the paper I wrote, along with other safety issues. In the paper I conclude by recommending that a hardened vent be designed so it would perform well in scenarios in which there were rapid containment pressure increases.

I state that if such a vent can not be developed, the NRC should perhaps consider, either shutting down or not relicensing BWR Mark Is and Mark IIs. And I also recommend that the NRC require that high capacity filters be installed in addition to hardened vents. Thank you.

CHAIR ARMIJO: Okay, thank you, Mr. Leyse. Now I'd like to just quickly ask for comments from the Committee. And if there are none, I'd like to thank the staff for the presentation.

I covered a lot of material and we're just a few minutes behind schedule. So I'd like to reconvene, take a break and reconvene at 10:20.

(Whereupon, the meeting in the above-entitled matter went off the record at 10:02 a.m. and went back on the record at 10:21 a.m.)

CHAIR ARMIJO: Okay, we're back in session. And John Stetkar will lead us through this briefing. We have a quorum.

MEMBER STETKAR: Thank you, Mr. Chairman.

We're going to hear this morning from the staff and EPRI on NUREG-1934/EPRI 1023259, about fire models. We had a subcommittee meeting on this topic on March 21st.

There are, and Mark I'm sure will give us some background on this. But part of the background on this particular new reg is it's developed primarily to provide some practical guidance to fire modeling to people doing fire analysis.

And how to use the available modeling capabilities, things to be aware of, kind of good things bad things about particular types of fire models.

It was also developed in part in response to a letter that the ACRS wrote back in, I think it was 2008 or 2009, regarding the treatment of uncertainties when people use these fire models, both in terms of addressing modeling uncertainty and uncertainties in the parameters.

So this new reg also, in addition to being practical guidance about the use of the fire models themselves, also addresses that issue. And with that I will turn the discussion over to Rick Correia.

MR. CORREIA: Thank you. Good morning. Just briefly, we feel we're ready to publish NUREG

1934. We've been through two rounds of public comments and stakeholder interactions.

We piloted it during our advance fire modeling training course. We had reviewed a comment by the PRA subcommittee, pretty much in sequence after their review of two major fire reports, the fire HRA and modeling efforts too. So we appreciate that very much. We believe or customers and NRR are satisfied with the project and the NUREG. And we look forward to a letter from the committee. Thank you.

MR. SALLEY: I'm Mark Salley from Research. The branch chief of the Fire Research branch. And Rick Wachowiak is here from EPRI. Again, we've worked together on this as a partnership. Slides here.

For anybody that's listening on the phone, and I got an ML number. Let me just get that out of the way if they want to download the slides so they can look at it. It's ML12192A143. Again, that's ML 12192A143. And those slides are probably available.

Again, the purpose of the meeting, and why we've come here today, is we've completed the project. We feel this project is done, it's ready for prime time. We're ready to move on to some other projects.

As John said, on the 21st of March we had

an excellent meeting with the PRA subcommittee. And I'd just like to take a second now to the side and re-emphasize what Rick said.

We had two major reports that we hit them with, both five year projects. And the one was a Fire HRA project. And the second one was this Fire Modeling. And I think we really, we threw some big projects at the subcommittee.

And I just am amazed at the detail and the quality of comments and the discussions, if you go back and look at the transcripts and the exchange. So I really want to thank you, John, and the subcommittee, because it was, I mean, they caught things we missed.

And we'd been working on it a while. And it was just an excellent exchange. So thank you for that. Today we're going to have our technical leads give you a quick overview of the project and how it came together.

And again, where we're heading in the future with fire modeling. We're not done. This just puts another cornerstone in for us. And we'd like to get a letter from the ACRS endorsing this document.

Again continuing on with the purpose of this report. EPRI had a report in 2001 that was

beginning to get a little dated. But it was a fire model users guide. It goes back actually to the FIVE method, if you remember, the IPEEE and Generic Letter 88.20 supplement 4.

That's kind of the origin of that and where the fire modeling started to pick up. So it clearly needed updated. We saw this as a good opportunity to team up and work under the memorandum of understanding, because both of us could use the document.

Also, we had other documents come into play since that original 2001 EPRI report. A big one was the V&V, where we did 1824, and we had a solid V&V, and how does that incorporate in.

Another area that we've been looking for is, there's a lot of textbooks on fire dynamics and fire modeling, but none for the nuclear industry. So we wanted something for our people, for our inspectors, and for our licensees that dealt with the unique situations and the unique construction of a nuclear power plant.

So we wanted to have a text for them that we've included as our fifth module now in our fire PRA training, which by the way is next week. If anybody's interested, it'll be the first thing. I could throw

a commercial in there, huh?

CHAIR ARMIJO: Yes.

MR. SALLEY: Commercial spot. And so we wanted to get that textbook. And it serves that purpose. And again it also, as we get more into fire modeling for the reviewers, we wanted a consistent way of doing it.

So we hope to present a model consistent way of doing fire modeling type calculations. So that was the purpose of why we did what we did. That probably drove how we assembled the team.

MR. WACHOWIAK: Okay. As Mark said, I'm Rick Wachowiak from EPRI. We worked on this project jointly with NRC research. We have a, what we call the memorandum of understanding that allows us to work together on these research projects, share data, share research, and come up with the, essentially the best available information concerning various topics.

And on this one we put the team together to address a standard or solid way of addressing use of fire models that are out there, and how to address things like the V&V information that's out there. And also to address uncertainties.

So we worked on this as a joint publication. We put a team together that consisted of

NRC experts, industry experts. We drew from the vendors and from the consultants that are doing fire PRAs, and NFPA 805 transitions in using non PRA methods.

These teams together -- We got the National Institute of Standards and Technology together, NIST, to work on this with us. And also had, made use of various universities to either help us develop the report, or to do the review.

So our review came from places like University of Edinburgh and Cal Poly. Also we used people from University of Maryland to help develop the examples that are listed in the report. So this is the team that we used.

And we think that after this collaborative effort we've come up with a substantive document that is very useful to the readers and to the users. Go ahead, Mark.

MR. SALLEY: Next slide is just a little time line. I won't get into detail here. This is something you can look at later. But it kind of gives you just a feel for this project.

And as we said, the same thing in the HRA, when you look at these big projects like this, and you see that basically this is going on a six year effort,

that you can look at it one way and say, how did it take you so long to develop this report?

Or you can look at all the steps and all the pieces and parts that went into it and say, you guys really made good time getting this done in six years. So it's, you know, half full, half empty, you know, the glass is twice the size it needs to be.

But there was a lot of steps in this dance. And I think we've done it properly. We've checked all the right blocks. And I think we have a quality document. So this kind of gives you a little overview.

MR. WACHOWIAK: So the next thing we're going to do is, we're going to bring up our technical leads to walk you through the various areas of the report. We've got Dave Stroup from the NRC, who pulled most of the report together, and did a lot of good work there.

Kevin McGrattan from NIST, and we want to congratulate Kevin, who recently received the Ralph Jensen Award from the Society of Fire Protection Engineers, for his work in influencing the state of the art in fire modeling, and the use of V&V, which is kind of the topic of what we're doing a lot in this report.

And then Francisco from Hughes Associates, who is the technical lead from the industry side. Between Kevin and Francisco they did a lot of the calculational work and things in the report to get these put together. So bring these guys up.

MR. STROUP: As Mark said, I'm Dave Stroup. I'm the Senior Fire Protection Engineer in the Office Nuclear Regulatory Research. We have been working on this guide over the last five years. And I think we've developed a nice quality product here.

I've put this sort of introductory slide up here about the fire modeling process, that I won't say we came up with it. It's pretty similar to the process that's been presented in numerous different publications with regard to using fire modeling and similar types of analyses in the fire protection performance based design arena throughout the world.

As Mark said earlier, we wanted something that was tailored specifically to the nuclear industry. A lot of the information that's currently out there in the mainstream of fire protection, if you will, remains generic in its application. And never gets down to anything very specific.

Specifically here, and what we've done with the uncertainty piece, is begun to attach numbers

to the model calculations. In most of fire protection today, you do a model calculation, you get an answer, and it's assumed to be the answer.

And it's presumably compared to some hazard criteria. And it's looked at as a pass/fail. Nobody ever takes the next step to say, how accurate is that model? See, we wanted our guide to be application neutral.

Fire modeling has a lot of applications in the nuclear industry. NFPA 805 is the obvious one. It also has applications in the significant formulation process, exemption requests, fire hazard analysis, and other areas.

So we wanted the guide to focus specifically on fire modeling, and how to actually do the fire modeling piece of the analysis. We went through two rounds of public comments, as well as did a peer review.

And as Mark indicated earlier we have pilot tested this document twice for our -- We hold an annual training class together with EPRI on how to do fire PRA. And typically there's two sessions of that class that are offered every year.

There's five modules. One new module that we added when we produced the draft of this guide was

the advanced fire modeling module. By pilot testing that document it gave us the opportunity to find out where the holes were.

I'll mention a little bit later, but in recent discussions we found that some of the problems that we tried very hard to specify were perhaps not completely specified to the degree we'd like.

So we used both the public comments and the pilot testing to identify holes in the document. We'll do one final pilot testing next week to try and make sure we've gotten all the typos.

I know I was responding to a question last week from a member of the ACRS and realized that there was a typo in part of that section. So there's a few more. I've read the document so many times now that it's hard to really read it with objectivity anymore.

During the first round of public comments, we had over 200 comments on the document. A lot of them dealing with various issues. But most specifically they wanted us to get down to the nitty gritty of how do you actually do these calculations?

And in the first draft maybe we were a little bit light on actually getting down to the specificity level that was necessary, and addressing some of the harder questions with regard to

uncertainty, and things like that.

As part of the peer review also we had university professors look at it to see if the document was, in fact, a reasonable teaching guide. One of the objectives of this guide obviously is to support our teaching of the advanced fire modeling class, and how do you apply fire modeling for the nuclear industry?

I guess part of the measure of success was during the second public comment period we only received one public comment. So hopefully that was an improvement.

CHAIR ARMIJO: I think you did well. I was going to say re-write the whole document. But that's okay.

MR. STROUP: I hope that's not the case. I mean, I've been -- Part of my background, I came from the NRC. Or I came to the NRC about five years ago from the National Institute of Standards and Technology.

And a month or two before I left NIST I actually started working on this particular project with the NRC. So I've been intimately involved with this project for the last five years. And while it's been a worthwhile endeavor, I'd like to move on to

something else.

And as we'll talk about a little bit later, towards the end of this discussion, there are new activities that we identified while developing this guide that we need to move into in order to further support the fire modeling initiative.

And we had a very rigorous discussion with the subcommittee a couple of months ago. And they identified a number of issues that needed clarification enhancement.

One of the biggest ones was use of the models outside the V&V range. When we first did the -- When we first looked at our examples, which we'll hear a little more about later, none of the examples really fit within the V&V ranges of any of the models.

So we were faced with the issue of how to address that. So hopefully we've provided some guidance on how to do that now. And there were some other issues about we attempted to bring in some new models into the discussion, THIEF and FLASHCAT, which are a couple of models that have been developed recently based on research by NIST and Sandia National Laboratories.

Just recently we had an inquiry from our friends in NRR about a new model that was, or a sub

model of the THIEF model that was developed out at Ohio State. And how or if, or whether it would be worthwhile to incorporate in that model. So we got some guidance in the document about how to incorporate results from new models. Or what to do if you've got a new model.

MEMBER STETKAR: Dave, is there a -- Do you have a plan in research to perform a formal V&V for THIEF and FLASHCAT? You know, akin to the 1824 type process?

MR. STROUP: Well we have recently -- One of the things you'll hear about at the end of this is we have recently initiated a new project with NIST. NIST has continued forward with V&Ving the models that they're responsible for, CFAST and FDS.

MEMBER STETKAR: Right.

MR. STROUP: But we have also initiated a project. And our friends at EPRI have joined in to continue V&Ving the models that are, the core models that are identified in the user's guide. You look at the information in the V&V guide.

Kevin will get into this with Francisco shortly, about the validity range. Well the validity range is not necessarily the range over which the model is valid. It's the range over which we chose to

incorporate test data at that time. NIST has moved on and expanded that range for their models. We want to do that with the FDTs, NUREG-1805, as well as everyone wants to include FIVE and --

MEMBER STETKAR: Okay. So for the moment it sounds like the focus is to essentially expand the range of the applicability of the five identified models --

MR. STROUP: Yes, and when --

MEMBER STETKAR: -- rather than add more to the mix.

MR. STROUP: Yes. We've also been talking to NIST. And Kevin actually came up with this idea that if you look at, for example, the FDTs and FIVE, they're really just spreadsheet implementations of a specific correlation algebraic model.

So what we proposed to do with this new round of V&V is to focus on the specific physical equation, which would allow us to bring in the THIEF kind of models, the FLASHCAT kind of models.

MEMBER STETKAR: Okay.

MR. STROUP: And look at those sub models, if you will, outside the broad zone model or CFD type model.

MEMBER STETKAR: Okay. Thanks.

MR. STROUP: I think that probably covers most of what I had to say. I'll turn it over to Kevin.

MR. MCGRATTAN: Okay. Thanks. My name is Kevin McGrattan. I'm a mathematician at the National Institute of Standards and Technology. And over the course of the last 20 years I've been busy developing fire models.

In particular FDS is, Fire Dynamic Simulator, is a model I'm the principle developer of. I want to just take a couple of minutes to discuss two of the issues that were raised in the ACRS letter that was mentioned during the introduction.

After we finished the V&V study of the five different fire models, the ACRS had a number of recommendations. And the first recommendation was that the user's guide should provide estimates of the ranges of normalized parameters to be expected in nuclear plant applications.

What this really comes down to is that, you know, we did a fire model study. We conducted validation experiments, and so forth. And after that, in talking to people, they said okay, so your models are now validated, right? You say, well yes and no.

To say that a model is validated has

different definitions depending on who you talk to. In the validation study we do list a number of -- And you can go to the next slide, please.

We listed six non dimensional quantities that describe the scenarios that we looked at. And these have to do with, you know, essentially the size of the room relative to the size of the fire, the ventilation rate, the equivalence ratio, the relative distance from the fire that you might have a target, okay.

For any given fire scenario you can take these six parameters and come up with values. And what you see on the chart here, on the right are the range of values that our experiments have. And it's obviously not a complete range.

So with the experiments that we had in hand back in 2007, you know, we tested these models, you know, in that range. But there's a considerable amount of area outside of that range that we didn't consider.

But it wasn't clear from 1824, the V&V study, how do you actually use this information. So what we've done in the current user's guide is that for each of the eight scenarios that we've looked at, we calculated the six non dimensional quantities.

And the cases where our non dimensional quantity falls inside the validation range, we say we're inside the validation range. We're using the model in a scenario for which it's been validated.

However, in many of the cases -- In fact, for every single case that we looked at, these hypothetical scenarios, there were a number of parameters that fell outside of this range.

And Francisco is going to talk, in a few more slides, about how we deal with a situation where you're trying to use a model for a fire scenario, for which the model may not have been validated.

MEMBER BROWN: Can I ask a simple question about validation?

MR. MCGRATTAN: Yes.

MEMBER BROWN: Did you ever really set any fires and validate based on actual fires and --

MR. MCGRATTAN: Oh, yes.

MEMBER BROWN: So you did the real physical stuff? Okay.

MR. MCGRATTAN: So the validation study consisted of 26 separate fire experiments.

MEMBER BROWN: Okay. Excellent.

MR. MCGRATTAN: But of those 26 experiments there were only essentially six. These

were six test series. So within one test series you might have multiple experiments. So when you actually calculate these non dimensional quantities you see that our validation study is somewhat limited.

And that comes up over and over again when you try to apply these models to the wide range of possible fire scenarios that you could have in a nuclear plant.

MEMBER BROWN: Were these volumetrically limited? Such that you had to extrapolate to larger volumes in scenarios based on, you know, trying to use the models? And obviously you don't go burn down seven story buildings.

MR. MCGRATTAN: Right, right. So all of these, in all of these experiments the fires were limited in size to, you know, relative to the compartment.

But if you look at these non dimensional quantities, I mean, much like a Reynolds number or Froude number, you can extrapolate based on the fundamental physics. And that's what we want to do.

We want to quantify, what does it mean when you say I have a big fire in a little compartment, or vice versa? What does it mean to be over ventilated, or under ventilated, oxygen limited,

fuel limited? We wanted to put numbers to that.

Because up to now what we're seeing in fire model analyses both inside the nuclear community and outside, is that there's a lot of hand waving that goes on, like yes, my fire scenario's kind of like that stuff that they tested at NIST 20 years ago.

But what does it mean, kind of like? We want to really say set forth in this document that we're reviewing today, how do you calculate these quantities and are you or are you not inside this range.

And a lot of the five years that Dave talked about was devoted to this issue. Because when we created these six or eight scenarios five years ago, we did it just based on what everybody assumed would be typical fires within plants, based on past experience, and so forth.

We didn't say, we didn't think, were these scenarios inside our validation range? And what we found was that most scenarios that you consider don't fall neatly within the range for which you test this.

MEMBER STETKAR: So there you go.

MR. MCGRATTAN: So there you go. And that's --

MEMBER BROWN: Why am I not surprised?

MR. MCGRATTAN: Yes. And a lot of the public comments came back, and rightly so, saying hey, you only tested this model in this range. Looks like you're pushing it. And indeed we were. So we had to come up with ways of justifying use of the model.

And in some cases, what we did is, we had to say, you know what, you're right. We can't use this model for this application. It's too much of a stretch. So we ourselves were disciplined in some sense.

MEMBER BROWN: Thank you.

MR. MCGRATTAN: Just a follow up on what I was saying before. This is a nice schematic diagram that Francisco put together. And it's in the guide. And we use it to discuss what we mean by sort of typical fire scenarios within plants.

So here you have, you know, in very simplistic terms, different kinds of compartments. If you're familiar with nuclear plants you could probably readily identify the types of compartments we're looking at.

And if you look at those, the L, the H, the L sub f, you know, flame heights, ceiling heights, the dimensions of the room, these are the fundamental quantities that go into these six non dimensional

quantities. So when you're given a new scenario what we ask the user to do is calculate these quantities to determine whether or not you're inside the range.

And your choice of model selection is going to be guided by whether or not you're inside this range. So even before you start calculating you've got to go through this exercise, even before you choose the model. Next slide.

MEMBER SIEBER: Is it fair to say that the models are more empirical than first principles models?

MR. MCGRATTAN: There are three classes of models that we've looked at.

MEMBER SIEBER: Okay.

MR. MCGRATTAN: Because Dave mentioned they are basically empirical correlations, just one formulas. If I have a heat release rate of a certain value, I can roughly predict the average temperature in this room.

MEMBER SIEBER: That's based on experiments?

MR. MCGRATTAN: Experiments. Drawing lines through data.

MEMBER SIEBER: Okay.

MR. MCGRATTAN: Then we move into what are

called the zone models, in which you start to build in more of the fundamental compartment physics, in which you have average hot layer temperatures and average lower layer temperatures. And these are ordinary differential equations that conserve mass and energy. Then you --

MEMBER SIEBER: Are there simplifications implied to those in order to make it easy to --

MR. MCGRATTAN: Well the major simplification is the assumption that, you know, in a compartment with a fire you just have two temperatures, the hot upper layer and the cold lower layer. That's a big simplification.

MEMBER SIEBER: I think so.

MR. MCGRATTAN: Okay. So sort of the next class we call the zone model. Then we have the CFD models, computational fluid dynamics --

MEMBER SIEBER: Right.

MR. MCGRATTAN: -- in which we're calculating in much greater detail the movement of the hot gases and the detail rated to heat transfer and all of that.

MEMBER SIEBER: Which avoids the two zone --

MR. MCGRATTAN: Which avoids the two zone.

MEMBER SIEBER: -- issue.

MR. MCGRATTAN: Downside of that these calculations can take days or weeks to run. And what we found in watching the licensees is that you typically start your analysis with the empirical correlations. It's to kind of get your hands around things.

Often times that's referred to as a sort of screening process. If in that screening process you find that, you know, a particular fire source doesn't present the hazard to this compartment, however you define that, you may stop there.

But then you move systematically up through the levels of complexity if the problem is warranted. So often times the CFD is not used, is used rarely for situations for which the other models don't apply.

MEMBER SIEBER: Yes. How do you make the decision as to what level you should be at? What's the judgement call?

MR. MCGRATTAN: Yes. And a lot of what you see in the guide in these examples is exactly that. We usually start the analysis with the hand calculations. What we call the hand calculations, the empirical correlations.

MEMBER SIEBER: Right.

MR. MCGRATTAN: If we see that these critical values, say the temperature of a cable, sprinkler activating or so forth. If we see that something --

The simple models are suggesting that we're approaching temperatures that might, you know, damage a cable, then we often go and use the next level of complexity, say the zone model, to get a second opinion. And finally we move to the CFD.

Often times the decision is that if the empirical models are based on certain strict assumptions. And in a lot of realistic fire scenarios these assumptions no longer hold. Like the fact that in most plants you don't have nice flat ceilings.

You don't have a ceiling jet that spreads nicely from a center point. And in which case you might use a hand, or an empirical correlation to see if you're in the ball park of failing a cable.

But if you're not comfortable with some of the assumptions in that hand, in the empirical correlation, you tend to move on to the next level of complexity.

MEMBER SIEBER: Okay. Now my picture of this is that these models give you a mathematical

numerical description of what's going on at a given point in time.

MR. MCGRATTAN: Yes.

MEMBER SIEBER: That the fire obviously is progressing.

MR. MCGRATTAN: That's correct.

MEMBER SIEBER: It's either using up the combustible material --

MR. MCGRATTAN: Right.

MEMBER SIEBER: -- or new sources of oxygen are available, or what have you.

MR. MCGRATTAN: Right.

MEMBER SIEBER: How do you move from time zero to time one to time two to time three --

MR. MCGRATTAN: Okay.

MEMBER SIEBER: -- to show that progression?

MR. MCGRATTAN: Well the zone model is an ordinary differential equation in time. So we're just simply solving these equations. And then we have a time history of the temperature in the upper layer and the lower layer.

MEMBER SIEBER: Okay.

MR. MCGRATTAN: The CFD model, that's a partial differential equation in which every little

grid cell that covers the room we have a time history of --

MEMBER SIEBER: Yes. Provided nothing changes.

MR. MCGRATTAN: Provided that, if we assume a door is open or a door is closed.

MEMBER SIEBER: That's different.

MR. MCGRATTAN: Right.

MEMBER SIEBER: The door, if the door burns down somewhere in the middle --

MR. MCGRATTAN: Right.

MEMBER SIEBER: -- then the CFD constraints change.

MR. MCGRATTAN: Right. But we do include in our calculations -- And you can do it with the zone models and the CFD --

MEMBER SIEBER: Can you do it step by step?

MR. MCGRATTAN: You can do it step by step. For example, there's always the assumption that the fire brigade arrives at a certain time. And you can actually build that into your model. So when the firefighter opens the door oxygen is going to come into the room.

MEMBER SIEBER: Right.

MR. MCGRATTAN: So we do include this kind of time dependence into the calculation.

MEMBER SIEBER: Okay. This sounds very complicated.

MR. MCGRATTAN: Well it can be. That's why it took us five years.

MR. JOGLAR: Well in most of our applications time is the output. What happens at this point in time is what we need to know.

MEMBER SIEBER: Right. When does the cable fail?

MR. JOGLAR: Yes. When I have to leave the control room. When is the cable fail? And then I compare it with my ability --

MEMBER SIEBER: When the sprinklers go off.

MR. JOGLAR: Yes, to suppress.

MEMBER SIEBER: Yes.

MR. JOGLAR: So often we run these calculations up to the point in time where we need to, we need an answer for. And we can do that very well. And what happens is that a number sensitivity cases get run next to it to account for the kind of changes you're mentioning, like opening doors or stuff, to make sure that our answer all the time doesn't change

if other things happen. And if they do, then we have to address them.

MEMBER SIEBER: Now hopefully I will limit the number of questions that I ask. But say you have a fire in a room and a sprinkler goes off. Is there -- Sprinklers from a fire protection engineers viewpoint are not installed by calculation. They're installed by the standard for the code that you're using at a given time. So many feet apart in such and such a grid.

MR. MCGRATTAN: Right. Correct.

MEMBER SIEBER: As opposed to where the real fire hazard is compared to the rest of the room.

MR. MCGRATTAN: Right.

MEMBER SIEBER: And therefore you have to calculate from a spatial point which of the sprinklers go off.

MR. MCGRATTAN: Right.

MEMBER SIEBER: When does this actuate? When does that actuate?

MR. MCGRATTAN: Right.

MEMBER SIEBER: And that's similar to when does the fire brigade show up and open the door. And all of a sudden --

MR. MCGRATTAN: Right. But one can

calculate when a sprinkler will activate. I mean, there are known parameters of thermal inertia for a given sprinkler.

And even the correlations, there is something known as a ceiling jet correlation that will give you the temperature as a function of distance from the center point.

MEMBER SIEBER: Right. I'm familiar with that.

MR. MCGRATTAN: And you can calculate the activation time of a sprinkler.

MEMBER SIEBER: Okay.

MR. MCGRATTAN: What happens after the sprinkler activates is still beyond the capability of these models.

MEMBER SIEBER: Oh, it is?

MR. MCGRATTAN: Yes.

MEMBER SIEBER: Oh.

MR. MCGRATTAN: As in terms of, will the fire be suppressed or not? That is still a very difficult thing to predict.

MEMBER SIEBER: Or would it cease to be, or not be suppressed to the extent that it would activate other sprinklers.

MR. MCGRATTAN: Exactly. Yes.

MEMBER SIEBER: So that's a weakness.

MR. MCGRATTAN: Yes. And these are the kinds of limitations in the models that we point out in this guide. That yes you can predict when the sprinkler will activate. But, you know, beyond that you may not want to use a model.

MEMBER SIEBER: Well I guess if you look at it retrospectively we're better off than when we were when it was all, you know, the 1905 National Park.

MR. MCGRATTAN: And outside of the nuclear industry, in my experience within the commercial sector, often times the authority having jurisdiction just wants to know, is that sprinkler going to activate?>

MEMBER SIEBER: Right.

MR. MCGRATTAN: Is something blocking it and so forth.

MEMBER SIEBER: They're hard to test.

MR. MCGRATTAN: Yes.

MEMBER SIEBER: Because when you test it the sprinkler no longer exists.

MR. MCGRATTAN: Yes.

MEMBER SIEBER: You can't test and then put it in service.

MEMBER STETKAR: I think also, I mean, you know, we're talking about fire models here in nuclear plant applications, especially the kind of risk informed applications.

These are part of the larger model of the fire scenario. And in many cases that larger model either will explicitly evaluate a probability or successful -- Maybe not extinguishing, but at least control of additional spread of the fire scenario, within the context of that larger probabilistic model.

So, you know, it's not a perfect world in terms of a dynamic simulation tool. But those types of issues, in terms of effectiveness of the sprinkler, at least in terms of preventing further growth of the fire, not necessarily extinguishing the fire, are handled within the context of some of the models.

MR. MCGRATTAN: And you'd think that -- I mean, in essence that might be what you call a sub model. And that is, sprinkler activates water, hits the fire source, and the heat release rate levels off. Or decays at a certain --

MEMBER STETKAR: Yes. It at least doesn't increase any further.

MR. MCGRATTAN: That's right. That is --

MEMBER STETKAR: And in many cases that's

all you need in the context --

MR. MCGRATTAN: That's an empirical sub model.

MEMBER STETKAR: That's right, yes.

MEMBER SIEBER: Well that's consistent with the NFPA codes of the old says. Because it never assumed that your fixed suppression equipment put fires out.

MR. MCGRATTAN: Right.

MEMBER SIEBER: The idea was to control --

MR. MCGRATTAN: Contain --

MEMBER SIEBER: Control the fire until your fire brigade got there and put the fire out.

MR. MCGRATTAN: Right.

MEMBER SIEBER: Or you ran out of stuff to burn.

MEMBER SKILLMAN: Kevin, you've described your effort to put together these models. And I've got a question, a curiosity question. With a sprinkler system you normally get a fine mist, or something more than a fine mist, a good spray.

And if you have a pair of compartments that are communicating, and you end up with hot gas on the ceiling, a lot of hot gas. And say it's a 20 foot high ceiling, and you've got an eight to ten foot, two

meters, three meters of very hot --

MR. MCGRATTAN: Yes.

MEMBER SKILLMAN: -- gas. You end up creating steam. How do your models address what is now not smoke? It's a heat layer --

MR. MCGRATTAN: Right.

MEMBER SKILLMAN: -- that you're now generating another material --

MR. MCGRATTAN: Right.

MEMBER SKILLMAN: -- which is steam?

MR. MCGRATTAN: Right. Well the empirical correlations don't address it all. Because they're simply not designed for something so complex. The zone models also don't because they just assume you have an average upper layer temperature composition. The CFD models, however, have the capability.

So the model that I've developed, fire dynamic simulator, we do track the water droplets. We evaporate the water droplets. We mix the water vapor in with the CO2 and the other fire products. Okay?

However, we haven't validated the model for these complex scenarios yet. It's one thing to write down equations and solve them. We can do that. But that's a very complicated fire scenario to test experimentally.

And for one, all of your fire experiments are typically monitored by thermocouples. And once you set off a sprinkler, thermocouples are gone. So we don't have a lot of good validation data on that kind of scenario, which is why I say that once a sprinkler has activated, except for the very simplistic assumption that the fire's not going to grow anymore, the fire models are pretty much --

At least the current state of the art is that they are limited in how they can predict what's going to happen after that. Again, the physics are in the complex models. But these physics mechanisms have not been tested yet.

MR. JOGLAR: A quick clarification what Kevin said. One of the zone models we have here has that type of ability. The room that you -- It absorb heat as the evaporation process happens. So that is in the physics. But it's very crude.

MR. MCGRATTAN: Yes.

MR. JOGLAR: It's fairly crude. And they have crude assumptions like, well the fire's going to stop growing after water starts, which is not even a calculation. So yes, they try to calculate the temperature given now you're adding water into the environment.

And you're evaporating, and some of that heat is going to evaporation instead of heating stuff. But the application of that process in practical result is very crude. It's very crude. And of course, it's not validated.

MR. MCGRATTAN: Yes.

MEMBER SKILLMAN: Thank you, thank you.

MEMBER SIEBER: Well the value of this, compared to the old deterministic methods is that you can arrive at some sort of a estimate of a probability that other events will occur, like failed wires, failed controllers --

MR. MCGRATTAN: Right.

MEMBER SIEBER: -- equipment that ceases to function, and so forth. And to me that's the difference. That's the motivation to pursue this path.

MR. MCGRATTAN: Right. And what I often see is that, you know, for a given fire scenario that's under analysis, the empirical correlation, you know, might be all you need. But what I see is often times the more complicated models are run just to see if there's anything more to the scenario that you might not think about.

MEMBER SIEBER: Right.

MR. MCGRATTAN: And I've had people show me interesting phenomena in --

MEMBER SIEBER: Oh, really?

MR. MCGRATTAN: -- CFD. You know, I didn't think the smoke would, you know, billow down to the floor over here, you know. I mean, that's the kind of thing that they might --

A little bit of insight that they get by running the more complicated models. Even if again, the empirical correlation, you know, does what you need, it just provides more insight.

MEMBER SIEBER: Okay. Thank you.

MR. MCGRATTAN: Okay. I'll continue with the next comment that was made. Can we go back one level? Yes. So following the V&V study we had to come up with a way of essentially boiling down all our results.

And you can imagine that we made thousands of point to point comparisons between model and experiment. We had 13 quantities that we were looking at. We had five different models. And we developed the system that's shown on the slide here of, for any given model shown on the top of the chart, and any different quantity.

And we looked at all of the comparisons

between model and experiment. And we sort of qualitatively assigned a color. Green being that the model agreed well. And I'll say that in quotations. The model agreed well with the experimental measurements.

Yellow, you know, not perfect, but not bad either. And we also had a red, even though we never actually assigned it. What you see in white are situations where the model simply doesn't predict that particular quantity, which some might say is red, and we put it as white.

Regardless of that the -- Go to the next slide. The committee didn't like it, to put it bluntly. The color designations provide no quantitative estimations of the intrinsic uncertainty. And that's, it was a very good comment.

Because what we say was that people were misinterpreting these colors. In particular yellow. What does yellow mean? Well if you think about a road signal, yellow either means slow down or speed up, depending on how you drive.

You know, what we saw was that, you know, people were saying, well for this quantity this model gets a green. I can use it carte blanche, regardless, right? It's always right. It's always good.

And yellow, some people were saying, well we'll use it cautiously. And some people were saying, well don't use it at all. So we thought that that was not the right interpretation. The HRS also agreed that that was not a good way to handle things.

And so in the guide now, jump ahead to, we now have this table, which is a little bit busier. But we think it is far better than the color chart. Because now for every quantity that we're interested in predicting, and for the five models, we have this delta, which is essentially a bias.

So a delta is one. That means that on average, the model and the experiments agree. And then there's a standard deviation. If you jump to the next slide you'll see what we mean by that. This is a --

The scatter plot is a typical result from the validation study, in which we're looking at one model predicting, in this case wall temperatures. And we have the measured values on the horizontal access. And the predicted temperatures on the vertical.

And obviously if the point falls on the diagonal line that means the model and the experimental measurement are in perfect agreement. Of course that doesn't happen. There's always some

scatter.

We've developed a relatively simple way to calculate the bias. Essentially whether or not the model, on average, over predicts or under predicts the quantity and the standard deviation.

And what we're showing here with the red dashed lines are the, what we call the model uncertainty. And we put black dashed lines in there to indicate the experimental uncertainty. And this calculation method that we developed essentially separates out the experimental uncertainty from the model uncertainty.

We want to know just how good are the models. Keeping in mind that the models are always compared against experiments that have some uncertainty. Obviously the experimental uncertainty is always less than the model uncertainty.

Our goal as model developers is to bring the red lines in line with the black. But we know that, you know, that's a long range goal. We're always going to have to deal with this model uncertainty.

So with the bias and with the standard deviation, we also tested the results of the validation study. We tested them for normality. We

found that in most cases the data was normal. You're shaking your head but --

MEMBER STETKAR: Yes, in most cases.

MR. MCGRATTAN: In most cases, that's true. And that makes the statistical analysis easier because if you -- And this chart in the lower right points out a typical problem, where you're using a model to predict a cable temperature.

We know from experiment that this particular kind of cable fails at a temperature of 330 degrees. So the question is, what's the probability that this particular fire scenario will cause this cable to fail?

Well let's say you predict with your model that the cable temperature reaches a maximum value of 300. And you also know from the valuation study that this model tends to over predict by say five percent, with a standard deviation of 20 -- If I can read that slide. I forget exactly what the numbers are.

But you can essentially draw a Gaussian distribution about your adjusted prediction. And then work out, via the area under that curve, the probability that the cable fails due to the model uncertainty only.

Francisco's going to talk after me about

the parameter uncertainty. Here we're just asking the question, if we knew exactly what the heat release rate from the fire was, if we knew all of the properties of the materials and so forth, what's the uncertainty of the calculation just given the model uncertainty only.

And that for us was a big step. Because in all my experience doing fire modeling, you rarely see this happen. You will see someone say, my model predicted 300, the cables fail at 330, thank you and that's all.

But we want to, as model developers, regulators and as users, go beyond that and say, no it's not perfect. The models are not perfect. There is the likelihood, or there is some chance that the cable temperature might exceed 330 degrees C. And one more slide. And in the examples --

MEMBER BROWN: Do those -- From your fire scenarios there's a difference between heat generation raising the temperature of the cable and exposure to direct flame. Well that means the cable fails faster.

MR. MCGRATTAN: Sure.

MEMBER BROWN: Or your model doesn't work. It shows that in the model?

MR. MCGRATTAN: That is in the model.

MEMBER BROWN: Direct flame as opposed to just --

MR. MCGRATTAN: Right. Again, if you go to the more detailed model then they will account for the flame --

MEMBER BROWN: Okay.

MR. MCGRATTAN: -- and the bypass layer. The empirical correlations, the simpler models, often just say if the cable is in the flame we just assume it fails. That's the simplest approach.

And then you move on to actually doing a heat transfer calculation through the cable, to predict when the inner temperature of the cable exceeds the 330.

Dave mentioned this THIEF model. That just means Thermally Induced Electrical Failure. It's really just a one dimensional heat transfer calculation into the cable to determine when it actually fails.

So in our examples, at the end we developed this chart here to summarize the results of the analysis. And this is just one example where we're looking at a control room cabinet fire, as shown in the pictures.

And we used in this case all of the

models. We used an empirical correlation. We used the zone model. And we used a CFD model, the FIVE the CFAST and FDS.

Each model has its own bias and standard deviation based on the validation study. We have a critical value. That's the temperature at which something fails.

In this case, in a control room we're talking about the operator him or herself, you know, being exposed to a temperature that's untenable. And we're actually now predicting the probability of exceeding this temperature.

So we've built into the final presentation of the results the uncertainty analysis. That's essentially to force the user to do it. Because like I said, if they're not forced to do it, they're not going to.

And I've been there. I've done fire analyses myself. And sometimes uncertainty analysis is a pain in the neck, and I don't want to do it. But now what we're saying is, look, you've got to do it. You can't just present the results of a model without expressing the uncertainty of it.

No one in the lab expresses a measurement without expressing the uncertainty. The same is true

for model results. What this chart now hopes to do, if you look in the final column on the right, is in a lot of cases the probability of exceeding these critical temperatures may be very low.

But you'll see right away, from this chart, that there's one number, .362. So one particular model is saying in one particular scenario that there is a probability of about .3 that this operator might be impaired from doing his or her job. And that might be what we look at.

So in this case what's failing is the optical density. The smoke density has become too great. And the operator can't see. And this might be what we want to focus on for further analysis.

When we look at sensitivity studies we might want to focus on this. We may not want to do, you know, an elaborate sensitivity analysis or a model that's predicting zero probability of failure.

We want to focus on the model or the scenario that suggests that there might be a problem. And then do further analysis on that. And I'll pass that on to Francisco to talk about that further analysis.

MR. JOGLAR: Thank you, Kevin. My name is Fransico Joglar. I work for Hughes and Associates.

And I've been involved in the EPRI NRC research that has been discussed here, from the first fire modeling users guide through the V&V.

And over the last few years I've been working at utilities under fire PRA and 805 transitions. All right. So Kevin was discussing model uncertainty.

And through the development of this project we came across the issue of parameter uncertainty. And we decided at the time to leave it out. Because this is an issue that is well understood. And people know how to deal with parameter uncertainty.

And when we presented that approach to the ACRS subcommittee, well they kind of suggested that we include examples of how to deal with parameter uncertainty in our guide. And we thought it was a good comment, of course.

MEMBER STETKAR: And joyfully went ahead and gratefully --

MR. JOGLAR: And added, I believe, a couple of examples of how to deal with parameter uncertainty. Now we kept is as a simplistic approach, probably the simplest way of addressing it. Recognizing that there is sophisticated ways to do it,

multiple parameters, numerical methods, all of that.

We tried to keep it at the same level as we have the model uncertainty, which is, you know, something that you can probably do by hand. Now at the same time, in my experience in the transitions of the plants, I have come across very specific applications with the tool that we incorporated, and the examples we incorporated in the guide would be very useful.

And I think I'm quoting some of the lines we have heard in the discussions we have on these transitions, where we're dealing 805, the maximum expected and limiting scenarios. And there are some margins presented between the two.

And we kind of have to discuss that the uncertainty in our maximum expected would not exceed those limiting. And it seems to us that the approach that we are presenting as examples can be used to address that kind of question. So I see it as a very practical and timely to include it here.

So as I said, the approach that we put in the guide is the simplest way of addressing parameter uncertainty. We have analyzed certain parameters. And in many cases it is the heat release rate. There can be others like distances.

So we used the probability distributions for that parameter that are available in 6850. And we recognize that the selection of these input distributions is not covered in the guide. And it's up to the user to come up with that distribution. In the guide we went and used something that is referenceable.

And so the couple of examples and the slide we have here is the place where we propagated the uncertainty of the heat release rate through the flame height, and came up with a distribution for the flame. So is straight forward application. I have seen practical applications of this in the transition. So we're happy that we got it into the report.

MEMBER STETKAR: Francisco, this is -- I thought it was a great example. And I honestly think you ought to do a little more self promotion for this example.

The reason it's a great example is that if you look at the actual calculations you find that the 98th percentile heat release rate that a lot of people use as guidance for their initial screening that everybody complains about is exceedingly conservative.

You know, shows that the flame height always hits the cable, which is good. I mean, that

confirms that indeed it's an appropriate screening value. So that's a good conclusion.

A couple other subtleties though are that if you use the mean heat release rate from the underlying uncertainty distribution, and just push that mean heat release rate through that equation, you'll conclude that the flame height does not hit the cable.

And I've seen many people do that. They say well now I'm going to do a best estimate calculation. And I will indeed listen to people and use mean rather than median for my best estimate.

And then draw the conclusion that indeed, as Kevin was mentioning earlier, well there's no damage. So therefore this scenario will not result in any cable damage, because I've done a best estimate analysis.

When you do the full uncertainty analysis, the uncertainty analysis says that the information that needs to be fed from the fire modeling effort, just looking at the parametric uncertainty, says that you return now to the folks that are doing the logic models, a 31 percent probability in this case, that indeed the cables would be damages.

And that's a really neat example. And it

doesn't quite come through the fact that, you know, the middle ground is what you're interested in. Because I've seen many, many people just use that, I'll call it point estimate best estimate, to draw the conclusion that indeed, I can toss out the scenario.

And the problem is once they toss the scenario out, they never go back and do -- They never post process that scenario for uncertainty and say, oh my God, there was really a 30 percent chance that it should have been in.

So there might be a little bit that you can add to sort of cast that in terms of people -- Like you said, Francisco, you know that people are doing this out in the NFPA 805, at least through transitions.

MR. JOGLAR: This distribution I made the point of saying we referenced 6850 because since those days the research team that put that together was -- This was a way of incorporating the actual scenario geometry --

MEMBER STETKAR: Sure.

MR. JOGLAR: -- into the analysis. And in the case you were discussing, if the tray is further away, but maybe the 98 percentile doesn't catch it. Maybe --

MEMBER STETKAR: Well that's --

MR. JOGLAR: So that percentile, that percentage that, let's say, I think used the number 31 percent as an example. What's intended to be the fires that were big enough to start the progression of damage through different targets. So since, say fires that were smaller than that would not catch the tray.

MEMBER STETKAR: Okay. Right.

MR. JOGLAR: And that percentage, since 6850 was developed, was intended to incorporate in the risk analysis the percentage of fires that would be large enough. And that's why those distributions are in 6850.

MEMBER STETKAR: That's right. And I understand that. All I'm saying is the example in there, in the appendix where we actually go through this calculation. And the area under, on the right side of this curve we're looking at, is indeed calculated to be .31. It's pretty straightforward calculation.

My only point is that from a guidance to a user, somebody who's actually going to use these tools and understand how to use the uncertainty results in a practical application. The point being that the 98th percentile shows damage.

And that's clear, that's good. The point being that using only the mean value of that heat release rate would show no damage. So that's something you shouldn't use.

As a user you should not use that to return information back to the plant logic model. You must use the results of the uncertainty analysis. You can't just use a point best estimate. And my point is that conclusion isn't really reinforced for the user. It's cast --

The uncertainty analysis is done correctly. All of the information is there. But most users will just look at it in the sense of, oh yes, I have to do an uncertainty analysis on my results.

Well in this particular case, if you screen out a scenario because your best estimate says no damage will occur, you don't have any results to do the uncertainty analysis on. The uncertainty analysis --

MR. JOGLAR: You don't need the --

MEMBER STETKAR: -- actually drives the result.

MR. JOGLAR: You'll miss the contribution.

MEMBER STETKAR: You will miss that contribution. You'll miss, you know, the answer is

not 100 percent that the cable is always damaged, or zero percent that it's never damaged, even though the zero percent is your so called best estimate. The answer is really 31 percent.

And it's a wonderful example. It really is. You couldn't have selected a better example I think. Even though it's a simple example. You're only looking at one parameter and so forth, to sort of illustrate some of the things we're talking about, about the importance of actually looking at the uncertainty.

Because it can actually influence your decisions going forward. It's not just something that you look backwards at a set of results and say, well here are the uncertainties in my results. This is actually part of the, you know, analysis process.

MR. JOGLAR: We appreciate the comment.

MEMBER STETKAR: It's a wonderful example. I really like it. It was great.

MR. JOGLAR: And actually we drafted three pages of this in discussing among the team. It ended up being what it is. It kind of --

MEMBER STETKAR: One more paragraph might do really well.

MR. JOGLAR: But the thing that when we

started treating parameter uncertainty, we started well, to include all the techniques that there are and all of that. And we ended up with something that fit nicely, you know. And that is where we are.

MR. MCGRATTAN: What I've seen, again in my experience is, you know, such a technique is already described in 6850. And in previous slides you'll see a snapshot from --

I think sometimes the analysts are a little intimidated by the statistics. It's not hard, but, you know, a Gaussian or a gamma distribution we're propagating. I mean --

MEMBER STETKAR: But heck, I'm a dummy. And I can hit that in Excel.

MR. MCGRATTAN: Well that's another --

MEMBER STETKAR: As well as anybody else.

MR. MCGRATTAN: That's why we tried to point out that this is not that complicated.

MEMBER STETKAR: It's not rocket, this is not rocket science.

MR. MCGRATTAN: This is doable spreadsheet. You don't need to be a statistician to do this. But sometimes, again, in talking to people they say I don't want to do that. You know, uncertainties, it's too complicated. I don't want to

do it.

MEMBER STETKAR: Well something that you said before, unless you're told with pretty much an explicit example that you really ought to do this. And it does make a difference. It's too easy to decide that it's too complicated. Or I'll do it after the fact, after I get the real work finished.

MR. MCGRATTAN: Right.

MEMBER STETKAR: I mean, that's more of the attitude I think.

MR. MCGRATTAN: Yes. I see that a lot.

MR. JOGLAR: I annotated here as a comment that one more paragraph to our parameter uncertainty example would be pretty nice.

MEMBER CORRADINI: You don't have to be that nice to him.

MEMBER STETKAR: I'm not --

MR. MCGRATTAN: Well we're already on the hook to add a little bit more description of this example, just to clarify how we actually did it.

MEMBER STETKAR: In E. Let it go. That's a little more complicated over in that example E. This is the simpler one.

MR. MCGRATTAN: Yes, that's why we made a slide out of it.

MEMBER STETKAR: The easier one.

MR. STROUP: You can add a little bit of something to flesh it out.

MR. MCGRATTAN: Yes, okay.

MR. STROUP: Because I think that --

MEMBER STETKAR: But I think that first one, because it's just so -- The other example, the mean values, we get kind of the same conclusion. So it's a little more --

MR. STROUP: Complicated.

MEMBER STETKAR: -- research, if you will. But the first one, it's Appendix B and it's brought forward into Section 4, or whatever it is, you know, is kind of the tutorial.

MR. MCGRATTAN: Okay.

MEMBER STETKAR: I think is really neat.

MR. MCGRATTAN: Okay.

MR. JOGLAR: Kevin also mentioned the real complication of people having to do fire models and fire modeling analysis in scenarios that when you try to match it to our V&V reports, they just fall up. And we tried to cover in our guide what to do. There is a recommendation to try to find V&V studies outside 1824. 1924?

MEMBER STETKAR: 1824.

MR. JOGLAR: 1824. And also we have examples of what in my opinion is a very powerful thing, which is just do sensitivity analysis. Make the argument that you're reshaping your scenario to something that goes into the conservative side.

Making a room smaller, for example. Shortening a distance. And see if those results -- If you don't change your conclusions that way. In my practical experience, it's a very practical way of solving this problem. And in many situations it works.

So we think that the examples that are in the guide are a reflection of reality. We have been doing this through the transitions. And if it doesn't work it's for a good reason. And perhaps you ought to double check your analysis, okay.

This slide is an example of the sensitivity analysis I am discussing. So this is one of our scenarios, which is a multi room complex. And we have a target that is being heated by the fire outside the room of origin. This is one of our "multi-compartment" scenarios.

And so we had to reshape the geometry to feed the V&V results. And the graph, the plot to the right shows that there is no difference in the

adjacent room. And we used that to argue, well our conclusions are okay.

Because although we rechecked the fire room to meet the V&V criteria, really our answers doesn't change. And we have seen that in my experience, even in the fire room itself. So it's probably the most practical way of addressing this issue.

Although we are beginning a V&V project to expand those ranges, this technique will stay. I mean, there are just too many scenarios around to claim that we're going to be able to cover all of them. So that's why we are including it in our report.

But our report includes also eight examples. And these eight examples are based on typical nuclear power plant applications. We hope they serve as a template of consistency for the utilities to develop their analysis, and the regulators to know what to expect, what sections to expect, what topics to be covered.

And therefore, we kind of streamlined the lines of communications. But it's expected and conduced in the -- For example, on 805 transition, we considered the requirements of NFPA 805 in our

examples. And we really challenged the capabilities of the fire models.

Now these examples -- It's perhaps one of the most difficult sections of our guide. Dealing with these examples was not easy. Because we keep scenarios that are typical of nuclear power plants.

When we submitted this for public comments, you get comments in the order of, well you're not solving these. Those may be specific issues of plants, right, that we are not addressing. But this is a generic guide. So we walk a fine line between what's generic, what's plant specific.

In terms of input parameters we always want to be sure we can reference our inputs in terms of geometry. And we work very hard to try to balancing to what, you know, the comments are asking for. Or these very specific issue in what is really a generic tool.

These examples, just by chance, did not meet all the V&V criteria. So we selected them before we actually applied the V&V criteria, to actually go through the sensitivity process. And also these examples, not by coincidence, just match the specific capabilities of the model.

That's why in our examples we go from the

engineering jobs, and sometimes have to go through an FDS. And the actual FDS calculation is necessary. It's not, well lets just do it for the example. It's actually necessary to answer the objective.

And through the development of the project we expanded our research team. And we brought people from the industry that routinely do this work. And they help us develop and comment on the examples. As I said, this was a subject of numerous public comment.

So we think that at the end our examples, you know, strike a balance into what our generic teaching guide is. And provides a solid template to conduct fire modeling calculations that will improve communication between the NRC and the plants. So those are the examples. I guess that's my last slide. I'll pass it to Mark and Rick to wrap this up.

MR. SALLEY: So in conclusion you've heard from the team. Again, this is a joint publication. It's worked under the MOU between NRC and EPRI. We believe it's ready for prime time. With that we'd like to request a letter.

And an important piece here -- If you look back, again in time line mode of where we were ten years ago and where we are today, we've made some pretty good strides. I mean, you know, one of the

first things we did was like 1805, teaching the inspectors the basics of fundamental fire dynamics.

And getting them to think in the fire dynamic way for the STP process. And then we did a PIRT, you know, for fire modeling, which gave us some insights. We then followed up with the V&V, you know.

That's the fourth major cornerstone is this application guide. And this is all done by design in the plan of how we did it. When we did the V&V, for example, we didn't -- We wanted to keep user error our of doing the V&V.

So we focused in on the model. So kind of divided it into two pieces, this being the second piece to bring it in. The mic doesn't like me. Let me back up here.

We're far from done. Like I said, this gives us the really good foundation to work from now. And I think it's our springboard to move forward to, as we'll see expanding the V&V, and starting to look at cataloguing material properties to reduce uncertainties in the calculations. As well as, I'm thinking in the future, get another PIRT together. And see what we go with for the next round of experiments.

So that's kind of the conclusions. If

there's any followup questions. But we request a letter to publish this shortly, and move on to the next phase.

MEMBER SKILLMAN: Yes. I do have a question. And that is, as this would be rolled out for the meetings that you had with the future users, have you had any push back from the utilities, or those who would support the utilities, relative to their ability to do the calculations? Do they have the talent necessary to do this?

MR. MCGRATTAN: You want to handle that? You're one of the guys that did it. Do you have the talent? are you talented enough?

MR. JOGLAR: Well correct me if I'm wrong, I heard two questions. If we have received pushback from the utilities. And if there is the talent.

MEMBER SKILLMAN: That is accurate.

MR. JOGLAR: Okay. I would say that through the public comments we received, we handled the push back through the report. There were a number of comments that really made us go back to the drawing board. And we believe we have resolved them in that way.

I believe there is the talent in the utility side. I would think most of it is in the

consulting companies. But I have seen fire modeling studies, like the ones we present in these examples, prepared for the utilities and used for the 805 transition. So that's going on.

Also, we included this detailed fire modeling as one of the modules in the course that is taught twice a year. And to make sure we have technology transfer. And we get students all the time from the regulator side, from the utilities, from the consulting companies.

So I think the answer to your question is yes in both. We have received some push back in the form of public comment that we have addressed. And most of the examples of how to do it for if there's to be what type of problem is being solved.

There are some challenges outside. Fire modeling doesn't have the capability to solve all the potential fire scenarios that could happen in a plant. So that is still a challenge that we see. There are some scenarios that simply cannot calculate with our tools. There is talent outside to do this work. And we have courses going on to improve on that.

MR. MCGRATTAN: And I'll add that most of these models that we're looking at were developed outside of the nuclear community. and they're widely

used in many sectors. And the people who do this kind of modeling often have bachelors and masters degrees in fire protection engineering.

And what we see in our training course, for example the one we'll teach next week, are people who already are familiar with the models. And what they want to know is, what is specific about nuclear power plants? What's different about nuclear power plants?

And as Mark said in his introductory remarks, what this guide is, is almost like an advanced course on fire modeling specific to nuclear power. So we assume that someone doing these kinds of calculations already has a fairly decent background in the fire physics.

And what this is doing is saying, here's some of the issues you have to think about when you're looking at a typical compartment in a nuclear power plant. So it gives them that next level of expertise.

MEMBER SIEBER: I think that it's good to point out that this is an alternate approach to providing power protection to licensed facilities. A licensee could choose between a deterministic approach, which has been in use since the beginning of licensed commercial facilities. Or choose NFPA 805.

And I think half of them have chosen 805.

And as a former utility executive, you look at your organization and decide whether you have the talent to do it or not. Or are you willing to contract it.

And usually that decision is made based on intricate and perhaps not solvable problems that you have in your plant. And that would drive you to this kind of compliance technique.

And some of the older plants were really not basically designed with fire protection as their primary objective. And because of that there's some places in those plants that are difficult to protect from a fire protection standpoint.

And you need every tool you can get to analyze that. And I also think that some people were using this application in specific areas in their plant, as opposed to the whole plant.

MR. MCGRATTAN: Right.

MEMBER SIEBER: And so that gives you the best of all worlds to solve your problems. Even though this requires talent, high level intellect and a lot of work, in my opinion, in order to arrive at a solution.

Or find your way through plant

modifications to an optimal solution. So I think this is great stuff actually. And I think it compliments the fire protection obligations of the industry and the NRC.

MEMBER SKILLMAN: Thank you.

MEMBER STETKAR: Any other members have any other questions, comments? If not, Mr. Chairman --

CHAIR ARMIJO: about 30 seconds early. Back to you.

MEMBER STETKAR: Before -- Thanks, that was a really good presentation. You crammed a lot into it. And thanks for being so responsive to the subcommittee on this. You did a lot in the last three months. And I know you did even more than may be apparent in the report. So thanks a lot.

MEMBER STETKAR: Okay. John, excellent work as usual. We're going to reconvene at 12:45. And we're returning to the St. Lucie Unit 2 power upgrade meeting.

(Whereupon, the meeting in the above-entitled matter went off the record at 11:43 a.m. and back on the record at 12:44 p.m.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

(12:44 p.m.)

CHAIR ARMIJO: Okay, we're ready to go. We will now take up the St. Lucie Unit 2 Extended Power Uprate application briefing and Dr. Joy Rempe will lead us through that discussion.

MEMBER REMPE: Thank you, Mr. Chairman. Our subcommittee on Power Uprates reviewed the Florida Power and Light License Amendment Request for St. Lucie Unit 2, EPU on June 22, 2012. Subcommittee members have had the opportunity to review the staff's SER, draft SER, excuse me. The licensee's power uprate license amendment request, staff requests for additional information and other specific topics presented at our subcommittee meeting.

During our subcommittee meeting we reviewed topics similar to what we've reviewed in the past for other EPUs. At the conclusion of our subcommittee meeting I believe that most of the remaining subcommittee questions related to the performance of the two replacement steam generators since they were installed at St. Lucie Unit 2, and the anticipated effects of the EPU on their performance.

So today, at our request, we've asked the staff and the licensee to devote most of this briefing

to this topic. I should mention to you that some of their presentations contain proprietary information, so part of our session will be a closed session, as indicated on the agenda.

And I should note that there are actually two different types of closed sessions so we'll need to stop at the beginning of Item 4 to change the individuals that are participating on the phone lines.

And at this point I'd like to turn this meeting over to the staff. And I believe that Ms. Michele Evans will start the presentations?

MS. EVANS: Yes. Okay. Good afternoon, my name is Michele Evans. I'm the Director of the Division of Operating Reactor Licensing in NRR. I appreciate the opportunity to brief the ACRS today on the St. Lucie Unit 2 Extended Power Uprate Application.

Today the licensee and the NRC Staff will address selected areas and open items generated during the subcommittee briefing. These include training, safety analysis and steam generator performance. During the course of our review the staff had frequent communications with the licensee, including conference calls, letters, audits and public meetings.

We issued multiple rounds of requests for

additional information to the licensee that spanned multiple technical disciplines. We believe this open dialogue contributed positively to the overall review.

Overall I'm pleased with the thoroughness of the staff's review. There were a diverse set of technical issues and the staff interacted extensively with the licensee over the course of our review.

At this point I'd like to turn over the meeting to our NRR Project Manager, Tracy Orf, who will introduce the discussion.

MR. ORF: Thank you, Michele. Good morning. My name is Tracy Orf, I'm the Project Manager in the Office of NRR assigned to St. Lucie. First, I'd like to take this opportunity to thank the ACRS members for your effort in viewing the proposed EPU Application. I also want to express my thanks to the NRC staff for conducting a thorough review of a very complex application and also for providing support during these meetings.

During today's Full Committee meeting you will hear from both the licensee and the NRC staff in providing you with the details of the EPU Application. The objective is to provide additional followup information relating to the details of the St. Lucie Unit 2 EPU Application and provide a status of open

items generated during and after the ACRS Subcommittee meeting on June 22nd.

Before I cover the agenda items for today's meeting I would like to provide some background information related to the proposed EPU. On February 25, 2011 the licensee submitted its license amendment request for the St. Lucie Unit 2 EPU. The proposed amendment will increase the Unit's license worth power level from 2,700 megawatts thermal to 3,200 megawatts thermal.

This includes a 1.7 percent measurement uncertainty recapture resulting in an 18 percent increase from the original licensed thermal power. The staff's method of review was based on Review Standard RS-001, which is NRC's review plan for EPUs. As you know it provides a safety evaluation template as well as matrices that cover the multiple technical areas that the staff is to review.

There were numerous supplements to the applications, responding to multiple staff RAIs. Overall there were approximately 70 supplemental responses which supported our draft safety evaluation. Also the staff completed several audits to complete its review and resolve open items.

During the June 22nd subcommittee meeting

the ACRS requested additional information regarding the St. Lucie training program, inputs to the LOCA analysis effecting peak cladding temperature, thermal conductivity degradation and steam generator performance. These items will be discussed this afternoon.

Unless there are any questions I'd like to turn the presentation over to Mr. Joe Jensen. Joe is the site vice president for St. Lucie.

MEMBER POWERS: I take it that the leadership on this particular issue has not provided us copies of the NRC.

MEMBER REMPE: I'm sorry. Say that again, Dana, I couldn't quite hear you.

MEMBER POWERS: You have not provided us copies of the NRC viewgraphs?

MEMBER REMPE: I think what you have are just the introductory of slides that we don't have copies of. And then later there will be some NRC viewgraphs. And I noticed that that was there, but do you really want the title --

MEMBER POWERS: This is a deficiency in our leadership here?

MEMBER REMPE: You never know, Dana, I prefer to stay in favor.

MEMBER SHACK: We emailed it to you, Dana.

(Laughter)

MEMBER POWERS: I am not in a position to refute that statement.

CHAIR ARMIJO: Okay, please go ahead.

MR. JENSEN: Good afternoon. My name is Joe Jensen, I am the site vice president for the St. Lucie Nuclear Plant. And I want to thank the Committee for the opportunity to speak on behalf of FPL and for my team to be able to be here today and be able to address the Committee as well, regarding the extended power uprate at St. Lucie Unit 2.

With me here today to share information about the St. Lucie Unit 2 EPU are Jack Hoffman, our licensing manager for the St. Lucie EPU. Rudy Gil who's the manager of our major component inspections group. Dave Brown, our senior operations representative on the EPU Team. And Jay Kabadi, the manager of the nuclear fuels group for St. Lucie as well as Chris Wasik, the licensing manager.

This is a significant undertaking that will not only increase the output of the plant but will also provide equipment upgrades to improve plant availability and reliability. We appreciate the opportunity to discuss the EPU license amendment

request for St. Lucie with the ACRS.

Since the ACRS subcommittee meeting, FPL and NRC staff have worked diligently to address the actions from subcommittee members. We recognize and appreciate the importance of the subcommittee's questions, particularly those on steam generator performance.

FPL's top priority is safety. We continue to proceed with caution through the remaining steps of the EPU. We look forward to any remaining questions that the Committee has this afternoon.

A little background about St. Lucie, to reintroduce ourselves to you. The St. Lucie site is located on Hutchinson Island, southeast of Fort Pierce, Florida and is a primary electrical generating source for St. Lucie County.

It's a combustion engineering PWR NSSS system with Westinghouse turbine generators. The original AE was Ebaso and our nuclear fuel supplier is Westinghouse.

The gross electrical output was 907 megawatts electric prior to EPU modifications. Now note since we replaced LB turbines during the last refueling outage we've gained another 31 megawatts, increasing our current gross electrical output to 938

megawatts electric.

MEMBER BANERJEE: Is that a beach there?

MR. JENSEN: Yes, sir. It is. I have been to most of the plants in the country and I thought Diablo Canyon was the most beautiful facility. I now think that the St. Lucie plant is the most beautiful facility. It's a lovely, lovely spot.

With regard to some of our key milestones and major equipment replacements at St. Lucie, the original operating license was issued in 1983. In 2003 a renewed operating license was issued for Unit 2, extended the operation until 2043. Also in 2003 we installed a new single failure-proof crane to support dry fuel storage operations.

The steam generators were replaced in 2007, with AREVA Model 8016 Generators. And additionally, in 2007, we replaced the reactor vessel head to address Alloy 600 issues. Finally we replaced two of four reactor coolant pumps in 2007 and 2011. And our current plan is to replace the other two motors in 2012 and 2014.

So that completes my introductory remarks and at this point I'd like to turn the meeting over to Jack Hoffman, who will provide a brief overview of the EPU. Jack.

MR. HOFFMAN: Thank you, Joe. Good afternoon. My name is Jack Hoffman and I'm the licensing manager for the St. Lucie Unit 2 Extended Power Uprate Project. As stated earlier by the NRC, FPL has submitted a License Amendment Request for an approximate 12 percent licensed core increase for St. Lucie Unit 2.

This proposed power increase is consistent with that recently approved for St. Lucie Unit 1 and consists of a 10 percent uprate from the current power level of 2,700 megawatts thermal, to a power level of 2,970 megawatts thermal.

In addition, the amendment request includes a 1.7 percent core power increase as a result of the measurement uncertainty recapture. Together these power increases raise the license core power to 3,020 megawatts thermal.

A bridge system impact study was performed to evaluate the impact of the EPU on the reliability of the electric power grid. This study was performed for the most limiting configuration of both St. Lucie units at the proposed EPU power level. Results of the grid simulations indicate acceptable grid performance for the most extreme event.

Finally, the remaining modifications to

support operation of St. Lucie Unit 2 at the uprated power level will be implemented this year, in the fall of 2012. Next slide.

As mentioned previously, the St. Lucie EPU license amendment request was developed using the guidance contained in RS-001. This Amendment addressed lessons learned from several previous pressurized water reactor EPU submittals. In accordance with RS-001, the St. Lucie EPU analyses and evaluations were performed consistent with the Unit 2 current licensing basis.

The impact of the EPU on license renewal was also evaluated in each license report section. These analyses and evaluations addressed system structures and components subject to new aging effects. SSCs that have been added or modified to support EPU and the impact of EPU on time-limited aging analyses.

The proposed measurement uncertainty recapture submittal follows the guidance of NRC Regulatory Issue Summary 2002-03 and the St. Lucie Unit 2 MUR methodology is identical to the uprates recently approved for Turkey Points Unit 3 and 4 and St. Lucie Unit 1.

Included in today's presentation is

information to address three ACRS Subcommittee meeting followup items. They include; Number one, acceptability of a single control room simulator for EPU operator training. Second, rackup of the pre-EPU and EPU loss of coolant accident peak clad temperature differences. And three, the continued discussion of the St. Lucie Unit 2 steam generators.

So unless there are any further questions for me, I would like to turn the presentation over to Dave Brown who will discuss operator training.

MR. BROWN: Good afternoon. I'm Dave Brown. During the subcommittee process a question came up concerning the fact that we have a single control room simulator modeled to Unit 2 specifically for training on both units. A single control room simulator is typical for dual unit sites.

It is important to recognize that the simulator training is one facet of a multi-faceted training process, including classroom training, on the job training in both control rooms and in the field training that is conducted with a specific emphasis looking at the Unit 1 control room differences including JPMs and TPEs to evaluate in that area.

The operator training program is an accredited program by the Institute of Nuclear Plant

Operations. St. Lucie's methods of training have been evaluated and continue to be evaluated and reaccredited every four years. And that includes the use of a single simulator has determined to be acceptable for that process.

Operators at St. Lucie are licensed and qualified on both units and routinely operate both of those units. The differences on the units are emphasized in both classroom and simulator training to make sure the operators are aware of all differences between the units.

And we've been working in EPU and in our EPU modifications we've actually been reducing the number of those differences between the units, like taking the steam bypass system and making them the same on both units, et cetera, et cetera.

MEMBER POWERS: Is that the most important difference?

MR. BROWN: Sir?

MEMBER POWERS: Is that the most important difference between the two units?

MR. BROWN: The steam bypass control system? I don't know that I would consider that the most important difference. It was one of the systems that we were modifying that we had an opportunity to

make the two systems alike. Probably the most important systems associated with the differences would be the ECCS systems, which were not modified for EPU.

Okay, if not anything else I'll turn it over to Jay Kabadi.

DR. KABADI: I think in the subcommittee meeting we presented the results of all of our safety analysis, including non-LOCA and LOCA. And in this presentation I'm going to go over some of the PCT deltas that occur between the Pre-EPU and the EPU.

MEMBER REMPE: Jay, just to make sure, the agenda had said this part was closed, but it is open and FPL is comfortable with this part being open, correct?

DR. KABADI: That is correct.

MEMBER REMPE: Okay, thank you.

DR. KABADI: Okay. This portion. There is concern that EPU would have some adverse impact on both the small break and large break LOCA. But one of the goals that we had set is try to maintain PCT in the same range as what we had for pre-EPU, so we are looking at what operational constraints we need to put and what other systems we have that are already safety-related that we were not correcting previously

and trying to correct it now.

So in the Large-Break LOCA the increase in power we saw roughly in Delta about 54 degrees increase. When we flattened our power distribution by reducing the total radial peaking factor, the Fr, on that one there was a penalty of about 19 degrees.

So we wanted to get the benefits, although the Fr gives a penalty in terms of radial power distribution, which affects the radiation heat transfer. But it give a direct benefit in the LOCA peaking factor on the fuel rods and that gives a benefit of 53 degrees.

The increase of our RCS flow rate, which was actually not a real change, we had replaced generators about, more than two cycles ago. Actually this is the third cycle we are running. But we have not taken credit for the higher flow which the generators produce and also our flow in the Tech specs and COLA. So that gives us the benefit of about 70 degrees.

So these two together pretty much balance these penalties there. However, we wanted to gain some additional margin for some of the plant operating parameters, such as containment spray flow. For that one was a penalty of about 23 degrees on that. We

increased some of the heat sinks in the containment that give a penalty of about three degrees.

So we looked into our methodology with Westinghouse, the way the metrics were applied compared to what they were previously approved by the staff and there was some additional conservatisms put into the matter figure I used specific for St. Lucie 2.

MEMBER CORRADINI: So can I just make sure I understand? So you're decreasing containment pressure by containment spray flow rate and containment heat sink so there's more bypass. Is that the reason that you get a penalty?

DR. KABADI: That is correct, exactly.

MEMBER CORRADINI: I don't understand the nine degrees for the ECCS flow.

DR. KABADI: Right. The ECCS flow is --

MEMBER CORRADINI: It sounds like a good thing.

DR. KABADI: I think what we did is we looked at the ECCS flows again for the full system and it provided little more margin to the IST, so we decreased slightly after there were no changes to the physical components, like the HSPI flow and all. But we left a little more margin for the ISTs and the

flows used in the analysis were slightly lower. So it --

MEMBER CORRADINI: Can I say that back to you? So you increased the flow rate but you didn't take credit for it?

DR. KABADI: No, no.

MEMBER CORRADINI: I'm still not understanding where the nine degrees comes from. I heard what you said but I don't appreciate --

DR. KABADI: That is the penalty because we decreased the flow using the analysis. And the decrease in the flow was to give us a margin for the ISTs and the testing.

MEMBER CORRADINI: Okay, so just from a viewgraph standpoint that should say decrease instead of increase?

DR. KABADI: Oh, I take it back. I think it has two impacts. We did look at the IST but I think this one is for Appendix K methodology. What happens is when you increase the flow, like in our maximum case, we in both cases decreased the flow and increased the flow. Increase the flow actually has a maximum PCT for St. Lucie 2. St. Lucie 2 is always limiting for the max HPSI flow.

So this was a analytical max flow

increase. In the real sense I think I started a little differently. In the real sense what we did is we generated our RCS flows and reduced the minimum flow used but also maximized the flow used for the max flow case. Both min ECCS flow and max ECCS.

Our limiting PCT for St. Lucie 2 comes from max ECCS flow. So that's why this thing, we increase our containment spray flow higher. And also the other flows at a higher level and we run both min flow and max flow. So min flow will provide it more margin for IST and the max actually was used to maximize our flow in the other direction. And that's what gave the penalty. Because for St. Lucie 2 --

MEMBER CORRADINI: He's my foil over there, do you understand?

DR. KABADI: I think, let me explain. For the plant schematics and most of the other plans, we don't need a max in both cases.

MEMBER CORRADINI: Well I wasn't on the subcommittee so I don't want to take too much of time at the Full Committee.

DR. KABADI: But I quickly say that real min flow and the max flow cases for St. Lucie 2, when you put the maximum flow because of the containment pressure decrease, other than the containment spray

flow, we get a penalty. We've too high PCT. So in this case we put on both sides more margin on the min side and on max side, and the max side that's what gives that penalty of nine degrees. On this one.

MEMBER BANERJEE: In some way you're splitting the flow, is that what you're saying?

DR. KABADI: Right. We run the case running both the HPSI flows and both the LPSI flows and a flow increase. And we also run one HPSI flow, one LPSI flow and predicting the minimum flow. And the maximum PCT comes from the max flow case. Then we try to put max --

MEMBER BANERJEE: Why does it come from the maximum?

DR. KABADI: Because the containment pressure. It has a big impact on the containment pressure.

MEMBER CORRADINI: So I'm bypassing more --

DR. KABADI: And that one gets the penalty.

MEMBER CORRADINI: Got it.

MEMBER BANERJEE: It's a bypass.

DR. KABADI: Right, that's exactly happen. So we ran both sides, do AST margin by minimizing, but

also ran with the max flow and that one gives the more higher --

MEMBER CORRADINI: Right. Thank you.

MEMBER SIEBER: These numbers apply only to the cycle following the EPU fuel loading, right?

DR. KABADI: That is correct.

MEMBER SIEBER: Cycles beyond that can have different numbers?

DR. KABADI: No, these are bounding values at every cycle when they do IST testing, these will be bounding. That is correct.

MEMBER SIEBER: Okay, so you have to watch the loading pattern in order to achieve the --

DR. KABADI: Yes. We have a IST criteria that they test, they check, and as long as we fall within that range this analysis remains --

MEMBER SIEBER: Your fuel analysis method maintains this envelope and each cycle has to fit inside the envelope?

DR. KABADI: That's correct. We check all the parameters going to the analysis of the reload and verify that we are within the limits what we can expect.

MEMBER SIEBER: We can expect you never to get above, what is it, 2,087?

DR. KABADI: Correct, 2,087, that is correct.

MEMBER SIEBER: Okay.

DR. KABADI: And the other changes I mentioned, more of a -- were assumptions used in the methodology analysis which were "a little more conservative" than what the methodology requires, we reduced them slightly. And that gave a benefit of about 60 degrees.

So overall the PCT adequacy, if you rackup come out as 22 but when you put that in the integrated all things are together then we get about a benefit of 17 degrees for the large break.

For small break, small break is one which is very, very sensitive to flows coming in only in the transient. So EPU by itself was giving us a penalty of about 335 degrees on this one. So a couple of changes which we did not include before.

One, is we have actually blankets in the fuel, but we never took credit for that. So when we actually took the credit for actual blanket our peak loads start to went down and gives a benefit of about 80 degrees.

We used the replacement generator parameters which were not used before. That gave

about 100 degrees, and we took credit for charging flow, which is very, very important for small break in terms of gaining margin. And that gave a margin of about 169.

MEMBER SKILLMAN: Are your tech specs changed to limit the plugging to ten percent or less?

DR. KABADI: That is correct.

MEMBER SKILLMAN: Thank you.

DR. KABADI: So it is actually not in the directly in tech spec, but that's one of the analysis of that we do have to reload. Tech spec does not have a tube plugging limit. But there is a limit on the axis flow that we verified that with ten percent plugging we meet that. If we do too much plugging then that flow may not be sufficient to meet that.

MEMBER SKILLMAN: Thank you.

MEMBER CORRADINI: And then, just so I understand, ten percent is what, 900 tubes, 1,000 tubes? What are we talking about here?

DR. KABADI: We have close to 9,000 tubes.

MEMBER CORRADINI: So 900 tubes is ten percent for generating. Just wanted to get a number. Thank you.

DR. KABADI: No, that's okay. So this is what the integrated impact came out about 40 degrees

benefit. Our PCT was 1,943 and the new one came out 1,903. So this is the last time we presented these numbers but did not, in the subcommittee meeting did not provide these rackups which are presented here.

MEMBER SIEBER: And how many tubes are plugged now?

DR. KABADI: Right now very little and Rudy probably can answer that.

MEMBER SIEBER: So steam generators are five years old, right?

DR. KABADI: This is the third cycle we are running.

MR GIL: This is Rudy Gil with FPL. Between the two generators we have about 33 tubes. And so you might have 20 at the most in one generator against that 900. So a quarter of one percent is the maximum in one of the generators.

MEMBER SIEBER: And what was the mechanism of deterioration that caused you to --

MEMBER REMPE: We're going to hear a lot about that later. So let's just wait and we'll hear about it, okay?

MR GIL: It is wear and I'll have a full presentation on that.

MEMBER REMPE: That's what we're going to

focus on today.

MEMBER SIEBER: Oh, all right.

DR. KABADI: Yes I think those are the slides I was going to present. And is there any questions, we'll proceed to the next part.

MEMBER STETKAR: Are you charging pumps in the tech specs now?

DR. KABADI: Yes.

MEMBER STETKAR: Were they before?

DR. KABADI: Before they were in some sections of the tech spec, but not enough.

MEMBER STETKAR: But now they're in the --

DR. KABADI: For simplicity too they were in the ECCS.

MEMBER STETKAR: Thanks.

DR. KABADI: That's right. Exactly. And the two we had in the tech specs.

MEMBER STETKAR: Okay.

MEMBER REMPE: The staff has a presentation and we're going to close the meeting with the Westinghouse participants, correct?

(Off the record comments.)

MEMBER REMPE: Is the room appropriately closed?

(Off the record comments)

(Whereupon, the open session of the Full Committee meeting went off the record at 1:11 p.m. and resumed in closed session. Open session resumed at 2:47 p.m.)

MEMBER REMPE: Is anyone out there? Is there any member of the public out there that wants to make a comment?

(Off the record comments)

MEMBER REMPE: Okay. Again, I'll ask, is member of the public out there on the phone line? Just if you're there, say you are there just to -- okay. So I don't hear any public comments, so at this point I think I'd like to turn it back to you, Sam.

CHAIR ARMIJO: Okay. Well, thank you very much, Joy, and thanks for all the presentations. I think very well done. Right now I'd like to reconvene at 3:05. We've got a deal with an EST issue that you'll be battling.

MEMBER SHACK: Don't the staff want to make a presentation?

CHAIR ARMIJO: No, the staff made their presentation.

MEMBER REMPE: No, that's it.

CHAIR ARMIJO: Yes. So I believe everybody that's wanted to say something has had a

chance and so we'll take a recess now until 3:05.

(Whereupon, the foregoing matter went off the record at 2:48 p.m. and went back on the record at 3:05 p.m.)

CHAIR ARMIJO: Okay. We're back in session. We're now going to cover the technical basis for regulating extended storage and transportation of spent nuclear fuel, and I'm going to turn this over to Dr. Michael Ryan who will lead us through the presentation.

MEMBER RYAN: Thank you, Mr. Chairman. The NMSS staff, EPRI, NEI, and DOE briefed the subcommittee on September 22nd and June 5th, that's September 22nd of 2011 and June 5th of this year, on the staff's development of a technical basis for regulating extended storage and transportation of spent nuclear fuel.

The EST program is focused on identifying and addressing the technical and regulator considerations for ensuring effective regulation of spent nuclear fuel storage and subsequent transportation over extended periods. During the June meeting, the staff discussed a draft report entitled, Identification and Prioritization of Technical Information Needs Affecting Potential Regulation of

Extended Storage and Transportation of Spent Nuclear Fuel.

The report addresses staff's evaluation of the degradation phenomena that may affect dry cask storage systems and how these phenomena may affect the ability of the systems to fulfill their regulatory functions. Industry representatives discussed their perspectives and efforts on EST and we'll hear from some of those participants from the subcommittee meeting here today.

I might, just by way of introduction, say I think we had a very thorough subcommittee briefing and we're going to have a short version of that today, so I'm sure there's a lot of details and maybe we'll have time for questions, but I'll turn the meeting over without delay to Jim Rubenstone of NMSS. Jim, welcome.

MR. RUBENSTONE: Thank you, Mike, and on behalf of me team I'm very happy to be here to brief the full ACRS on what we've been doing on the extended storage and transportation issue, and especially the initial step, which is identifying the technical information needs related to dry storage.

Just take make a minute to introduce some of the other players in the group here. The two

technical leads, Bob Einziger and NMSS, and Darrell Dunn from Office of Research, will be there. My counterpart as branch chief is Mirela Gavrilas, who's sitting over there next to Chris Jacobs, who's the project manager, and some of our other technical staff are here if we have any questions that we need to go into that level of detail.

So what I'll be talking to you about today are what we're doing to get started on this question of extended storage and transportation and what changes, if any, need to be made to NRC's regulatory framework; rules, guidance, other documents that may need to be enhanced in order to handle a changing policy environment where it looks like storage of spent nuclear fuel, either at reactor sites or at some other sites will be happening for extended periods into the future.

As I said, we were looking at our regulatory framework. The current framework, dry storage is done under 10 CFR Part 72 and transportation under 10 CFR Part 71, and looking at the current framework, if there are things that may need to be enhanced within that to handle future needs.

The first step, as I said, is to identify

those technical information needs so NRC can see what needs to be done in a regulatory space and I'll closeout by just discussing what the next steps are.

Just a quick background, this is where we stand now and where we're going in the spent fuel storage situation. This is from an EPRI report from a couple years ago. It's not complicated graphics, but the idea is that, right now, we have about 18,000 metric ton of commercial spent fuel in dry storage out of about, getting close to, 70,000 metric ton total.

That's about 1500 casks that are currently loaded. The industry produces about 2000 metric ton of new spent fuel every year. What are our needs? Potentially, we may need to change the regulations to accommodate a period of longer than originally anticipated storage for spent fuel. And the first step, from our point of view, was to identify those technical information needs that we would need to support any potential changes in future licensing reviews.

So as a first step, we've tried to go through systematically and identify what technical issues need more work in order for NRC to know what the regulations need to be and then perform some focused research on those issues, especially those

that have significance, and I'll explain in a little more detail how we identified those.

So this is the report. This is, literally, the report right here that we've produced. I think you've all been provided electronic versions of this. It was put out for public comment in early-May. The public comment period just closed about a week ago after a request for an extension. We've gotten about a dozen commenters coming in with a number of comments and those commenters include NEI, EPRI, a number of state organizations, and some individuals, and also one Native-American Tribe provided comments.

What we're doing in this report is looking at the potential degradation phenomena that may affect dry storage systems, structures, and components; consider their impact on the safety functions that are identified within the regulations for storage and transportation; and what level of understanding staff feels they need in order to do a regulatory review.

We started with some previous technical gap assessments for this problem that were out there, including one which we sponsored through the Savannah River Lab. The Department of Energy has done their own gap assessment nuclear waste technical review

board and EPRI also have done gap assessments for dry storage.

We looked at the level of knowledge for the various degradation processes and three things which were most important about the processes, the time and the conditions for them to initiate, how fast they progress, and then what's the end state? And some of these will progress to an end state that doesn't really affect much, so they've become less important.

Many have an end state where a system becomes fully degraded; can't perform its function anymore. And then we took that set of information on the level of knowledge and crossed that against the need to meet the regulatory criteria. So what we ended up with in terms of our prioritization are those areas which had relatively low level of knowledge about one of these aspects relating to the degradation process and a high impact on a regulatory criteria.

Those criteria are spelled out as design criteria in 10 CFR 72. There are five specific design criteria that have safety functions; confinement, control of criticality, shielding from radiation, structural integrity, and control of heat generating and ability to dissipate that heat.

There's an additional criteria in the regulations which is the ability to retrieve stored fuel by normal means. It's the retrievability at the assembly level is the way NRC treats that now. And we also looked at the possible impacts on transportation under Part 71, especially for fuel that has been stored for an extended period when some of the systems being used are no longer in their pristine state and may be affected by some of this degradation.

We came up with a set of high priority areas and just focusing on those areas that we have considered high priority. There were three that rose to, sort of, the first priority and then three cross-cutting areas. These are outlined on this slide.

I should stress that some of these issues, even though we're looking at them in the extended framework, because of the uncertainties about these progression rates and time of initiations, overlap to issues that are being looked at within the current regulatory framework, and, you know, issues for already loaded casks, not just casks that may exist at some distant point in the future.

The first is a good example of that, that's the phenomena of stress corrosion cracking of stainless steel canisters in marine environments.

We've had discussions at the subcommittee level. Certainly, this is a well-known phenomena, stress corrosion cracking in the presence of chloride. For these canisters, when they are loaded, the heat generation is such that the surface temperatures are probably high enough, in almost every case, that this is not a major issue, because there's no water present.

As chloride salts can be deposited on these stainless steel canisters, and not all the systems use the same canisters, but a large fraction of the U.S.-loaded inventory uses a stainless steel canister, 304316 series stainless steels in concrete overpacks. When these are sitting in places where they're exposed to marine fogs or marine atmospheres, you can get accumulation of salts on the surface, and those salts, when the temperatures drop low enough, can deliquesce and begin pulling moisture out of the air.

This is an issue because there are stresses built into these canisters from the welding and the forming of the canisters. And, as I said, this is well-known as a phenomenon in these stainless steels. When exactly this can occur in terms of the loaded systems now is what we're looking at in some

detail to try to track that down and there is complimentary industry work, and I'll talk about that in a little more detail in a few slides.

Some of the other issues that came up, degradation of cask bolts. Bolted systems are not predominant in the U.S., but there are a number of them out there. They're more common in Europe. Cask bolts serve an important safety function in keeping the pressure on the seals so that these bolted systems stay tight.

The last group in this first category are effects of swelling and pressurization on cladding. And the stress on the cladding is an issue that can have further issues tiering off it, so to speak. How the cladding behaves over time, there are a number of things that change in the cladding with heating during the drying process and then with the storage.

If there's no pressure on the cladding, a number of these issues are not particularly relevant. If there are mechanisms by which you can start putting directed stresses on the cladding, especially focused stress that you might get if the fuel pellets are pressing directly on the cladding, then there may be issues with cladding failures over time.

So we're looking at the stress as the

first level issue, to understand that a little better, if that becomes less of an issue then a lot of these other issues also drop in importance.

We have three areas that we identified as cross-cutting and they're cross-cutting for two reasons. One, they can affect a number of components within the system. And secondly, they bear on a number of the phenomenon and how fast they can progress. These are, basically, the thermal state of the entire system, the fuel itself, the cladding, the internal bits, and the canister's surface.

Again, a good example of that for the stress corrosion cracking, if the temperature is high enough, you don't have stress corrosion cracking because there's no water present, as temperatures drop over time, it's important to understand when that could happen and when this may become a phenomenon you need to worry about.

There's also questions regarding residual moisture within the canister after drying. There are drying procedures which are in place, predominantly, vacuum drying. There's very little information to benchmark exactly how much moisture is left after that drying.

We've done some preliminary studies that

suggest that if we are getting down to the levels that we think we are, this is not a big issue, but there are a couple possible ways where you can retain additional moisture within the canister, perhaps a fair amount of moisture, and if that's true, then there could be some issues of degradation that come off that.

CHAIR ARMIJO: Jim, just there. We do not have a specification for residual water in the canister or --

MR. RUBENSTONE: The specification is not written in terms of how much water is left. It's more a procedural spec, and Bob can explain that.

MR. EINZIGER: Yes. We have a procedural spec that was developed by PNNL, basically, it says that they have to pump the cask down to 3 tor, shut the valve off, and then watch the rate of rise, and if it's below a certain value, then they're okay to go. If you do some calculations, that should be equivalent to a little less than a quarter of a mole.

The problem with the specification, if you look into it deeper, is that, one, it's never been tested that it actually -- is that when you do that, that you actually get the water out. The second thing is, for it to be a valid calculation, you essentially

have to be in thermodynamic equilibrium and there's a lot of little nooks and crannies in the cask.

And so knowing that you're at a certain pressure at the outlet tube of a pump doesn't necessarily mean that there's not liquid water sitting around somewhere in the cask.

CHAIR ARMIJO: Okay. Thank you.

MR. RUBENSTONE: The last one is a very broad category. It's looking at methods by which these casks, when they're in service, could be monitored for some of these potential effects. Right now, the dominant method for monitoring and inspecting casks is visual. Basically, walkarounds, make sure the ports for the air circulation are clear.

There's a lot of, sort of, hidden components that are not easily accessible, and there may be methods out there where one could do monitoring or inspections to see how these phenomena are progressing and catch them before they become issues. So trying to look at what the modern techniques available are, we saw that as a priority cross-cutting issue.

These are some of the other high-priority areas that didn't quite get as high up on the list. This first one is the one that tiers off the stress in

cladding and that's propagation of various flaws, fatigue of the cladding, low-temperature creep, which these are all stress-dependent phenomenon. If our initial investigations show that there's no good mechanism to develop these stresses, then these issues are not issues at all, so that's why we're doing this somewhat stepwise.

There are a number of other issues that come up over the long term; behavior of the hardware inside the neutron absorbers, microbial influence, corrosion is an area that needs to be explored a little bit in some environments as things get cooler, and degradation of concrete, again, there's plenty of opportunity for visual inspection of the exposed concrete, but many of these systems have concrete and rebar that are not easily inspected, so we wanted to understand what issues might come up in concrete.

And this is, again, an area that's very well-known, and well-studied, and in many contexts. It hasn't been looked at specifically in dry storage systems.

CHAIR ARMIJO: But the concrete is really just a shielding issue, isn't it?

MR. RUBENSTONE: Well, structural integrity, shielding, are the two main purposes of the

concrete.

CHAIR ARMIJO: And microbial influenced corrosion, has that been shown to actually occur in the radiation environments at the surface of a cask with a lot of spent fuel in it? Is it possible that microbes could live?

MR. DUNN: There are some microbes that have been responsible for microbially-influenced corrosion that can live in fairly high radiation.

CHAIR ARMIJO: Those are tough suckers.

MEMBER RYAN: Most of those critters are tens of thousands of rad.

CHAIR ARMIJO: Okay. Please go ahead.

MR. RUBENSTONE: So, yes, they are.

CHAIR ARMIJO: They're tough little buggers.

MR. RUBENSTONE: They're more robust than one might think. And again, there's been a lot of work in a number of environments, mostly in buried environments, but as these things get cooler and moisture is present, and the potential for nutrients coming in by surface deposition, we thought it was worth looking into.

MEMBER SHACK: What new phenomena would you expect to see in the concrete degradation that you

haven't seen?

MR. RUBENSTONE: I don't think there are new phenomenons so much as looking at how one would be able to be ahead of the curve on this, that there's a number of phenomena that have been identified that could happen. There have been even some examples where through inadvertent mistakes of leaving weather caps off, water has gotten into concrete structures and they've started chipping already.

It's mainly a question that you have some of these structures, the systems are built where you have concrete inside of a steel case. So you could be getting water inside, degradation of the concrete, and not necessarily be aware of it until you try to move it. So we're trying to avoid the situation of discovering things when you're ready to move.

MEMBER SHACK: You know, are you aiming at this by inspection or, you know, you're not going to make concrete impervious to everything.

MR. RUBENSTONE: No, no, I don't think there are things -- there are some phenomena, I think, that you're aware that, if you have tight control on what you put in the concrete you can minimize those possibilities. This is mainly aimed toward inspection and monitoring methods. So we know what the phenomena

are that we're looking for. So you know what you're looking for and you can design your procedures to go for that, you know, for things that aren't immediately visible.

MR. EINZIGER: One of the goals of this exercise was to provide guidance to the inspectors of how frequently to inspect and what to inspect for. And so while we know these mechanisms are occurring, the level of knowledge so that we can give them that guidance isn't that great. So there's a need to improve the information basis for improving that guidance.

MR. RUBENSTONE: These are a few areas that we have begun work on or will imminently begin work on. I've talked about them a little bit. The next slide goes into a little more detail on what we're doing on the stress corrosion cracking, so I'll skip over that. The moisture, we talked about a bit. We've done some preliminary scoping work and there's some follow up planned.

The thermal models, we've started looking into developing more realistic thermal models. The biggest issue, traditionally, thermally, has been, what's the maximum temperature you should let cladding experience?

If you're familiar with the loading process, these casks are loaded in the pool, and then the water is taken out, and they're dried, and that's the period where they experience the greatest temperature excursion before they're backfilled with the inert gas.

So most of the models have been focused on what should be the maximum temperature we allow the cladding to reach during that process. NRC's guidances are, standard is 400 C.

MR. EINZIGER: Maximum, 400 C for normal conditions.

MR. RUBENSTONE: Right. So all, I would say, of the thermal models are conservative to that side and make some assumptions in order that you don't breach that 400 degree limit. As we've discovered by looking into some of these other phenomenons, lower temperatures may become an issue. For the cladding, there is a fairly well-established ductile to brittle transition that happens at lower temperatures in the cladding.

That won't happen during the loading period, but it could potentially happen down the line as these things have sat for a long time and the thermal loads have decayed away. And again, the

question of what the temperatures on the outside of the canisters are for these questions of other corrosion mechanisms for the canisters are important.

And then the other area we're just beginning to look at are the inspection and monitoring techniques to gather, sort of, what the modern state-of-the-art methods are that are out there that might be applied to these, you know, somewhat unique conditions where you don't have great access to the insides of these canisters and you have to work with the radiation thing.

MEMBER SHACK: What kind of access do you have?

MR. EINZIGER: Very limited. In some cases, virtually 1/4-inch spaces. So part of the whole problem with this is getting access and knowing how much access you have. You might be able to get access to part of the cask, but is it the right part of the cask? You might be able to stick a thermal couple in there to get a temperature, but is the thermal couple making contact with the right surface?

If it's not, you could have considerable error in your measurement. So it's a matter of monitoring what's going on. In some cases, with respect to the inside of the canister, we really don't

have any access. And if you go to, especially a lot of the international reports, somewhere in the report you'll see a little statement like, we don't expect anything to happen inside the canister because we have an inert atmosphere.

But now, there's an assumption that you put the inert atmosphere in there that, for the full length of the time it's going to remain there. Do we know that? If a crack occurs will we be able to know when we lose that? If it occurs at a higher temperature, then certain effects take place. If it's at a lower temperature that a crack -- and we lose the atmosphere, losing the atmosphere has a number of consequences.

It could change it from an inert atmosphere to an oxidizing atmosphere. It also changes the thermal conductivity. And so here's a region where there's an assumption made where we really don't have any current monitoring techniques. So one of the things we hope the industry is going to do is look at, what are ways to insert monitoring techniques? Is there a way we can use the decay heat as power; a sensor that'll stay in the high-radiation field?

How do we transmit the signal out? That's

what their job is. Our job is to make sure we're prepared to evaluate if they come into us with various techniques. Do we think it'll work? Do we have to change a regulation; the way that we have access to the canisters? So that's where this comes in.

CHAIR ARMIJO: Well, you know, but let's just assume that you had access to some stainless steel canisters that are out there right now in a marine environment and have been there for many years. And you had enough access you could go out and look and you found some stress corrosion cracks. What is the regulatory position? Would you insist on repair, reloading, or what?

MR. EINZIGER: Right now, the regulations as they're stated says that, for storage, the canister or the cask, depending on what type of system you're in, is the primary containment vessel. If we started inspecting these and seeing cracks, we would have to evaluate what the temperature of the canister is, how that translates into the temperatures that are inside the canisters, and subsequently, what would be the degradation we would expect?

For instance, if a canister needs to be down below 80 degrees C, let's say, you're starting to get deliquescence and getting water formed, well, that

may mean that the temperature of the fuel is a 150, let's say. Well, at a 150, we know that if we have breached fuel and we get oxygen in there that there is no effect.

And we've identified, I guess, about a dozen to nine different effects that could go on if you breach the canister. Obviously, if, let's say, you had a bad weld, or a weld stress state in the seal, that you split the longitudinal canister over, that would affect retrievability.

CHAIR ARMIJO: I'm just saying, is there a position now to --

MR. EINZIGER: No, our position right now is, until we've analyzed what the potential safety ramifications are of having a breach, we have not put any guidance out to the industry of actions that they have to take.

CHAIR ARMIJO: Okay. So if anybody found some cracks on the surface and could demonstrate that it wasn't breached, it wasn't actually leaking, the inert atmosphere hadn't come out, you could buy off on it and say, well, as long as they're not growing.

MR. EINZIGER: If we saw cracks on it we would have to sit down and decide, how deep are the cracks? Do we have to do a better visual examination

to see how deep they are? Do we have to put a monitoring process in place --

MEMBER RYAN: We can't go through all the details because we've only got another hour.

MR. EINZIGER: But the bottom-line is we'd have to do work.

MEMBER RYAN: I was going to say. I think what I'm taking away from Bob's, you know, very well and very detailed thought process is that there would have to be a plan developed for that specific case and then execute that plan of monitoring to see what, and to what extent, things have happened, and then what might be happening over time as time progresses. Is that a fair summary?

MR. EINZIGER: Good summary.

MEMBER RYAN: Yes, okay.

MEMBER CORRADINI: So can I ask one question about the aging? So you had in your slide earlier, a number of dry casks, and I can't remember if it was -- what is it, a 1000?

MR. RUBENSTONE: It was about 1500.

MEMBER CORRADINI: 1500. And there are various ages.

MR. RUBENSTONE: Correct. The first casks were loaded in the late-1980s.

MEMBER CORRADINI: So is there an inspection program that is age-related such that you are looking at older casks in a different way than newer casks? Has that been thought through?

MR. RUBENSTONE: That's exactly what we're getting at; what we're moving towards now.

MEMBER CORRADINI: Okay. And right now, the dry casks are licensed for 25 years?

MR. EINZIGER: It originally was they were getting 20-year licenses because it was anticipated things were going to move into a repository. Recently, the regulation has been changed to grant them a 40-year license with the extensions of 40 years. In the process of going for a license extension, one of the requirements is to inspect a cask.

With that said, the criteria for inspecting it and what you're going to inspect it for has not been thought out completely yet and it's sort of a bootstrap process.

MEMBER CORRADINI: Okay. So if I treat this like a power plant, what's the first cask to come up for a renewal?

MR. EINZIGER: The first one that we've seen so far is Calvert Cliffs. No, wait, under this

system, is Calvert Cliffs, that's a canisterized system, and just recently, there was an inspection done of two canisters in that system and we're waiting the results of those inspections.

MEMBER CORRADINI: Okay. All right. So we're early into the whole renewal process and, in essence, guidance has yet to be developed.

MR. EINZIGER: Well, there is guidance out in a 1927 Standard Review Plan, but this is the first renewal that that review plan is being exercised under there's changes that are going to have to occur. It's a learning.

MEMBER CORRADINI: Okay. Thank you.

MR. RUBENSTONE: That's what we see as the longer term product of this whole program, is to develop what guidance needs to be for this extended period.

CHAIR ARMIJO: In the meantime, particularly with the issue of stress corrosion cracking, is the staff reconsidering the criteria for which they will accept stainless steel canisters for marine environments that haven't been fabricated in a way that would make them highly resistant, if not immune?

MR. RUBENSTONE: I think that's one of the

areas we're looking at is fabrication and qualification of what materials for certain environments.

CHAIR ARMIJO: Okay.

MR. RUBENSTONE: Because traditionally, there hasn't been that distinction made.

CHAIR ARMIJO: Yes, because there's going to be a lot more going out the door and you already know that there's problems.

MR. RUBENSTONE: Yes.

MR. EINZIGER: The answer to your question is, yes, we are considering it. We have not gotten very far in the consideration process.

MR. RUBENSTONE: Yes, we're early in the game.

CHAIR ARMIJO: Got it. That's all I want to do. I want to get that on the record.

MEMBER RYAN: That's a key point in our recommendations. We'll get to it and get the letter writing.

MEMBER REMPE: You said you have inspected a couple of canisters?

MR. EINZIGER: Last week.

MEMBER REMPE: And what exactly was done? And they were in an ISFSI? I always have trouble

saying that acronym, but you pulled it out? Was it just opened or what did you do?

MR. EINZIGER: No, I think you have a picture here.

MEMBER RYAN: The NUHOMS.

MR. EINZIGER: It's a NUHOM system with a canister inside a concrete overpack.

MEMBER REMPE: Right.

MR. EINZIGER: They snaked a camera in the entrance and the exit --

MR. RUBENSTONE: That's the system that was examined and I think John Kessler will speak about this as well.

MR. EINZIGER: And they also slid a probe in to try to take a measurement of the salt content on the surface.

DR. KESSLER: Yes, this is John Kessler. I have a slide or two in my presentation that'll describe that in a little bit more detail.

MEMBER REMPE: Okay. Great. Thanks.

MR. RUBENSTONE: Yes. This is where I was? Yes. This is just a little more detail on what we're doing on the stress corrosion cracking because this is, as you may have noticed, a high-interest area.

MR. EINZIGER: Yes.

MR. RUBENSTONE: There was some earlier work done, contract work, a couple of years ago, looking at this phenomenon when deliquescing could occur on these containers, and at what humidities; what temperatures. Building off that, we have another set of experiments going right now. We've gotten some preliminary results. We're trying to tighten up what were rather loose bounds on what the conditions were there using more realistic amounts of salt deposition, more realistic temperatures and humidity conditions, and seeing when one could initiate SCC.

Some of those preliminary results suggest that, even with relatively low amounts of salt on the surface, and at, perhaps, lower humidity levels than people had initially thought, considering just pure sodium chloride, you can get deliquescence occurring with sea salt and the potential for SCC. So we're finishing up those experiments now.

So NRC's angle on this problem has been focused on trying to better understand under what conditions this could occur you would be in, sort of, the window for SCC. Industry is working in parallel with this and their current efforts, and John will talk about this in a few minutes, are focusing on what

are the actual conditions of installed canisters now?

What sorts of surface temperatures are in place now, especially for these that have been loaded for some time. And in marine environments, what amounts of salts have been deposited? And as he will talk about it, it's a challenge to try to get surface measurements on these materials because of the radiation fields. There's been no efforts to actually physically pull these out of the containers because of the high consideration when you take them out of the concrete. That's a non-trivial exercise.

The first cut is seeing, how can we get into these using the existing installation.

CHAIR ARMIJO: Just a ballpark estimate, do you have an idea of how many years it would take with the existing systems before the surface temperature got below a 100 degrees centigrade?

MR. EINZIGER: That's going to depend upon the particular temperature at the loading and the burnup of the fuel.

CHAIR ARMIJO: Yes, just pick a number.

MR. EINZIGER: The casks that are out there at Calvert are supposedly below the deliquescent temperature already. We're trying to confirm that.

CHAIR ARMIJO: Okay.

MR. EINZIGER: If you have high burnup fuel that you transferred in early, let's say in three years instead of five, it may take 25, 30 years; in that range.

CHAIR ARMIJO: Okay.

MR. EINZIGER: I've seen estimates of it may be even longer.

CHAIR ARMIJO: Thanks.

MR. RUBENSTONE: Yes, so this is where --

CHAIR ARMIJO: Just to put it in perspective so everybody understands.

MEMBER SHACK: So this is like a 20 to 40 year kind of thing, is that what we're talking about?

MR. EINZIGER: No, it's a little bit broader than that. If you take the data that's out there now and try to make an estimate of when you would initiate stress corrosion cracking, you have the very narrow band of somewhere between 10 years up to maybe 420 years.

MR. RUBENSTONE: This is one of the reasons we think it's worth attacking it from a couple of angles, which is the better, more realistic thermal calculations, the industry's efforts to actually go out and make some measurements that help us benchmark those models, and the lab experiments that say, well,

what is the window where you have to worry about this?

CHAIR ARMIJO: And some of the really old fuel that was barely warm when it went into a cask --

MR. RUBENSTONE: Yes.

CHAIR ARMIJO: -- if it happened to be put into a stainless steel canister on a seaside --

MR. RUBENSTONE: May be your worst case.

CHAIR ARMIJO: -- could be your worst case.

MR. RUBENSTONE: And happened to be put on a coastal environment, yes.

MR. EINZIGER: I want to say a few things. One is, we're not only considering coastal environments. This could be a case by a system where there's an ISFSI next to a road that, in the winter, just gets a lot of salt. It could be near a system where there's cooling towers and you have condensation. And we're also looking at industrial pollution.

The other thing is, this isn't a U.S. problem. We are taking full advantage of the work that's been going on in England, Japan, Korea, I think those are the major actors in this game who all are attacking this problem.

MR. RUBENSTONE: Yes, the Japanese, in

particular, have been on top of this for some time. Swedes don't have much dry storage, but the Japanese, almost all of their sites are coastal environments, and that's what is simulating a lot of the further work because they have some systems in place to try to measure salt deposition, not directly on canisters, but in sort of an analog box to simulate the airflow and such.

MR. EINZIGER: Well, the systems at Fukushima were under water.

MR. RUBENSTONE: Yes.

MR. EINZIGER: Under salt water.

MR. RUBENSTONE: Well, that became an issue as well. They have pointed out that, yes, there is probably chloride on the surface of those canisters. But if you use some of the Japanese data, the salt deposition can be very rapid.

CHAIR ARMIJO: Yes, I mean, but if they fabricated very carefully, solution heat, a bunch of things, they may not be a problem.

MR. RUBENSTONE: Right. There's certainly things you could do upfront that would make this --

MR. EINZIGER: The Japanese are working on a number of ways to try to mitigate stress.

MEMBER SHACK: I mean, chloride cracking,

yes, I mean, you'd really have to get the stresses low with those welds.

CHAIR ARMIJO: Yes. Solution heat treatment or polish --

MR. RUBENSTONE: Well, basically, we have two classes. We have what's out there now. We have the future loadings, as you can see from that curve, that's only going to be going up. So, you know, we want to be looking at both issues of the best way to deal with it. So, like I said, this is one of our number one priorities. There's active work going on by us and industry, and as Bob said, we're harvesting as much as possible and cooperating with the international players in this as well.

So I think we're on top of this. There's still more to find out, but we think we've got a good start on it. Just so we don't lose sight of the fact that in addition to the technical areas that we've looked there is some regulatory issues that will come up for extended storage and transportation. And this is not intended to be a comprehensive list.

Our next effort, as we move into the finalization of this report, is to do a similar analysis on the regulatory issues, go through them, and make sure that we've captured all the things that

come up. There's always the integration issues from the various parts of the fuel cycle and coordination with some efforts that are under way now for process improvements in the licensing of current storage and transportation.

So our immediate next steps, we are finalizing this report. Bob's been working on the comments. As I said, we have about a dozen commenters. Although we haven't made a final decision, I think we'll probably end up adding an appendix to this report discussing the comments that we got and how we are addressing them.

We're going to complete a research plan for all the technical investigations going out over the next couple of years. As I said, look at these potential regulatory issues, continue the work we've done on the technical investigations, again, that's just to get NRC the information it needs to determine what the issues are and how we're going to be prepared to review applications and renewals as they come in.

We're engaging industry, other stakeholders, and looking at what's going on elsewhere in the technical world.

MR. EINZIGER: I think it's necessary to say that, because we identify an issue as a high

priority doesn't mean that we believe that that issue is going to really cause a lot of problems with dry storage. It just means we don't have enough information to evaluate it. Likewise, because we identify an issue as being low priority, that doesn't mean that we don't think that, maybe, the industry doesn't need to get more data. It only means that we think we have enough information in order to make a regulatory decision.

That's why you might see a difference in the priorities you see what we give to an item and what DOE, or EPRI, or somebody else, gives the priority. As I say, our job is to get information to determine whether there's an issue, their job is to solve the issue.

MR. RUBENSTONE: That's a good point to remember because the ultimate goal of this whole project is any necessary changes in regulations and guidance, and staff training to review future applications. Industry's goal is a little different. We all are looking for safety, they're coming at it as the ones who are actually holding the materials.

I put this slide in because the Blue Ribbon Commission had some recommendations that touch on our extended storage and transportation issues. As

you probably know, the Blue Ribbon Commission put out its final report this past January and the response from the Department of Energy is due to Congress this month.

These are the three specific ones that touch on extended storage and transportation. And I think the second one there about developing one or more consolidated storage facilities is something that we have to keep in mind as we look at technical issues that may affect storage and transportation.

What this brings into the fold, which hasn't been the traditional practice, is the idea that you may be having material in storage for some time, then transporting it to another storage facility, leaving it there for another period, and then transporting it again.

So the idea of multiple transportation stages with some periods of indeterminate, perhaps long storage in-between, is an important consideration for the technical issues, especially for these degradation issues and how they could affect both transportation and storage.

MEMBER POWERS: Has anybody looked at what I would call the macro risk of all that? I mean, we have the spent fuel stored at the individual sites.

It seems to be working well. Poses some sort of risk by itself, but now if you think about transporting it from those sites to some centralized location and, as you say, perhaps from there to some place else, that seems to entail another set of risks, and I have no idea what the combined risk is.

MR. RUBENSTONE: We've started looking at, sort of, a systemwide approach with these various steps and some of these things you can do relatively straightforward. Some of them get a little more complicated. I think one thing that's clear from all risk studies that have been on the backend and the handling question is that, your highest risk period is when you're actually moving things around, not necessarily moving them in a transportation load, but loading canisters, moving them off pads onto trucks, or trains, et cetera, like that.

So when you add those steps, yes, you're adding more risk. Is it an acceptable risk? That remains to be seen from the various things, but, you know, something sitting on a pad, there are very few spontaneous things that can happen there.

MEMBER POWERS: Which is nice.

MR. RUBENSTONE: You're picking something up with a crane, yes.

MEMBER POWERS: A lot of things.

MR. RUBENSTONE: So I think that's where we're trying to get this bigger picture view, and we've started some work on that, and we're not very far along, but we are doing that. I think one of the pushes for the consolidated storage facilities was the question of decommissioned sites and that's something that, going forward, we're going to have to look at, especially if the number of the decommissioned sites, where all that's left is a fuel storage facility, if that starts growing, especially questions that came up in the Blue Ribbon Commission.

Framework is, these decommissioned sites, many of them have only an ISFSI and they really don't have facilities for handling anything except the stored systems now. Could that be a potential problem if these things exist for a long time? Would you want to have a facility where you could actually have a more comprehensive handling capability than at a decommissioned site?

MR. EINZIGER: One of the things that has been put on the radar, though, from the point of possibly transporting it more than once and storing it more than once, is that, most of the analysis that are done to determine whether systems are safe are

dependent upon what the initial condition of the system is, but when you start now, after you've been in storage and are going to transport it, you're no longer dealing with a pristine system.

You're dealing with one that's aged some and vice versa for storage after transportation. And so that degradation has to be taken into account in determining the safety.

MR. RUBENSTONE: And that's why some of these monitoring issues come up is that, the more you know about the system the more competent you are that you're actually making the right analysis. And as Bob said, as something's been stored for awhile, there are a number of assumptions that gon into the transportation that may need to be challenged, tested, evaluated, as to what the condition of the material is in.

The question Sam brought up about cracks. Even if these cracks don't develop to the point where they're through growing, you need to analyze, what's their affect on the structural integrity before you start picking things up again. So there's a lot of interconnection and the system approach, I think, will help point that out. We don't really have any conclusions yet.

CHAIR ARMIJO: Okay.

MR. RUBENSTONE: So that's all I have, basically. These are the conclusions. I think we've hit most of these. If you have further questions we can take those.

MEMBER RYAN: Let's see. Okay. That's great. I think what we'll do is maybe hold questions to the end. We really don't have that much further to go, unless there's some pressing issue that you haven't touched on yet. Hearing none, it's Mr. Jeff Williams from DOE.

(Pause)

MEMBER RYAN: Go ahead, Jeff.

MR. WILLIAMS: Okay. Thank you. Yes, for those of you who don't know me, I'm with the Office of Nuclear Energy and DOE, and with the withdrawal of the license with Yucca Mountain, and the termination of licensing activities, we embarked upon a program to do research on alternative geologic disposal environments as well as extended storage.

And, let's see, I just have a few slides here. When the program was initiated in the 2009/2010 time frame, we put together a report to Congress, all of NE did, on our research objectives. And we're still following that report to Congress which is

called the NE Roadmap. And the approach was a science-based engineering-driven approach that originally defined our program and continues today.

In terms of the dry storage work that we're doing, we're doing this from a total system approach, from looking at the fuel pellets all the way to the cladding, to the fuel assembly hardware, to the canisters, to the concrete casks, and to the pads. And the first thing we need to ask ourselves is, how do we know we're doing the right kind of work?

And what we were doing in the first couple of years here is trying to identify the work that needs to be done. We started by doing a functional requirements analysis, looking at the safety functions that Jim had on his slides, thermal shielding, containment, criticality, retrievability, and structural integrity.

And then we conducted a technical gap analysis that was completed earlier this year. NRC has done them, NWTRB has done them, EPRI has done them, and we compared our gap analysis that was done independently with the NWTRB's, with NRC's, that came subsequent to that, and we shared it throughout the industry to, basically, validate the gaps that we identified.

And right now we believe that we're competent that we're going after the right things, although we could go after a lot more if we had a lot more money, but we had to focus on certain items that we could do. This is a slide I showed before that, this year what we did, in 2011 and '12, was we did a gap analysis. We came out with a whole bunch of gaps that needed data gathering.

And since we don't have infinite resources, we decided we were going to try and prioritize those gaps. And we tried to quantify qualitative discriminators. And the gaps are identified in the left here, that we identified, mainly, cladding, different aspects of cladding, the assembly hardware, the neutron poisons that are included, the welded canister itself, bolted casks, and the concrete.

And then we identified several different criteria to use and some criteria weren't real discriminators, but then we identified likelihood of occurrence, consequences, difficulty for remediation, and tried to quantify those, and then add them up, over to the right side, to identify what are the most important ones.

Last time when we talked, I didn't talk

about what those numbers are in there, it went from 1 to 4 likelihood of occurrence. This was based on subject matter experts opinion's, but they were quantified in terms of; a 1 meant it's not expected to occur; a 2 means it may occur; 3, it's likely to occur; and 4, it's very likely to occur.

And then with consequences, we basically --

MEMBER SHACK: What's the second number in the likely --

MR. WILLIAMS: Oh, okay. I'm sorry. Yes, what we were trying to do there was to say about the near-term and long-term. The one on the left is near-term, like, on the order of five years or so, and again, this is subjective. Subject matter experts got together and tried to identify that. And the second number is --

MEMBER RYAN: So just so everybody's focused right. I think it's important to say, this is really just a scoping analysis --

MR. WILLIAMS: Yes, what it's trying --

MEMBER RYAN: -- based on an expert elicitation.

MR. WILLIAMS: Exactly.

MEMBER RYAN: Okay.

MR. WILLIAMS: It's taking our team of people from the national labs and trying to define where we should spend our money.

MEMBER BROWN: So in the short-term, you say, 3, it's not very likely, but --

MR. WILLIAMS: No, no; 1 is, not expected, 2 is, it may occur; 3 is, it's likely; and 4, it's very likely.

MEMBER RYAN: Start with 4 and work down Charlie.

MEMBER BROWN: But that's a near-term. The first one is a near-term. The second term is a far-term.

MR. WILLIAMS: Yes, right.

MEMBER BROWN: Okay.

MR. WILLIAMS: And then they're added up across there and you can see the ones that came out to be important are the cladding effects, hydride effects, reorientation and embrittlement, and then the welded canister ones down here. All the ones that are the 11s and the 10, and that's where we've started to focus our work on.

We also are looking into aging management plans a little bit. I think you were briefly talking about that in that, let's say we determined that there

was some sort of corrosion on the canister or something, is there any kind of aging management plan that could address that? That's something we've just started, so I don't have any results from that.

I think Jim talked about concrete, and inspections, and so forth, and there are ways to remediate concrete degradation. You can see the remediation one wasn't much of a discriminator. They were all rated 3 by our team, except for the bottom two, were 1 and 2. I could really spend an hour or so on this slide, but I know I only have five minutes.

CHAIR ARMIJO: But you can't. At least you put the numbers. We understand them now.

MR. WILLIAMS: Right. Okay. So I'll just go on to the next one. I only have --

MEMBER RYAN: Before you leave that I just want to ask one question of you both while you're both up there. I took away from the subcommittee meeting, Jim, that Jeff's kind of qualitative alignment here on some of the priorities really were not dissimilar from what your work has led you to believe, so you're both really on the same page. Is that a fair summary?

MR. RUBENSTONE: Yes, I think if there's one general statement you can make for what we've done, what DOE has done, what EPRI has come up with,

and TRB, is that, there's fairly good alignment on what the major issues are. As Bob pointed out, we have a little bit of a different angle on it because of what we're trying to get as opposed to where DOE is going.

MEMBER RYAN: And that's reasonable. Sure.

MR. RUBENSTONE: But I don't think there's big discrepancies in somebody saying you really should be doing this and we're saying, no, you don't need to do that.

MEMBER RYAN: Fair enough.

MR. RUBENSTONE: All right.

MR. WILLIAMS: Right.

MEMBER SHACK: Of course, you probably asked the same people.

MR. WILLIAMS: Well, it wasn't really all the same, but, yes, we --

MEMBER SHACK: There's only so many people out there.

MR. WILLIAMS: Yes, right. You know, we sent out our report through the John Kessler escape process that you've heard about to get comments and so forth. So we've tried to vet it through everybody we know that are experts on this. Okay. And this is the

other slide, I think, that you asked me touch on and it's in another, we call them, work packages, and this is an engineering analysis.

It's all related in the storage and transportation area and this is just to describe some of the additional work we're doing. One thing that we've got some money earmarked for was to develop multi-purpose canister systems. So that's something we've just started some work on and we're in the procurement stage so I can't really talk much about that.

Conduct thermal analysis of the Calvert Cliffs system and what we're trying to do there, we're participating in this inspection, is looking at how does our modeling match up with the measured temperatures? And I just received an email that the coldest, you were asking about the coldest temperature, it was, we modeled it at a 112 and it was measured at a 110, or vice versa, for the --

MR. RUBENSTONE: Fahrenheit.

MR. WILLIAMS: Yes. Right.

CHAIR ARMIJO: Yes, surface temperature after what?

MR. WILLIAMS: Right.

CHAIR ARMIJO: Fifteen years or ten years?

MR. WILLIAMS: That was the oldest one, so that was about 20, maybe 18 or so, and then the hotter one was a 124 versus it was modeled at a 120. And they even have suggested some rationale for why there was a difference, which I don't think there was much.

CHAIR ARMIJO: Hot off the press thing.

MR. WILLIAMS: Right. Like I said, just 15 minutes before I left I got an email about this. I wasn't able to make the examination. Okay. Then on hydride reorientation, we're trying to do some actual calculations to try and predict how they would happen, the theory behind it, and then tie that up with our testing that we're doing down at Oak Ridge with doped cladding to see if we can actually predict how it's happening, and this is work that's just under way right now.

Another bit of work that we're doing --

MEMBER POWERS: Just the zircaloy clads?

MR. WILLIAMS: Yes. Well, I believe that's where they're starting. I'm not sure, the details, on all the different cladding ranges, but it's just getting underway. I haven't seen any reports out of it yet, so I would think that the first priority would be on the zircaloy clad.

And then the last bullet down there, one

of the other important elements that's been identified in here, I think Bob or Jim touched on it, was the transportation, you store it, and then you transport it, and then maybe you transport it again, what are the stresses? And so we're looking to setup some actual vibration testing of fuel cladding to look at the testing.

And this work will support the gap analysis that we've done and so, basically, where we're going in DOE is, we've done this work trying to identify the gaps and now we're starting on the experimental programs. And one other one that we want to put in here is a full-scale demo that we just started to work on, again, with the industry.

We're just laying out the scope of that demo this year, trying to determine where it would be done, what fuels would be done, focusing on high burnup fuel, and how casks would be instrumented, and so forth. And that's just getting underway as well.

So in conclusion, basically, DOE/NE is supporting the development of the technical basis for certification of very long-term storage followed by subsequent transportation.

We're looking at the development of a plan to support he experimental data gathering, we're

conducting experiments, we're working with NRC to properly integrate the information, we're participating closely with industry to make sure we're doing the right thing, as well as with the international programs that Bob mentioned, the Japanese, and the Spanish, the Koreans, and I think the Germans also, and so this is mainly a little bit of our program.

MEMBER RYAN: That's great, Jeff. Thanks. That's a great summary. I think the takeaway message from the subcommittee was that it has pretty good coordination and alignment with what DOE is doing and what the NRC is sponsoring, so there's good communication and hopefully, you know, a better dataset from the combined effort, so appreciate that.

MR. WILLIAMS: Yes. We feel we have some resources, and, you know, money, and facilities that maybe we can help answer some of the questions.

MEMBER RYAN: That's great.

MR. WILLIAMS: Okay.

MEMBER RYAN: Thank you very much, Jeff, appreciate it. We have John Kessler on the phone. John?

DR. KESSLER: Yes, I'm here. Can you hear me okay?

MEMBER RYAN: Okay. You have 18 slides and not that many minutes, about seven or eight.

DR. KESSLER: Not to worry. Jim and Jeff have covered some of this stuff and a lot of them go fast, so I should be okay.

MEMBER RYAN: Okay. Great.

DR. KESSLER: Some of the committee members, I can barely hear when they ask questions, so you may have to repeat them, but let's get going here. Okay. Slide 2, you kind of heard about this already and it's, extended storage is an international issue. It's not a U.S.-specific one in the sense that most nuclear countries to or are already facing extended storage because they don't have reprocessing, they don't have disposal, and while some of them have centralized or consolidated storage, it's still storage.

And so with everybody having the same issue and starting to do work on it, there is a major need to share data and collaborate. Slide 3, so in 2009, EPRI launched the Extended Storage Collaboration Program, or it's now dubbed ESCP. The purpose that we had was to bring together U.S. and international organizations engaged with active or planned R&D programs in this area.

And across the, you know, globe now we have a lot of storage and transportation vendors. We have regulators and their R&D contractors, one of which is NRC. We have lots of national waste management organizations. We have R&D organizations, DOE and EPRI, as well as with a lot of outside ones, and industry, which includes utility and cask vendors.

We have participants from roughly 20 countries now and we have roughly a 150 people that have shown up to various meetings from those countries. Slide 4. This is getting into a bit of what Jim talked about, but in terms of this ESCP program, the purpose is just what Jim talked about for NRC; provide the technical bases to ensure continued safe long-term used fuel storage and future transportability.

That program that we're working on is in three phases. Phase 1, you've heard about already, pretty much, reviewing the current technical bases and conduct gap analyses for the storage systems. Phase 2, you just heard from Jeff, is that conducting experiments, field studies, and additional analyses to address those gaps. We're all getting going on that next. Phase 3, this long-term performance confirmation effort that, again, Jeff alluded to right

at the end.

Slide 5. So again, not to spend too much time on it, this is a summary of the highest priority gap analyses that I pulled together from the various gap analyses that you heard about. Definitely welded stainless steel canisters, stress corrosion cracking is at the top of the list, high burnup cladding, because of hydriding effects that could cause embrittlement, is on the list, bolted casks, those kinds of corrosions, and then fuel pellet swelling, you heard from Jim earlier.

Slide 6. Cross-cutting needs was also addressed a bit by Jim. There's quite a few listed there. The two that are at the top of the list, the improve thermal modeling, Jim already talked about in terms of why that's valuable. The degradation monitoring systems, I think it was Bob talked a little bit about, which is, you know, can we do things from the outside or what kind of R&D, and I think it's a very long lead time R&D to do things from the inside, setting signals right out through the canister.

There's other cross-cutting needs like stress profiles, you heard about adequacy of drying, some criticality issues, et cetera. I'm not going to go into those details. Slide 7. Now I'm going to

switch from ESCP to what EPRI's plans are and actually activities we have now.

The first one I'm going to talk about is the in situ inspection of stainless steel canisters that you already heard a bit about. Slide 8. I really don't think I need to go through it again. You heard a pretty good detail from Jim and a bit from Jeff about, what are the conditions to cause stress corrosion cracking? What we care about is at the bottom.

What we don't know are, what are the conditions on the canisters and how well do those line up with these lab experiments and other R&D in terms of, do we have the same conditions on the canisters that could support stress corrosion cracking? So that's what we're setting out to do. Slide 9. Jim and Bob mentioned the inspection at Calvert Cliffs that was done just two weeks ago, or whenever the dates are.

We picked that because, yes, it's about a half mile from the Chesapeake Bay, so it's semi-marine environment. We also wanted to pick canisters that were in service for a while so that they were cooler and you heard temperature measurements from Jeff that are the ones that I understand they've collected too.

And also, if they're older, they've had a chance to pick up some salt on to the surfaces, so we wanted to look at those.

There were two canisters that were inspected as Bob mentioned. HSM-15 was where they did the visual inspection, that was the warmer of the two, for their license renewal. This is Constellation I'm talking about. And then HSM-1, which was their oldest, coldest one, is kind of the R&D canister, for lack of a better word.

In addition to doing some further inspections, we took surface temperature measurements that you heard from Jeff as well as took a look at some of the deposits on the surface of the canister. We have those deposits collected and EPRI is looking now to find somebody to do the analysis for it. We're pursuing some leads there.

Current situation is that Constellation is preparing a report for NRC that is due later this year. You did hear about we're planning to do more inspections, starting our focus with systems that are near the coast. We may go inland. We are planning to do several more and for the follow-on ones, the Department of Energy is providing co-funding, which we appreciate.

Slide 10. This entailed the Calvert Cliffs system. This gives you kind of a cutaway view of what we're looking at here. You can see, if you look in the bottom left, kind of a slanted green thing there, that is the air inlet that brings in air underneath canister, which is sitting horizontally in the middle, it's convection cooled from the decay heat, and the air then goes out those outlet vents.

The boroscope that Bob mentioned was inserted through those air outlet vents and fished in and around the outside of the canister, and they got a pretty decent look at the canister there. And then through the front door that we took off, or Constellation took off, we did the temperature and surface contaminant that's on the left.

Slide 11. This is a picture of the two guys during the drop-in, slipping in the tool right around that door entrance where we had a 3/4-inch gap to put in something to collect surface contaminants. Slide 12. This is from the mockup. I mean, in real life, from that picture, you'd be standing right inside the module, but for the mockup, we could actually see that instrument making sure that it would actually sit on top of the canister.

This is one where they were deploying

what's called a SelfSmart, which is essentially a glorified -- that you could get wet and it dissolves the salts that are on the surface of the canister for a certain area so that you can determine the salt concentration. So that's just an example of the kind of tool that was used.

Slide 13 is another photo. This is a surface deposit collector. It's literally a glorified Scotch-Brite sponge that you use in your house where they pulled a vacuum with a particular filter behind that sponge and then we've collected the sponge as well as the particulate filter for more of a gross contaminant analysis to, you know, backup that SelfSmart measurement.

Slide 14. So where are we headed with all this? This was mentioned a bit before. Industry's goal is to develop this industry-wide stainless steel canister aging management plan. And this gets to the I think one of you had earlier, which was, are they all being inspected on the same schedule or should some be inspected differently?

That's exactly what we want to address in the aging management plan. Which containers might be susceptible to stress corrosion cracking, where are they, and when might they be entering the range of

susceptibility? And so then you might want to do inspections at the right locations and at the right time, you know, stepped up inspections of those, and that's the idea.

We want to develop the inspection plan and then part of the aging management plan will be mitigation, additional inspections if required, all the way through replacement of the systems if necessary. So that's the goal, is an aging management plan and we've got to collect a lot of information to get there.

CHAIR ARMIJO: Jim, quick question.

DR. KESSLER: Slide 15. Now I'm going to switch to talking about the stainless steel --

CHAIR ARMIJO: John. I'm sorry.

MR. RUBENSTONE: Hang on. We have a question.

CHAIR ARMIJO: Quick question.

DR. KESSLER: Okay.

CHAIR ARMIJO: In your mitigation plans, what is your thinking now? I know you don't have specific plans, but --

DR. KESSLER: I can barely hear you. Can you get closer to your mic or something?

CHAIR ARMIJO: Yes.

MEMBER RYAN: The microphone is up there is where you need to talk.

CHAIR ARMIJO: Okay. I'll talk as loud as I can. What are your mitigation plans? What are you thinking about as far as this stainless steel stress corrosion cracking problem?

DR. KESSLER: Mitigation could be, one of the things that we've talked about internally is, if, say, we have stress corrosion cracking and it's minor, in the sense that it's not extensive, but you may have one or two places, we've talked about maybe simply applying some patch which would not be a structural patch, but would be enough to (telephonic interference) a crack, assuming there is one.

We're doing analyses, in fact, analyses already exist about the consequences of, if you did have a through-wall crack, what might that mean for release? I believe that Constellation has already, in their safety assessment, that kind of a calculation. We are also going to start looking at, you know, do we need to develop dry transfer systems?

Everything from, can we pull this canister out and take the fuel out into a new canister? There's been discussions about maybe taking the canister and just sliding it into a brand new canister

that's a little bigger. We have not gotten that far in terms of mitigation techniques, but we are thinking about that.

We're also encouraging Department of Energy to work with us in terms of developing some of those techniques, particularly the dry transfer systems could be of use for R&D as well as general use for, say, at a centralized storage facility. So we're just getting going in trying to address that question.

MEMBER RYAN: Next.

DR. KESSLER: All right. So back to Slide 15. Switching gears now and talking about this high burnup confirmatory data collection effort, preferably full-scale in the end. Jeff Williams mentioned it, this is the very end of his talk. Slide 16. So what is it that we need from this high burnup demo? Ultimately, what we're after is confidence and understanding of longer term behavior of dry storage systems.

And that's going to require the model development and the benchmarking data you've heard a bit about. We certainly need these small-scale separate effects testing, everything from lab scale, understanding what each of the effects may be on the system to, maybe, some small-scale more than just

single effects testing type of experiments that could go on for quite a few years.

Ultimately, we think we're going to have to do a confirmatory test under prototypic conditions to really have confidence in our understanding to develop aging management plans and understanding how long these systems will last. Prototypic means full-scale. We have representative dry storage conditions, that would be the way it's dried, the temperatures at the beginning, the way the temperatures evolve, et cetera.

We would like to take a look at multiple high burnup fuel types because not all fuel is the same. There's ZIRC4, M5, ZIRLO, et cetera, and it would be good to have high-burnup fuel from all those kinds involved in this test. Slide 17. For the activities that need to go on for this full-scale high-burnup demo are listed here.

And one of the things that industry is interested in is getting this demo going sooner rather than later because both NRC and the industry are aware of when some of these license extension requests are coming up, especially for some of the high-burnup systems, which are starting to hit in, say, 15 years or so, so the sooner we get some of these demos going

so we've got some data to support those license extension requests, the better off we are.

So back to what the activities are. First bullet there, obtain t=0 data from sister rods. We want to, essentially, understand what's the condition of the rods in the spent fuel assemblies as they are being put into the dry storage system so that later one when we take some back out and look at them we know what's changed.

And the t=0 data is everything from profilometry so we know whether the cladding cracks during storage to how many hydrides, you know, the concentration of hydrides in the zirconium, the orientation of those hydrides, helium pressure, et cetera.

Then, the things that need to be done for this special demo are the next set, which is to modify some existing casks with a special lid that includes things like thermocouples and ability to gas samples for helium, fission product gases, in case there's been a leak at one of the pieces of cladding. Water, also, you heard Bob talk about adequacy of drying, so being able to get some water samples in terms of, you know, water vapor, oxygen ingress, all those kinds of things would be of interest.

DOE may have interest in doing a few other things like, maybe, strain gauges. Then the idea would be to load the cask, and replace the modified lid, and you're going in terms of collecting data. The data collection, as soon as the lid goes on, because you're starting to get the thermocouple data and the gas data from day one of storage.

And so we'll periodically capture the temperature data and the gas evolution during drying. Then it could sit there. The bottom bullet. So it sits at this host site for maybe ten years or so, continuing to take temperature and gas measurements. Then at that point, you reopen it, you take some rods out, you visually inspect them, compare them to the t=0 properties, and now you have a pretty good idea how much the cladding has changed, how much the internals of the canister have changed over this X year time period.

This is the kind of thing that was done for the lower burnup casks that are sitting at Idaho. We want to repeat this now for a higher burnup system that's going to be required. Slide 18. Again, getting back to this industry need to get things going sooner rather than later. A high-burnup demo option that keeps the startup time short would be to, let's

get this demo going at a reactor site.

So you don't have to worry about transportation upfront to a national lab to get all the assemblies in one place. It avoids having to wait for a full-scale hot cell to be funded and constructed because, right now, the U.S. no longer has a hot cell big enough to handle a full-sized cask, and it keeps the cost lower prior to test initiation.

Right now, Dominion and Transnuclear are proposing an option where Dominion would host this at either North Anna or Surry, they could maybe get it going in three to five years. North Anna has three different kinds of high-burnup fuel, which is good. TN is going to supply some casks at a lower cost. We, at EPRI, are providing initial funding for the instrumented lid design.

We are going to invite NRC and DOE to provide us input in terms of how that lid should be designed and we are very strongly looking for co-funding because this is going to be quite an effort to get this done. So those are the two things that I wanted to talk about in terms of particular projects that EPRI is working on as well as a bit about the ESCP program.

CHAIR ARMIJO: Is that lid on a bolted

cask or is it on a welded? You better repeat it.

MR. RUBENSTONE: John, did you hear the question?

DR. KESSLER: No, I really could barely hear.

MR. RUBENSTONE: The question is, the lid of this demo, is that on a welded or a bolted system?

DR. KESSLER: Yes, it'll be a modified bolted lid because we will have penetrations through for the thermocouples through the lid as well as penetration through to take a gas sample. But it's a TN 32 bolted lid design with a modified bolted lid. And the modifications and getting the license approvals is something that is where we obviously will need to interact with NRC as well as making sure that the data we collect are the data that people need.

MEMBER RYAN: Okay. John, thank you very much. We appreciate you being on the phone and going through your slides. I think that worked quite well, so we appreciate you taking the time to do that today. I know you're busy.

DR. KESSLER: You're welcome. I'll go back on mute and listen.

MEMBER RYAN: Okay. Great. Our last speaker is Rod McCullum from the Nuclear Energy

Institute. Welcome, Rod.

DR. MCCULLUM: Thank, Dr. Ryan, and I want to thank the committee for taking its time to consider this topic. The topic of extended storage is something that is of great interest to the industry and something we consider a high priority, and we think that this committee's consideration, input, and recommendations will be highly valuable in that regard.

It is very important that as -- you know, there's a lot of uncertainty in the world of repositories and ultimate disposal, and such, but one thing that is certain is that we will be storing used fuel for extended periods of time. So I'm encouraged that, hearing from my colleague at DOE, there's work going on there and also from the NRC staff.

We definitely need the regulatory framework to be sharp and able to address the challenges of extended storage, and the DOE role here is huge. The fact that we are moving into extended storage is a direct result of DOE's decision making. DOE also has the infrastructure and capabilities to do the work and certainly, a lot of DOE decisions yet to be made will influence how the system works, that I will get to in a minute.

In the interest of time I was going to spend a fair amount of time here on this first slide talking about why we believe there already is a strong basis for extended storage. I'm not going to go over these things. I would just encourage the committee to consider the record that exists. I will correct. It says over 1700 casks. It's really right around 1600 now. That's where we'll be by the end of the year.

I was looking at my projection somehow. But anyway, and also, to point out one thing that was in your earlier discussion, Calvert is not the first one to go for renewal beyond 20 years. HB Robinson and Surry have been renewed, as has Oconee, and when you look at the record, you'll find that those things are --

CHAIR ARMIJO: You never know what's --

DR. MCCULLUM: -- that there's a lot of information gleaned from those. Sorry, John. And what I want to focus on is the going forward piece. Now, the last thing I'll say is that there really is, you know, a lot of safety margin here, what you see in the PRAs, I would look at those as well. But looking, and this is what John Kessler talked about, is the opportunities to verify.

You know, the confidence we have going in

that we can safely store these things for extended periods of time, to further verify and further provide assurances, to further support the changes in the regulatory framework that we know will be coming. The first thing I would encourage is, we have done a substantial project.

The DOE INL dry storage characterization project looked at a 14-year-old cask, opened it up, examined the fuel, and found the fuel in pretty much the same condition it went in after it was stored for 14 years and transported. The project John talked about, the demo, that's going to repeat that project with a higher level of sophistication in looking at higher burnup, more challenging fuel.

And of course, John also talked about the canister inspections. These last two pieces, above what was done for the previous renewals, above what was done in the Idaho project, and above all that we've learned from our experience with these 1500, 1600 casks is more pointed towards extended storage, which is now more known as a certainty.

And this is where, really, all the gap analyses and risk prioritization work that you were hearing about comes in together. It's important to industry that we get a good common understanding of

what is needed, that we look at, you know, what the risks really are and what is needed to mitigate the risks, recognizing the safety margin we have going in and that these are dry casks.

So we were thankful to be able to comment on the staff's RIS prioritization, on DOE's, we've been commenting on DOE's gap analyses, we've been participating, our utility members in the EPRI project, because we believe that we are in a position where we already, again, when you look at the record, have a strong safety basis, have the opportunity to extend that in a timely matter to consider further extended storage, and making sure that we're looking at the right things, and not simply chasing speculation, is very important.

It's also important to look at this in the context of the system that it exists in. This was, I think, alluded a little bit in Dr. Powers' questions earlier in terms of, you know, the real risks here are when you start moving it around and doing stuff with it. You know, we envision storing at reactor sites for multiple decades.

You know, again, some systems have been licensed for as long as 60 years already. The regulation allows for 80 years. Transporting it,

perhaps transporting it to a consolidated storage site, and it's at the consolidated site where we believe a lot of the demonstration, research, and development work can be best accomplished if that's the way it comes together, which we hope it would.

And what I'm talking about is an integrated system here, perhaps transporting again, perhaps not, if the consolidated storage site becomes a repository site, and then ultimate disposal. Industry filed contentions in the Yucca Mountain licensing proceeding to seek to amend the Yucca Mountain license application to allow for direct disposal of the casks we already loaded.

We believed that was possible. I thank EPRI, even though I hung up on them, for the work that supported that and we believe that now, if we have to design a new repository, we should be looking to integrate that to be able to dispose of the existing casks. Again, we have to integrate around the system we have; 1600 casks, soon to be 1700 casks into this.

We can't design the system. We can't reverse engineer it from the beginning. We think that the casks we have, you know, again, it's a strong safety basis to go forward and do that. That's why the DOE component of this is so critical. So you have

the regulatory component and you have the DOE component designing the whole system around the part of the system that is irreversibly now already in place.

The last point here, which is vitally important, is that, as we integrate this system it must be supported by a more efficient regulatory framework. This is a topic, perhaps, of a different meeting. Industry will be coming forward later in the year with proposals to improve Part 72. Right now, we're in a situation, and it has to do with how the regulatory framework evolved as dry cask storage came in place before it was a mature industry, which it is now.

The dry cask storage is regulated at a greater level of detail right now than reactors, even though the risks, I think you'd all agree, of dry cask storage are much less than those of the reactors; remember the PRA number I had on the first slide. So it's basically, to us, the long and the short of it is, if we're going to be cutting down more trees, or cutting down bigger trees, or longer lived trees, in the case of extended storage, we have to have a sharper saw.

And so I would appreciate the opportunity

to talk to this committee and relevant subcommittees about that in the future. So in conclusion, you know, we believe and we encourage the committee to look at the things that we've referenced here. There is already a strong basis going forward. We are being proactive and we're trying to work with DOE, which has the capability to really do the lion's share of the work, to further verify the basis for extended storage.

And this can't be done in a vacuum, it has to be done considering the ultimate system that we're putting in place and have already put in place, and must, you know, be considered. We fully endorse the recommendations of the recent risk management task force. Those are consistent with some direction the staff got in the SECY for looking at extended storage long-term waste confidence, that we need targeted regulatory improvements to go so this whole system works together.

So I'm sorry for rushing through that, but, you know, we're only four minutes late.

CHAIR ARMIJO: Pretty well done.

DR. MCCULLUM: And I would certainly love to entertain any questions, and again, encourage continued discussions on this issue with the

committee.

MEMBER RYAN: If I may, Mr. Chairman, I just asked the question, you mentioned waste confidence, how does that play into your considerations for this issue?

DR. MCCULLUM: Well, we think that extended storage is about extending waste confidence. And although there was a recent court decision which remands the rule and vacates it, that court decision focused on three specific defects, none of which go to dry storage. You know, the question of doing the environmental analysis of the case, which there's never a repository, which, fine, you can do that. That's not an eventuality I think we'll ever get to.

And then two tasks with respect to fuel pool fires and fuel pool leakage, which we think can also be addressed and analyzed. The court did not contend to rule at all the basis for confidence in dry cask storage that exists in the 80 years of regulatory coverage was in any way deficient.

So what we see the linkage to waste confidence, it's really about extending waste confidence to longer periods of time. Keeping in mind waste confidence ultimately goes to a repository. Will we have a repository in the next 20, 40, 60, 80

years? I certainly hope so, but, you know, I deal with technical issues. That's a political issue.

And our industry is committed to providing safety in dry cask storage, hopefully at a consolidated site, as long as we need to. And we have a high confidence. You know, these are very robust systems. There are no moving parts. They basically are structures. And if you look at the way these structures are designed and built, and look at all the structures all over the world that have withstood decades and centuries --

MEMBER POWERS: Like Seabrook.

CHAIR ARMIJO: But, Jeff, you know, you just had to activate me. You know, it seems to me that the industry is really neglecting, particularly on this issue of chloride stress corrosion cracking potential on certain kinds of casks in a marine environment. The industry is ignoring preventative maintenance, simple things that could be done.

If you can get a wand in there to scrape salt, and sample salt, and measure temperatures, you certainly can get a hose in there and rinse these suckers off every once in awhile. So, you know, just simple practical stuff that doesn't --

MEMBER SHACK: You wouldn't get it all.

CHAIR ARMIJO: You'd have a whole lot less than you had before.

DR. MCCULLUM: There are differing opinions as to whether or not spraying it down with a hose is the right thing to do or not. And I would point out --

CHAIR ARMIJO: It may not be the thing, but there ought to be some preventative maintenance on things where you know you've got a risk out there. The chloride stress corrosion cracking happens in a marine environment.

DR. MCCULLUM: Well, and that's what the effort that John Kessler alluded to, and even before that effort was launched, we had been engaged in what we call a regulator issue resolution protocol on this very issue. Mark, this has been well over a year, year and a half, two years, yes, it's been about two years where we've been focused with NRC staff on that very issue.

So I guess I take to great heed your call for us to get more action on it, but we're trying to assess the need for maintenance, identify what the right maintenance would be, and I think we have high confidence that we have the time to put those programs in place.

CHAIR ARMIJO: Well, just don't wait until you find a bunch of stress corrosion cracks.

DR. MCCULLUM: I think I can credibly say we are ahead of that.

CHAIR ARMIJO: Okay.

DR. MCCULLUM: And we are not going to drag our feet.

CHAIR ARMIJO: Happy to hear that.

DR. MCCULLUM: And we're going to continue to stay ahead of that.

MEMBER RYAN: I'm reminded of the pilot at 10,000 feet that was asked, how are the landing gear? He said, okay, so far.

MEMBER BROWN: Can I ask one question?

MEMBER RYAN: Please.

MEMBER BROWN: Along with this demo project that, you know, they're proposing building something, stuffing stuff in it, monitoring it, and sticking it out there and just looking at it for 10 or 15 years, whatever the case is. If you've already got stuff sitting around, you did a 14-year inspection, then why can't you just keep looking at casks that have been sitting around? I mean, you looked at it and it was --

MR. EINZIGER: I think I can address that

one. First off --

DR. MCCULLUM: Well, Bob, if I could. There's, I think, a distinction here between what goes on inside the casks and the cask. You're absolutely right in terms of looking at -- the canister is the primary barrier and I kind of glossed over -- you know, when I talk about integrating the system, I'm specifically talking about the role of retrievability.

If these canisters could be disposable, that puts more emphasis on the canister itself. The demo is intended to look at, what is the condition of the fuel inside the canister? We've done that once with low-burnup fuel. We intend to do that again now with high-burnup fuel, hoping we'll get the same results.

MEMBER BROWN: Oh, okay. So you already have a thought in process to look at existing dry cask storage of high-burnup -- okay.

DR. MCCULLUM: Right. It's a defense in-depth approach, yes.

MEMBER BROWN: Yes, but one you can now and the other one is going to take a long time.

DR. MCCULLUM: Right. And the one that's going to take a long time, we're already thinking about how we factor that into license renewals so that

there's a link to, you know, as those things go into their extended license period, actions they would take depending on what we learn from the demo project. So again, it needs to be an integrated effort, and I think it is, and we're committed to continuing it.

MEMBER RYAN: Bob, just for the court reporter, tell us who you are again.

MR. EINZIGER: Bob Einziger from the NRC. The examination that was done before, as Rod mentioned, was low-burnup fuel. We don't see big issues with that, but one of the things that came out of that examination is that there was a difficulty and an uncertainty added into the interpretation of the data because there was no baseline.

In other words, if we had any major changes in the fuel from what you would normally expect, there would have been a problem in identifying what those changes were. The stuff that's already in storage, we have no baseline on.

MEMBER BROWN: So nobody has looked at it for this type of an assessment.

MR. EINZIGER: That's right. And so any demo that's going to start now would establish that baseline and follow through so we have something to compare it with.

DR. MCCULLUM: Yes, I agree. This is going to be a much more sophisticated test. We're going to build on what we've learned.

CHAIR ARMIJO: I just hope you guys don't turn this into a great science program when it's really an engineering issue. You don't necessarily need a baseline to measure change if you have acceptance criteria on ductility, or fracture toughness, or strain energy to fracture, or something that says this is my acceptance criteria and this stuff that's been in storage for a long time, I don't know the baseline, but it meets it.

MR. EINZIGER: The acceptance criteria is that it's been in a reactor, it's been irradiated, and it hasn't had a gross failure.

CHAIR ARMIJO: No, but also, when --

MEMBER SHACK: What he's saying, you need the rates for is so to set inspection intervals. You know, it meets the acceptance criteria now, when do I next look at it again or do I ever have to look at it again?

CHAIR ARMIJO: Well, that's my argument, you know, that you've got stuff that's been out there for a long time. It's been in, you know, hot cells. It's been sitting around. Well, there's a lot of old

fuel sitting in dry environments, not all of it in casks. And so you can measure the fracture toughness, or ductility, whatever it is you're worried about, right now and see if it's susceptible to the kinds of things you're worried about.

DR. MCCULLUM: Absolutely. Again, that's exactly the type of input I was hoping to get from this committee and, you know, that's exactly why reaching a common set of agreements on these gap analyses and risk prioritizations is so important, so that we do focus on, you know, what those criteria need to be and making sure that everybody understands what it is to say that they're met.

MEMBER RYAN: Thank you, Rod. Any other questions for our speakers from the panel today?

CHAIR ARMIJO: Excellent.

DR. MCCULLUM: Thank you.

MEMBER RYAN: I want to thank all the speakers today, the NMSS staff, and our representatives from DOE, and NEI, and EPRI for participating in this full committee meeting. We had a very productive subcommittee meeting -- okay. And, Chris, you're going to open up the bridge line? I guess so. John was on the line. He dialed in to the other line, he just couldn't speak, so I think he's

been listening effectively. Our end worked okay, I guess it was his end that dropped off. I'm not sure.

MEMBER POWERS: There's one question that comes to my mind is, we've spoken a lot about chlorides and stainless steel for locations near big chloride sources, such as oceans and things like that. What about other kinds of things? I know that certainly the gaseous effluents from internal combustion engines affects a lot of things. I don't know how much it affects stainless steels and whatnot.

MEMBER SHACK: Well, I think Bob sort of alluded to, you know, the other things that you might worry about besides chlorides, but I don't know that effluents from engines, or something, but I mean, there's an awful lot of contaminants out there in the world.

MR. EINZIGER: We're concerned about sulfides?

MEMBER POWERS: It's what comes immediately to mind, Bob, but I don't know that that's the only thing.

MR. EINZIGER: No, but there is a part of the plan to investigate that further.

MEMBER POWERS: Sulfides and sulfuric acids, you know, just come immediately to mind.

MR. EINZIGER: Right.

MR. DUNN: This is Darrell Dunn from the Officer Nuclear Regulatory Research. We have looked at the composition of atmospheric deposits that we would expect to occur in non-marine environments. It certainly includes things from, you know, coal-fired power plants, for example, and other types of deposits.

So we have looked at what type of deposit chemistries we would expect and we've actually initiated testing to look at the effects of those deposits on the stainless steel materials that are used in dry casks, but that's ongoing work that we have right now.

MEMBER RYAN: Thank you.

MEMBER POWERS: Anything written up on them?

MR. DUNN: I'm sorry?

MEMBER POWERS: If you have anything written up on that it'd be real interesting to see.

MR. DUNN: Yes, it is ongoing testing that's scheduled to be completed in September of this year.

MEMBER RYAN: Actually, just a list of the projects you've got going, you know, by title, would

be helpful just to get a sense of where you're going.

MS. GAVRILAS: We'll give them to Chris.

MEMBER RYAN: Okay. Great. That's terrific. Thank you. Any other questions? Okay. Are there any members of the public on the bridge line who wish to make a comment? Hearing none, Mr. Chairman, I'll turn the meeting back to you.

CHAIR ARMIJO: Okay. Thank you. I thank everybody for good presentations. We're going to have a recess now for about 15 minutes. Be back at 5 o'clock. Thank you.

(Whereupon, the meeting in the above-mentioned matter went off the record at 4:44 p.m.)

Development of Interim Staff Guidance (ISG) Supporting the Tier 1 Fukushima Orders

July 11, 2012

Background

- SRM-SECY-12-0025, the Commission directed the staff to take certain actions related to lesson learned from Fukushima
- On March 12, 2012, the staff issued Orders EA-12-049, 050, and 051, which evolved from the NTTF Recommendations 4.2, 5.1, and 7.1.
- Developing Interim Staff Guidance
  - Draft ISG Public Comment Period ended July 7
  - Final ISG scheduled to be issued by August 31, 2012

Mitigation Strategies Order ISG

- NEI 12-06 Guidance
- Draft JLD ISG-12-01
- Additional Information

NEI 12-06, Diverse and Flexible Coping Strategies Implementation Guide

- NEI document provides licensees with guidance on how to implement FLEX for their site
- Each site is to follow an assessment process
  - Initial conditions and boundary conditions
  - Establish plant-specific baseline coping capability
  - Determine applicable extreme external hazards
  - Define site-specific FLEX capabilities
  - Programmatic controls
  - Offsite resources

Define Site-Specific FLEX Capabilities

- Aggregation of FLEX capabilities for the site based on hazards
  - Protection of equipment
  - Deployment of equipment
  - Procedural interfaces
  - Off-site resources
- Need to have N+1 sets of portable on-site equipment (to accomplish the 3 key safety functions)

JLD ISG-2012-01

- Endorsement of NEI-12-06 with exceptions
- Reporting requirements
  - Overall integrated plan
  - Status report
  - Full implementation letter

Additional Information

- NEI 12-06, Revision C Received
- Consensus standards
  - INPO AP-913, Equipment Reliability Process Description

Reliable Hardened Vents Order ISG

- Overview of Order
- Order Requirements
- Interim Staff Guidance

March 2012 Order

- BWR Mark I and Mark II containment designs.
- Requirements focus on strategies relating to preventing core damage.
- HCVS to protect containment from failure due to overpressure until core damage is averted and the plant stabilized, or until core damage is imminent.

March 2012 Order

- HCVS shall be capable of reliable operation under a range of plant conditions, including a prolonged loss of AC power and inadequate containment cooling.
- Does not provide any requirements for severe accident service (e.g., hydrogen).
- Severe accident service and filtration to be treated as separate issues in an upcoming Commission Paper.

Reliable Hardened Containment Vent

- The HCVS shall be designed to minimize:
  - reliance on operator actions,
  - personnel exposure to occupational hazards, such as extreme heat stress, while operating the HCVS system,
  - personnel exposure to radiological consequences that would impede actions needed for event response.
- Capacity to vent the steam/energy equivalent of 1 percent of licensed/rated thermal power (unless a lower value is justified by analyses)

Reliable Hardened Containment Vent

- Remote or manual operation allowed
- Drywell and/or wetwell venting allowed
- Include a means to prevent inadvertent actuation
- Minimize cross flow between units
- Discharge effluent above main plant structures
- Include a means to monitor the effluent discharge for radioactivity that may be released
- Capable of functioning following a seismic event; Not required to be safety-related beyond 2nd containment isolation valve

Draft Interim Staff Guidance

- Draft ISG prepared by NRC staff (No industry guidance to endorse)
- Stakeholder interactions key
- ISG aligned with requirements for mitigating strategies order (NEI 12-06 points to HCVS Order requirements).
  - The HCVS shall function with permanently installed equipment providing electrical power (e.g., DC power batteries) and valve motive force (N_2/air cylinders) for first 24 hours.
  - Durations of less than 24 hours will be considered if justified by adequate supporting information from the licensee.
  - Licensees are allowed to credit manual actions, such as moving portable equipment to supplement electrical power and valve motive power sources.

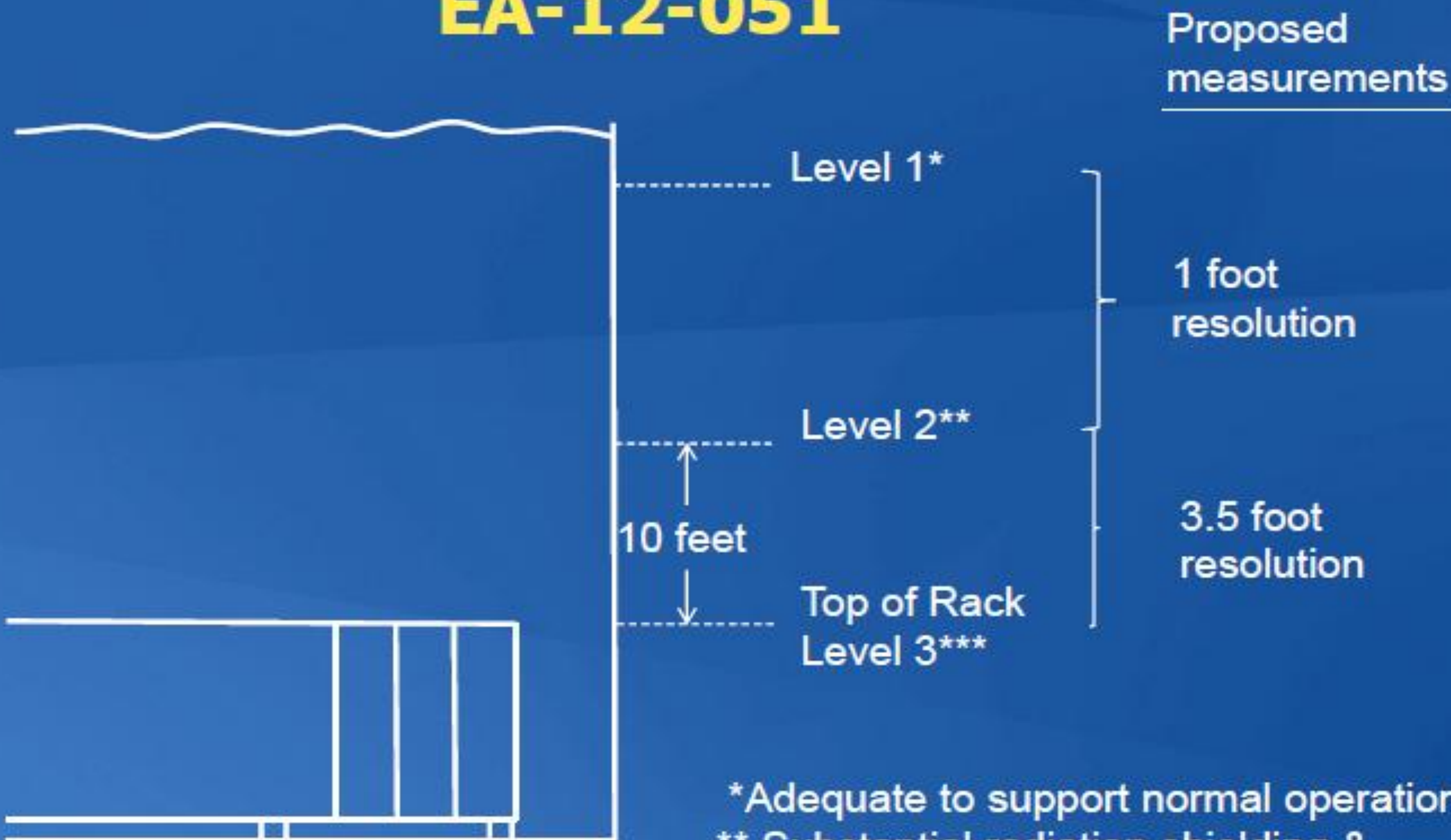
Spent Fuel Pool Instrumentation Order ISG

- NEI 12-02, Revision B
- Draft JLD-ISG-12-03

NRC Instrumentation Criteria

Design Features	NRC Expectations in ISG
Instruments	• Permanent fixed primary level instrument • Backup level instrument (portable or fixed)
Monitoring Availability	• Continuously available, indication on-demand • Calibration maintained through power interruption
Display Locations	• Control Room, Alternate Shutdown Panel, or other • Portable device usable from accessible location
Supports Prompt Identification of these Pool Conditions	• Level adequate for operation of forced cooling • Level threatening access – inadequate shielding • Level at just above top of stored fuel
Qualification	• Augmented quality (e.g., fire protection QA) • Optimize missile protection using existing structures • Seismic Category I mounting of equipment • Demonstrated to function in harsh environment • Equipment resistant to radiation and vibration
Power Supply	• Non-safety power plus alternate (battery replacement or external power connection)

Level Indications EA-12-051



*Adequate to support normal operation
** Substantial radiation shielding &
***Actions to implement makeup water should no longer be deferred.

NEI 12-02 Guidance Document

- NEI 12-02, Revision B, submitted on May 11 for NRC review and endorsement
- Instrument Design Features
- Program Features

Draft JLD-ISG-2012-03

Endorsement of NEI-12-02 with exceptions:

- Specify that instruments must be able to resist beyond design basis external events
- More explicit discussion on differences between resolution and accuracy
- Modify guidance used to establish Level 2 (dose rates limit access to pool deck)
- Specified that level readings are to be available when required / promptly accessible
- Provided detailed integrated plan template

SL2 EPU Fuel Design Review

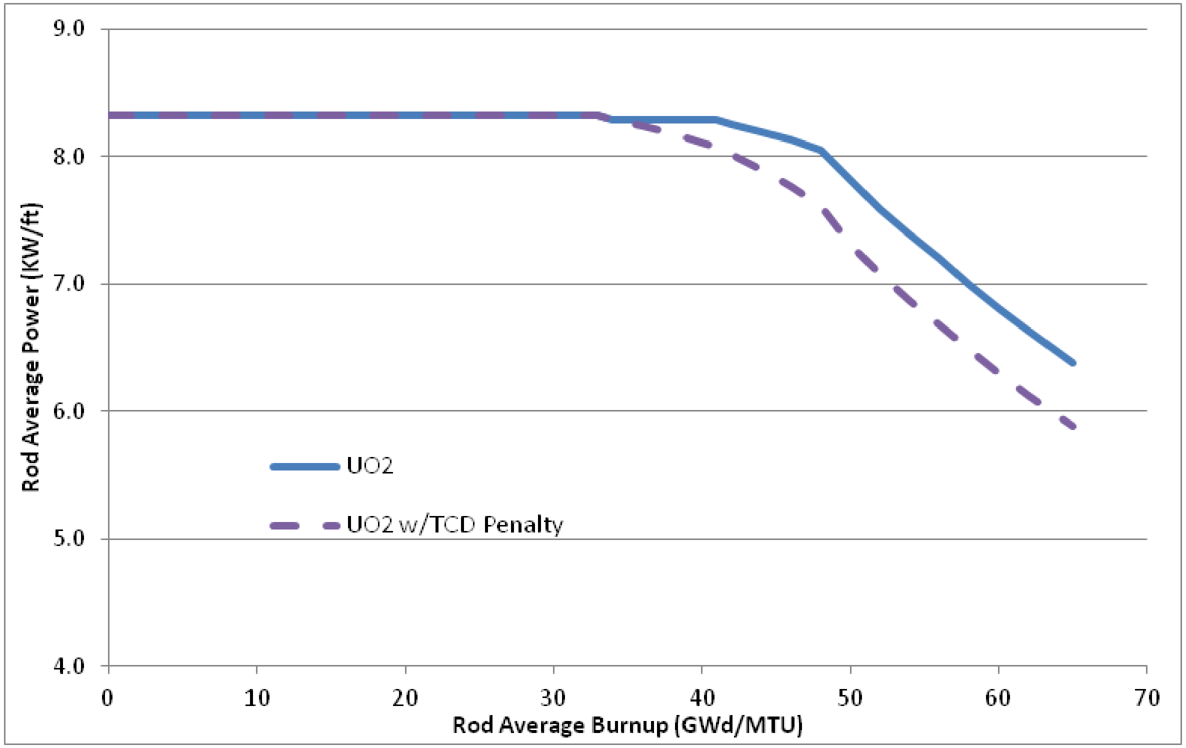
Two stage approach:

1. Reviewed SL2 EPU fuel thermal-mechanical design.
   - Reviewed FATES-3B fuel rod design calculations w.r.t. TCD.
   - Negotiated TCD penalty based on comparison to expanded Halden fuel temperature database.
   - Audited Westinghouse calculations.

2. Performed FRAPCON-3.4 confirmatory calculations for UO2 and Gadolinia fuel rod designs.
   - End of life rod internal pressure
   - LOCA initialization fuel stored energy
   - AOO power-to-melt limits
   - AOO cladding strain

TCD Penalty – UO2 Fuel

- Fuel design calculations based upon original rod power profiles.
- More restrictive rod power profiles, preserved via reload design checklist, maintains TCD penalty.



Confirmatory Calculations

- NRC staff performed FRAPCON-3.4 fuel rod design calculations on the SL2 16x16 CE HID-1L design (ML12082A196).

- Calculations confirm that SL2 fuel rod designs satisfy design requirements at EPU conditions.
  - Sufficient plenum volume to accommodate EPU FGR.
  - Penalized radial fall-off ensures BOL stored energy limiting.
  - AOO power-to-melt limits found acceptable.
  - AOO pre/post power limits found acceptable.

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Protecting People and the Environment

NUREG-1934/EPRI 1023259
Nuclear Power Plant Fire Modeling Analysis Guidelines

ACRS Committee

July 11, 2012

Mark Henry Salley, NRC/RES

Rick Wachowiak, EPRI

Office of Nuclear Regulatory Research

Fire Research Branch

Purpose of the Meeting

- NRC and EPRI have completed the project
- ACRS PRA Subcommittee – March 21, 2012
- Today we would briefly like to discuss:
  - Need & Use of the Report
  - Stakeholder Involvement
  - Response to Comments
  - Future Work in Fire Modeling
- Request a Letter from the ACRS

Purpose of Report

- Replaces 2001 EPRI Fire Model User's Guide
- Provides updated fire model information, 2007 V&V study enhancements, model validity ranges, uncertainty analysis, more realistic examples
- Serves as the text book for NRC/EPRI Fire PRA Advanced Modeling course
- Provides a consistent framework for reporting the results of fire modeling calculations

Fire Modeling Team

- NRC/EPRI Memorandum of Understanding
  – Fire Research Addendum
  – Provides for Joint Publication
- Team Composition
  – NRC Experts
  – Industry Experts
    - NSSS Vendors
    - Consultants
  – National Institute of Standards & Technology
  – Universities

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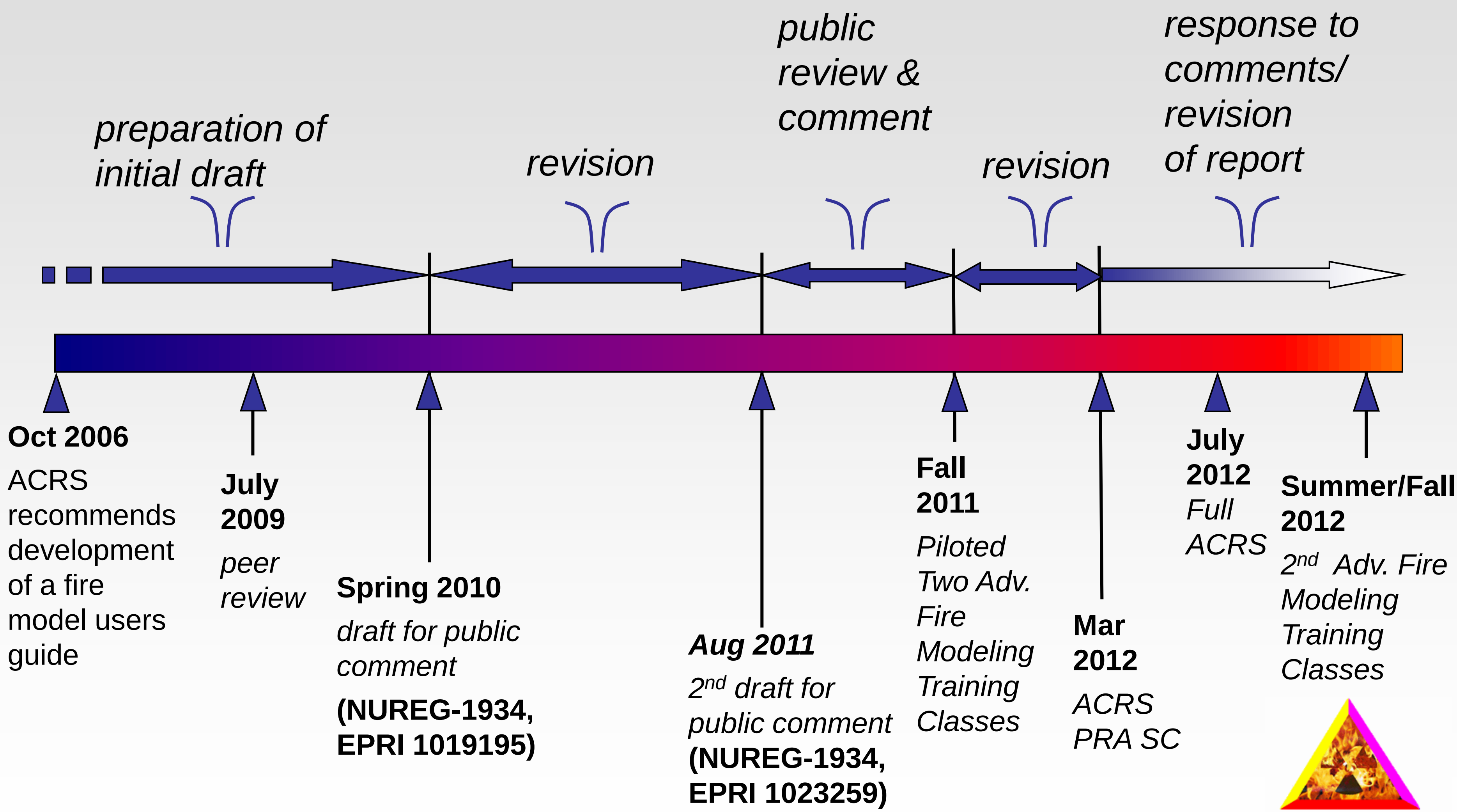
Project History



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Today's Presenters

- David Stroup, NRC
- Kevin McGrattan, NIST
- Francisco Joglar, Hughes Associates

Fire Modeling Process

1) Define objective(s)
2) Describe fire scenario(s)
3) Select fire model(s)
4) Calculate fire-generated conditions
5) Conduct sensitivity and uncertainty analyses
6) Document the analysis

Public Comments

Two Rounds of Public Comments

- Expand uncertainty discussion
- Selection of fire scenarios and model inputs
- Use of fire models beyond their range of validation

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ACRS Subcommittee Comments

- Use of Models Outside V&V Range
- New Models (THIEF, FLASHCAT)
- Consistent Selection of Models
- Sensitivity Analysis – Conservative
- Parameter Uncertainty Propagation
- Clarity
- Editorial

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ACRS Review of NUREG-1824

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555-0001

ACRSR-2219

October 25, 2006

Mr. Luis Reyes
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington DC 20555-0001

SUBJECT: DRAFT FINAL NUREG-1824, "VERIFICATION AND VALIDATION OF SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS"

Dear Mr. Reyes:

During the 536th meeting of the Advisory Committee on Reactor Safeguards, October 4-6, 2006, we met with representatives of the NRC staff, Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST) to discuss the draft final NUREG-1824 (EPRI 1011999), "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications." Our Subcommittee on Reliability and Probabilistic Risk Assessment (PRA) also reviewed this matter during its meeting on September 21, 2006. During our review, we had the benefit of the documents referenced.

CONCLUSION AND RECOMMENDATIONS

1. The report provides a systematic evaluation of the predictive capability of five commonly used compartment fire models. It should be published.
2. The user's guide to be developed by the staff should include:
   a. Estimates of the ranges of normalized parameters to be expected in nuclear plant applications.
   b. Quantitative estimates of the uncertainties associated with each model's predictions, preferably in the form of probability distributions.

BACKGROUND

Fire models are used in a number of safety evaluations, including fire risk analysis; demonstrating compliance with, and exemptions to, the regulatory requirements for fire protection in 10 CFR Part 50, Appendix R; the significance determination process of the Reactor Oversight Process; and establishing the risk-informed, performance-based voluntary

ACRS Recommendation 1:

The user's guide should provide estimates of the ranges of normalized parameters to be expected in nuclear plant applications.

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Normalized Parameters

Quantity	Normalized Parameter	Validation Range
Fire Froude Number		0.4 – 2.4
Flame Length Ratio		0.2 – 1.0
Ceiling Jet Distance Ratio		1.2 – 1.7
Equivalence Ratio		0.04 – 0.6
Compartment Aspect Ratio	or	0.6 – 5.7
Radial Distance Ratio		2.2 – 5.7

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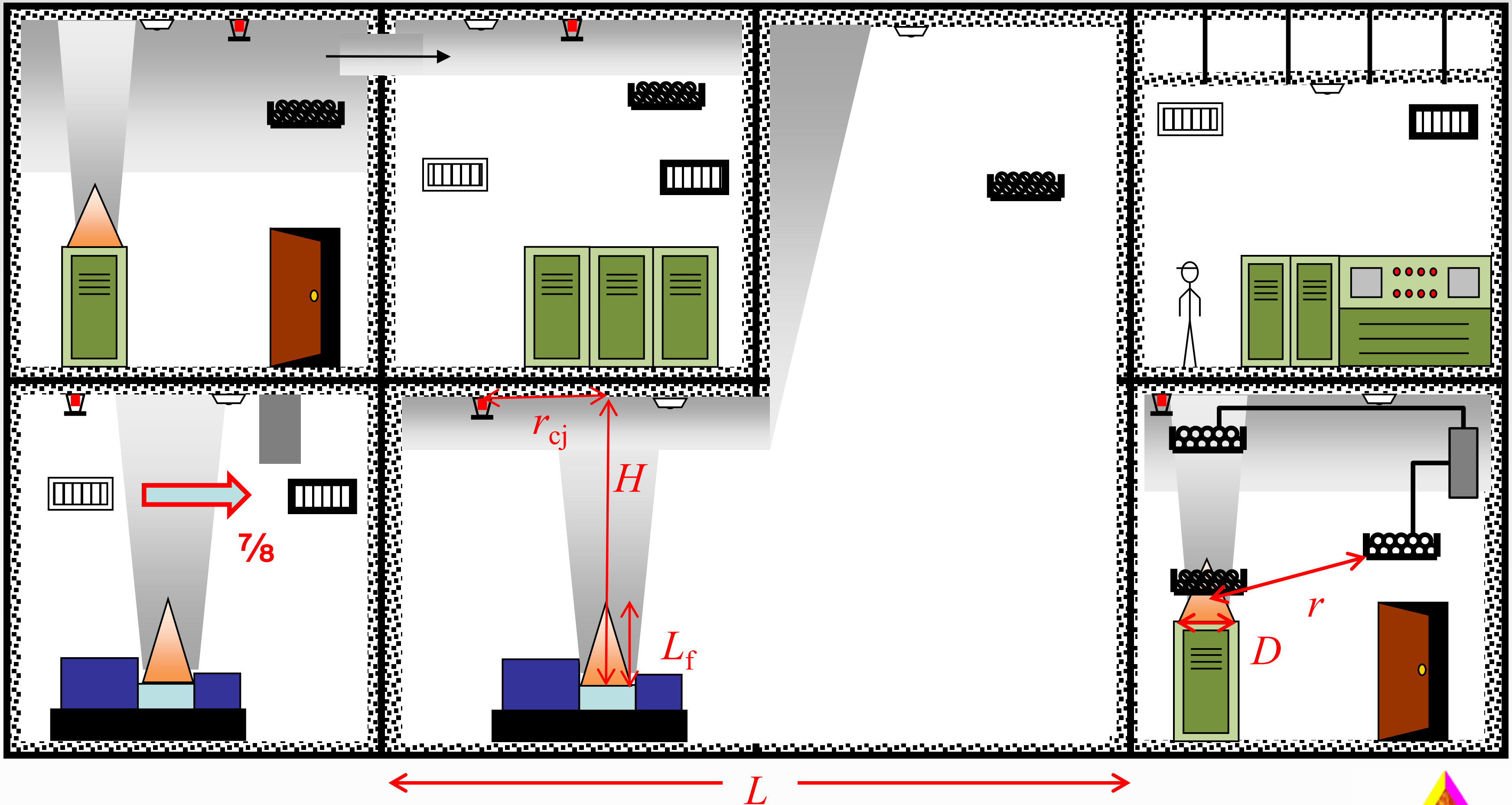
Typical fire scenarios and important parameters



Summary of NUREG-1824 V&V Study

NUREG-1824 EPRI 1011999 Final Report

Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications

Volume 1: Main Report

U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Washington, DC 20555-0001

Electric Power Research Institute
3420 Hillview Avenue
Palo Alto, CA 94303

Table 3-1: Results of the Validation & Verification of the Selected Fire Models for Nuclear Power Plant Fire Modeling Applications

Parameter[5]		Fire Model				
		FDT[s]	FIVE-Rev1	CFAST	MAGIC	FDS
Hot gas layer temperature ("upper layer temperature")	Room of Origin	YELLOW+	YELLOW+	GREEN	GREEN	GREEN
	Adjacent Room	N/A	N/A	YELLOW	YELLOW+	GREEN
Hot gas layer height ("layer interface height")		N/A	N/A	GREEN	GREEN	GREEN
Ceiling jet temperature ("target/gas temperature")		N/A	YELLOW+[2]	YELLOW+	GREEN	GREEN
Plume temperature		YELLOW–	YELLOW+[2]	N/A	GREEN	YELLOW
Flame height[3]		GREEN	GREEN	GREEN	GREEN	YELLOW[1]
Oxygen concentration		N/A	N/A	GREEN	YELLOW	GREEN
Smoke concentration		N/A	N/A	YELLOW	YELLOW	YELLOW
Room pressure[4]		N/A	N/A	GREEN	GREEN	GREEN
Target temperature		N/A	N/A	YELLOW	YELLOW	YELLOW
Radiant heat flux		YELLOW	YELLOW	YELLOW	YELLOW	YELLOW
Total heat flux		N/A	N/A	YELLOW	YELLOW	YELLOW
Wall temperature		N/A	N/A	YELLOW	YELLOW	YELLOW

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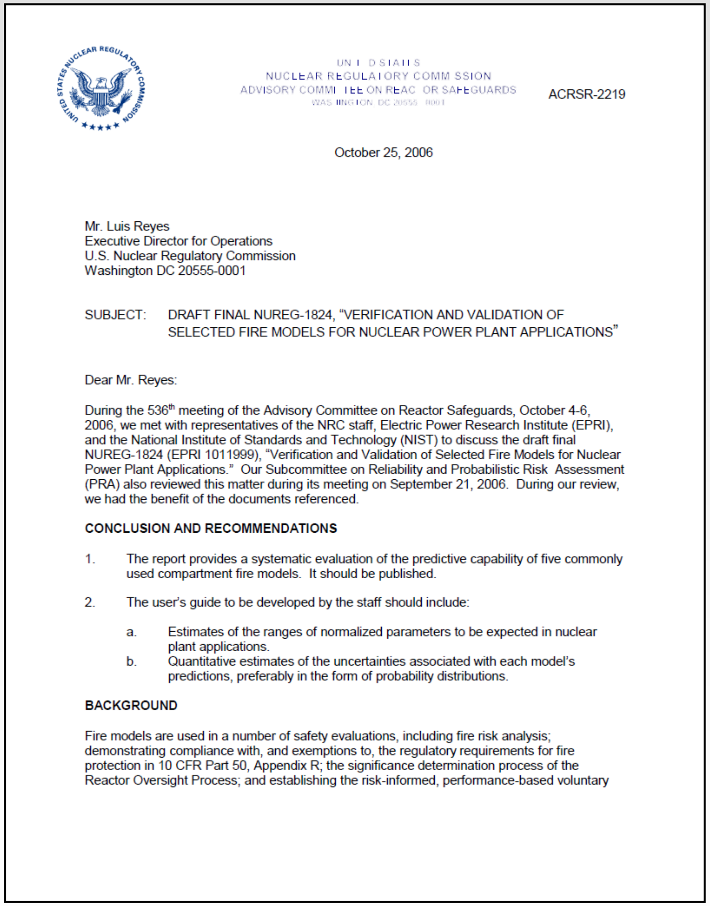
Fire Research Branch

ACRS Review of NUREG-1824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ACRS Recommendation 2:

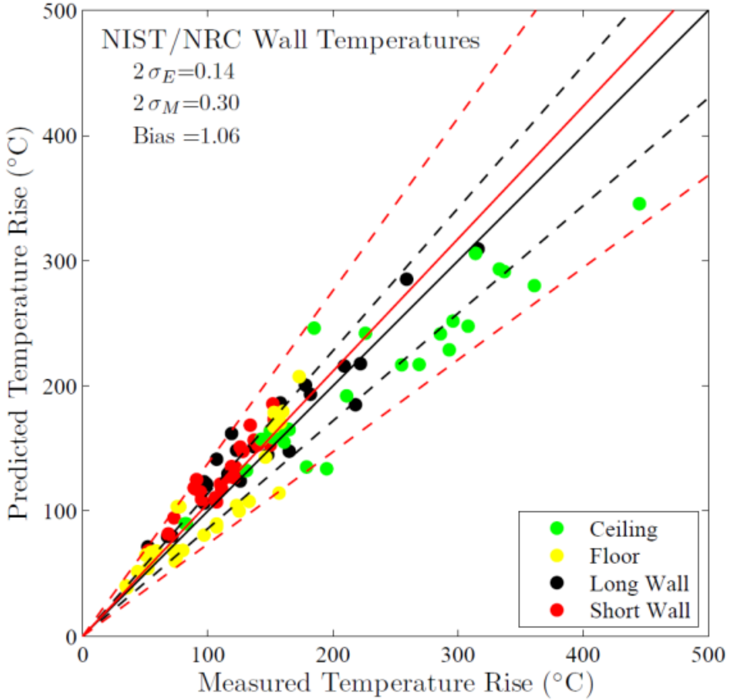
The color designations provide no quantitative estimate of the intrinsic uncertainty.

Improved Model Uncertainty Metrics

Table 4-1. Results of the V&V study, NUREG-1824 (EPRI 1011999).

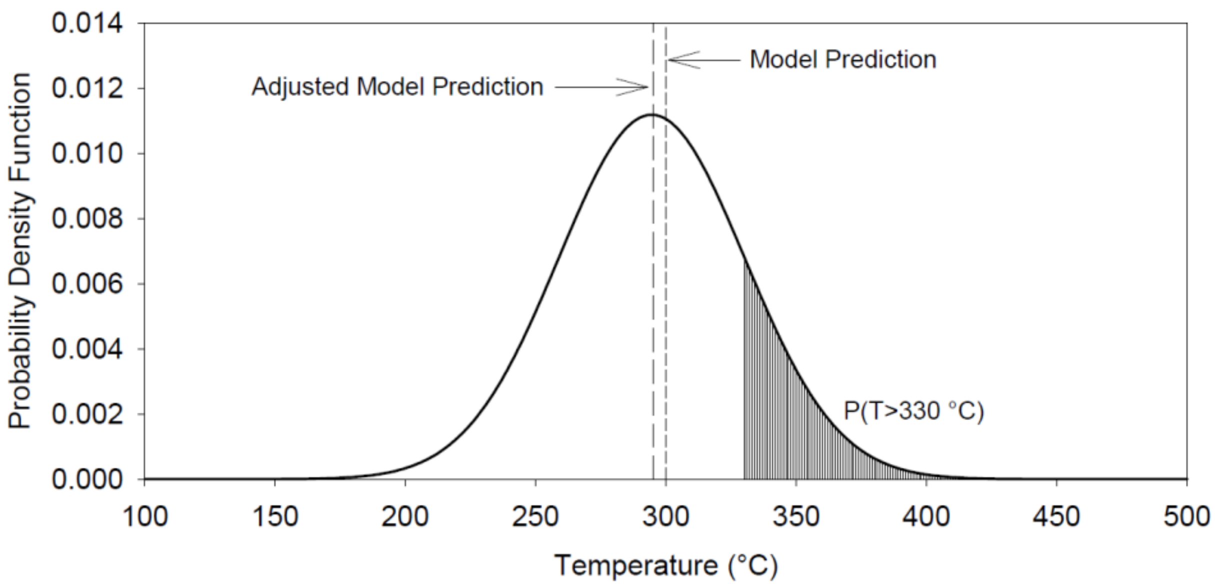
Output Quantity	FDTs		FIVE		CFAST		MAGIC		FDS		Exp
	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	$\tilde{\sigma}_E$
HGL Temperature Rise*	1.44	0.25	1.56	0.32	1.06	0.12	1.01	0.07	1.03	0.07	0.07
HGL Depth*	N/A		N/A		1.04	0.14	1.12	0.21	0.99	0.07	0.07
Ceiling Jet Temp. Rise	N/A		1.84	0.29	1.15	0.24	1.01	0.08	1.04	0.08	0.08
Plume Temperature Rise	0.73	0.24	0.94	0.49	1.25	0.28	1.01	0.07	1.15	0.11	0.07
Flame Height**	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.
Oxygen Concentration	N/A		N/A		0.91	0.15	0.90	0.18	1.08	0.14	0.05
Smoke Concentration	N/A		N/A		2.65	0.63	2.06	0.53	2.70	0.55	0.17
Room Pressure Rise	N/A		N/A		1.13	0.37	0.94	0.39	0.95	0.51	0.20
Target Temperature Rise	N/A		N/A		1.00	0.27	1.19	0.27	1.02	0.13	0.07
Radiant Heat Flux	2.02	0.59	1.42	0.55	1.32	0.54	1.07	0.36	1.10	0.17	0.10
Total Heat Flux	N/A		N/A		0.81	0.47	1.18	0.35	0.85	0.22	0.10
Wall Temperature Rise	N/A		N/A		1.25	0.48	1.38	0.45	1.13	0.20	0.07
Wall Heat Flux	N/A		N/A		1.05	0.43	1.09	0.34	1.04	0.21	0.10

I.D. indicates insufficient data for the statistical analysis.
N/A indicates that the model does not have an algorithm to compute the given Output Quantity.
Underlined values indicate that the data failed a normality test because of the relatively small sample size.
* The algorithm used to compute the layer temperature and depth for the model FDS is described in NUREG-1824.
** All of the models except FDS use the Heskestad Flame Height Correlation (Heskestad, *SFPE Handbook*). These models were shown to be in qualitative agreement with the experimental observations, but there was not enough data to further quantify this assessment.

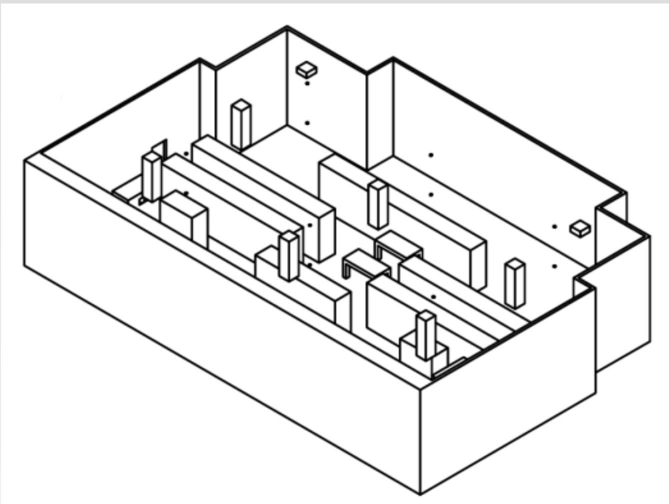


(Left) Typical results from a validation study. The black lines indicate the experimental uncertainty and the red lines indicate the model uncertainty.

(Below) Given a model prediction of 300 °C, what is the probability that the actual temperature might exceed 330 °C, the failure temperature of the given target?



How Model Uncertainty is Applied



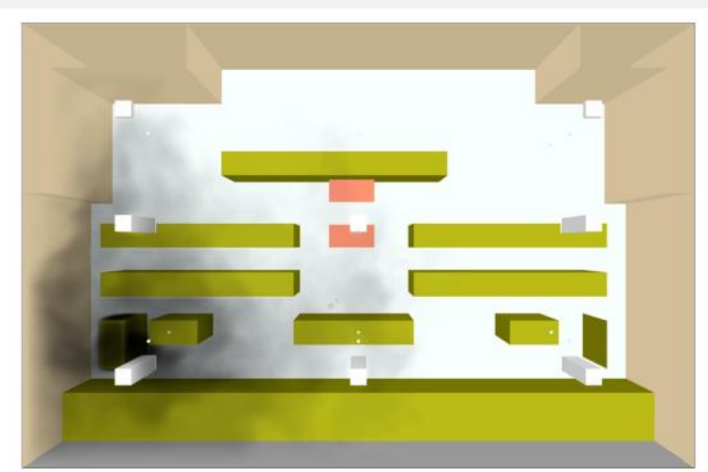
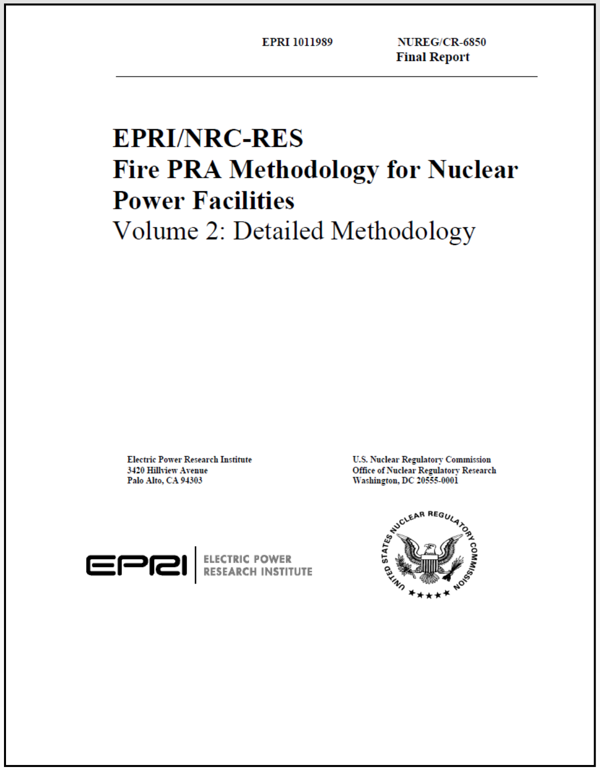


Table A-4. Summary of the model predictions of the MCR scenario.

Model	Bias Factor, δ	Standard Deviation, $\tilde{\sigma}_M$	Ventilation	Predicted Value	Critical Value	Probability of Exceeding
Temperature (°C), Initial Value = 20 °C						
FIVE (FPA)	1.56	0.32	Purge	70	95	0.000
CFAST	1.06	0.12		60	95	0.000
FDS	1.03	0.07		48	95	0.000
CFAST	1.06	0.12	No Vent.	82	95	0.009
FDS	1.03	0.07		70	95	0.000
Heat Flux (kW/m^2)						
FIVE	1.42	0.55	Purge	0.4	1	0.000
CFAST	0.81	0.47		0.1	1	0.000
FDS	0.85	0.22		0.2	1	0.000
CFAST	0.81	0.47	No Vent.	0.6	1	0.228
FDS	0.85	0.22		0.4	1	0.000
Optical Density (m^{-1})						
CFAST	2.65	0.63	Purge	6.5	3	0.362
FDS	2.7	0.55		0.5	3	0.000
CFAST	2.65	0.63	No Vent.	47	3	0.906
FDS	2.7	0.55		31	3	0.909

Parameter Uncertainty Propagation


EPRI 1011989
NUREG/CR-6850
Final Report

EPRI/NRC-RES
Fire PRA Methodology for Nuclear Power Facilities
Volume 2: Detailed Methodology

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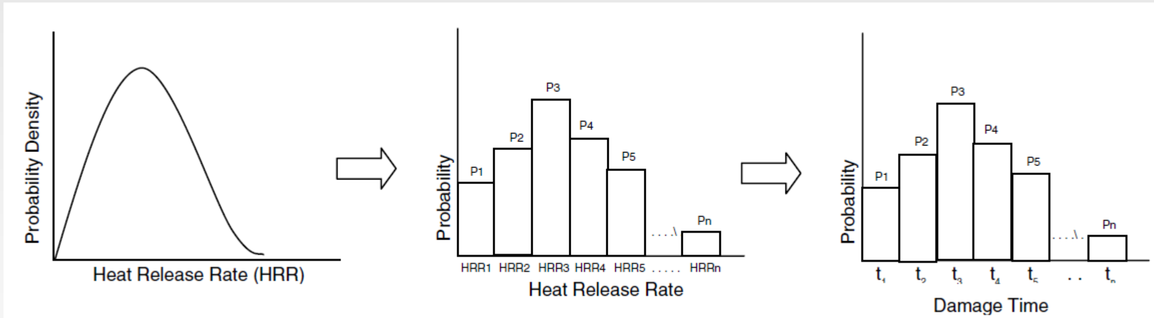
APPENDIX FOR CHAPTERS 8 AND 11, SEVERITY FACTORS



Currently, NUREG/CR-6850 contains a simple method for propagating parameter uncertainty. Several examples have been added to the Fire Model User's Guide.

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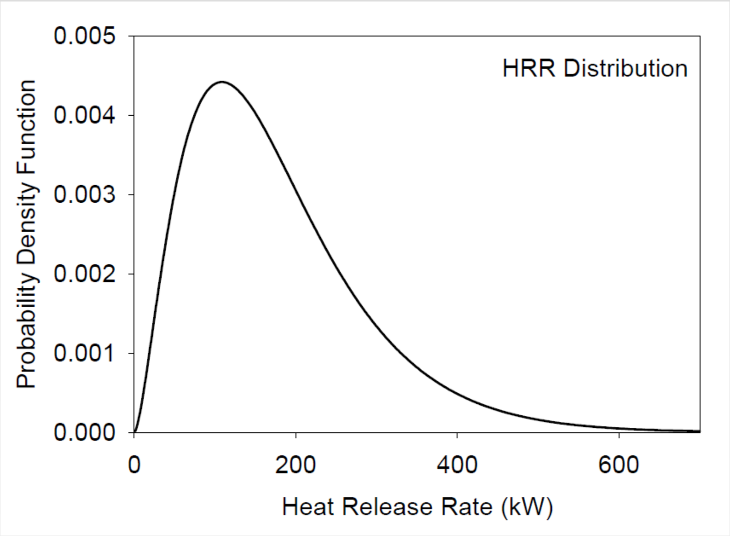
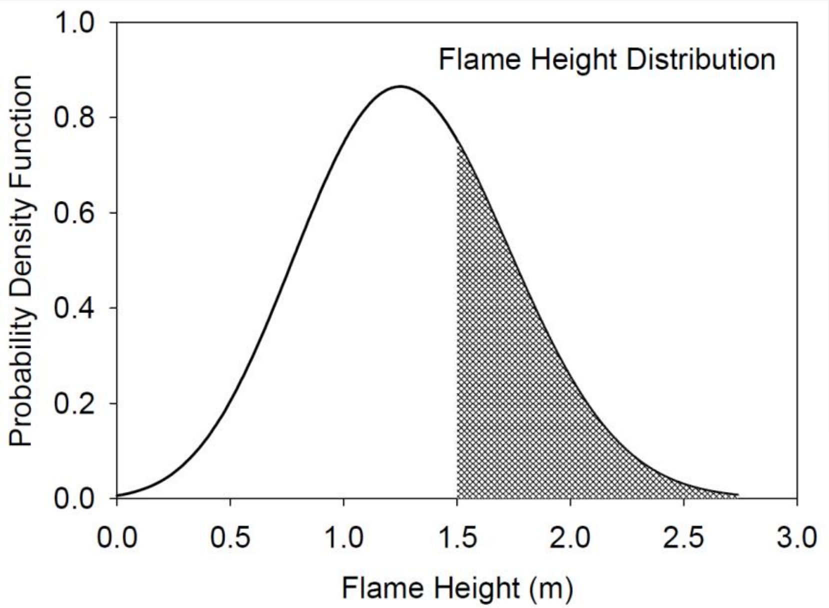
Model Input Parameter Distribution



Model: Flame Height Correlation

$$L_f = 0.235\,\dot{Q}^{2/5} - 1.02\,D$$

Model Output Distribution



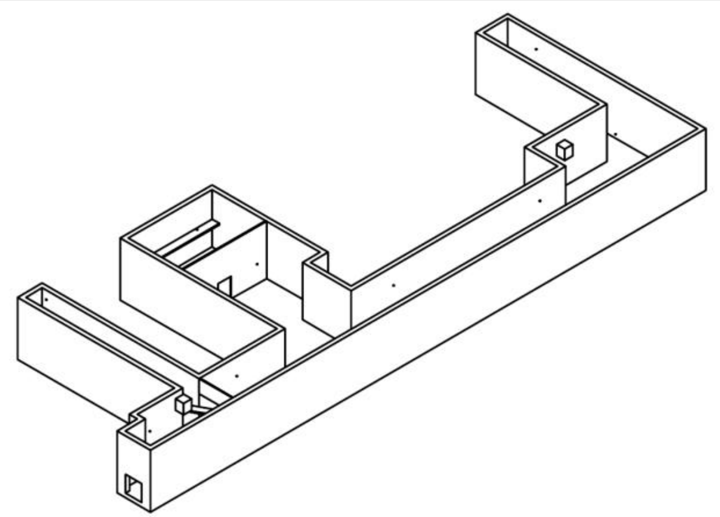
Question: What is the probability that the flames from a particular type of cabinet fire will reach a target 1.5 m above the cabinet?

What to do if the scenario is out of the validation range?

1. Sensitivity Analysis – Perform a calculation for a similar scenario that is more severe yet in range.

2. Reference other validation studies performed by model developers or others (i.e. universities, professional societies)

Example of Sensitivity Analysis



Problem: The corridor length to ceiling height ratio (L/H) is outside of validation range.

Solution: Redo calculation (or apply a simple correlation) to determine if a similar (yet more challenging) scenario increases the probability of failure.

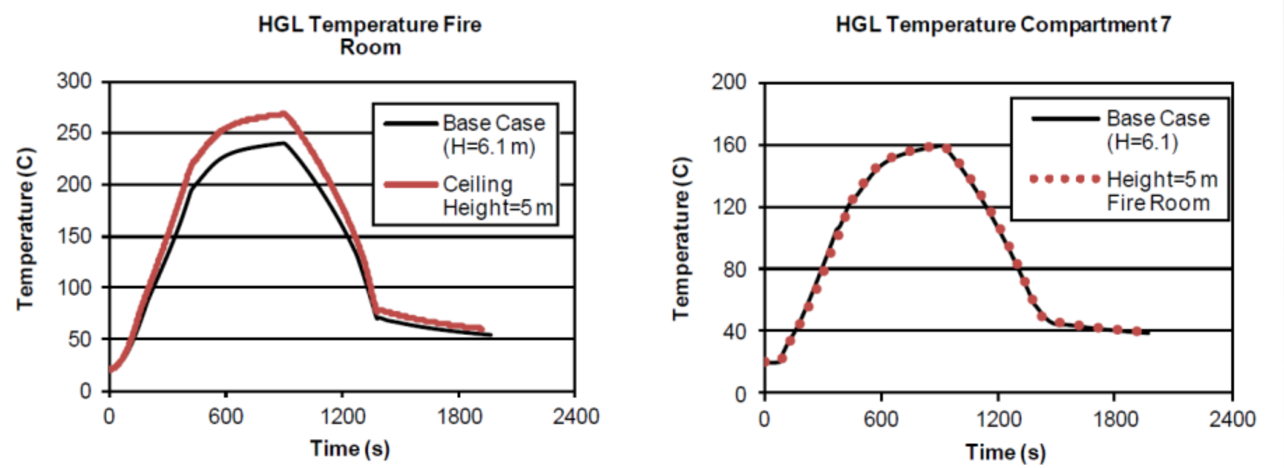


Figure G-10. Hot Gas Layer Temperature for Reduced Ceiling Height by MAGIC.

Appendices

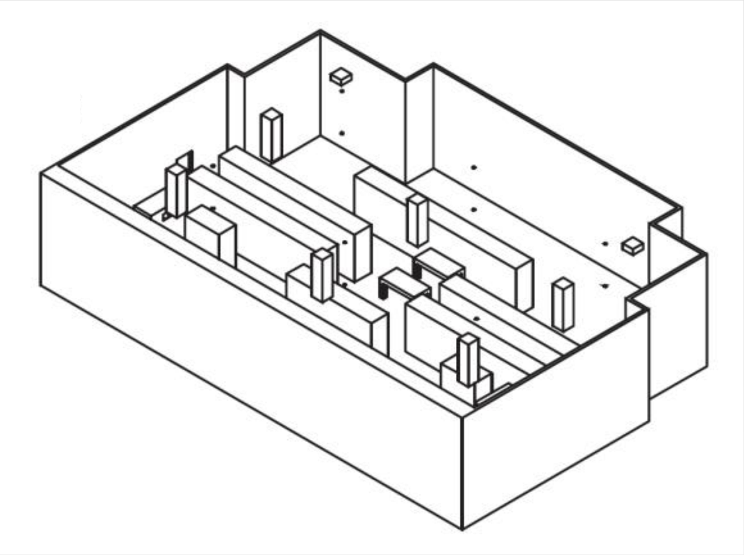
- Eight example applications, each documented in an individual appendix
  - Based on typical fire scenarios in NPP's
  - Serve as a template for consistency in the analysis and documentation of fire modeling calculations
  - Consider the fire modeling requirements of NFPA 805
  - Cover the routinely used capabilities of the fire models

Conclusion

- Team believes NUREG-1934/EPRI 1023259 ready for publication:
  - Fulfills the need to support Quality Fire Model Implementation and Review
  - Fulfills the need to support Education and Training
  - Request a ACRS Letter
- Future Fire Modeling Projects
  - Fire Model Material Properties Catalogue
  - Revisit Fire Model V&V - NUREG-1824 Update

Backup Slides

A. Cabinet Fire in the Main Control Room



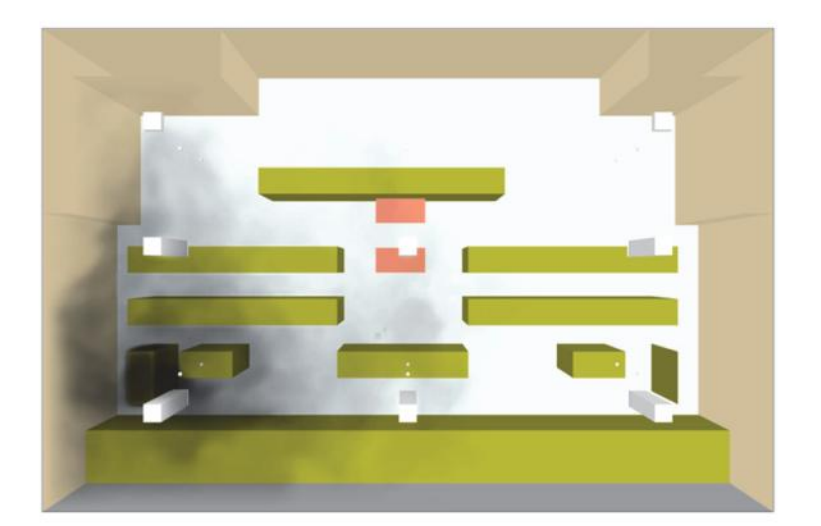
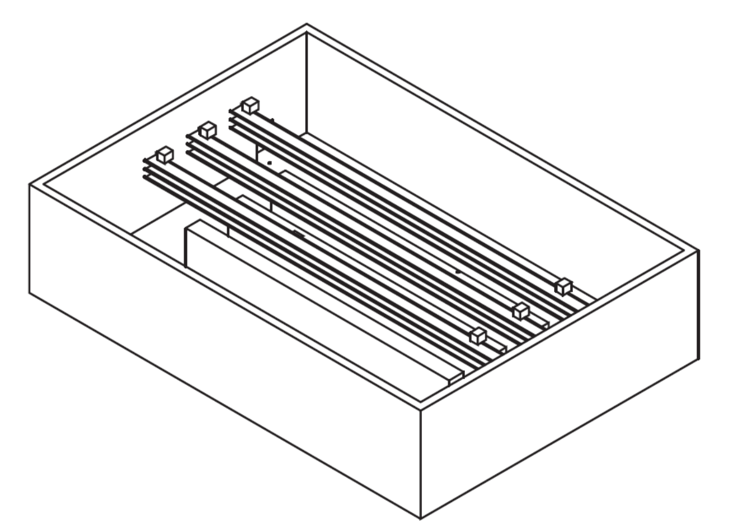


Figure A-11. FDS/Smokeview rendering of the MCR, as viewed from above.

B. Cabinet Fire in a Switchgear Room



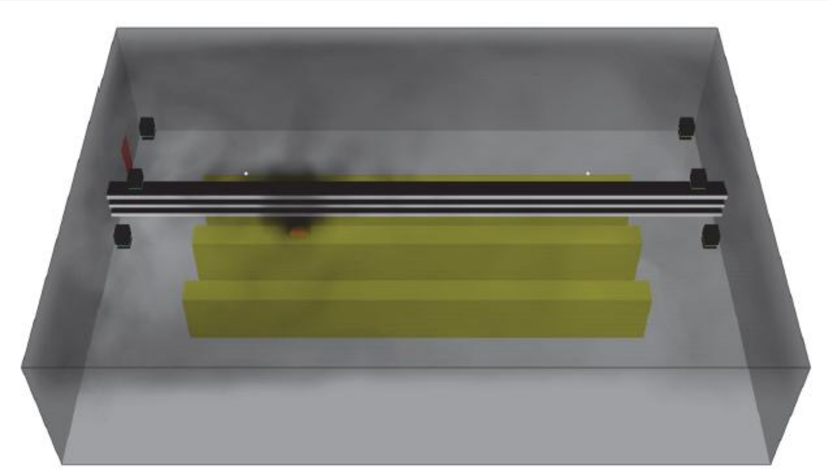
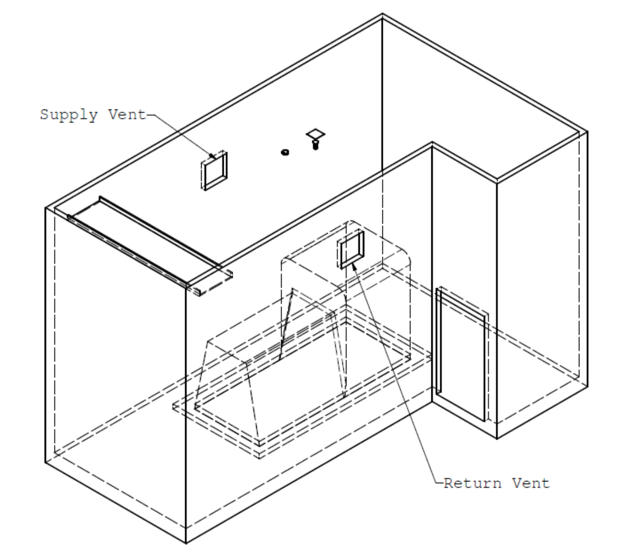
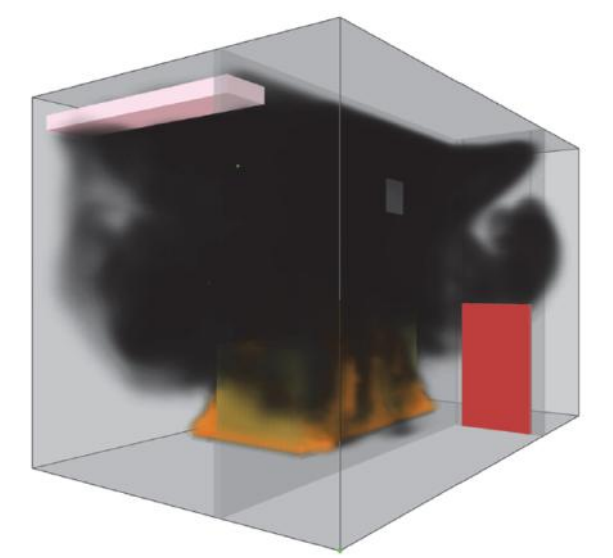


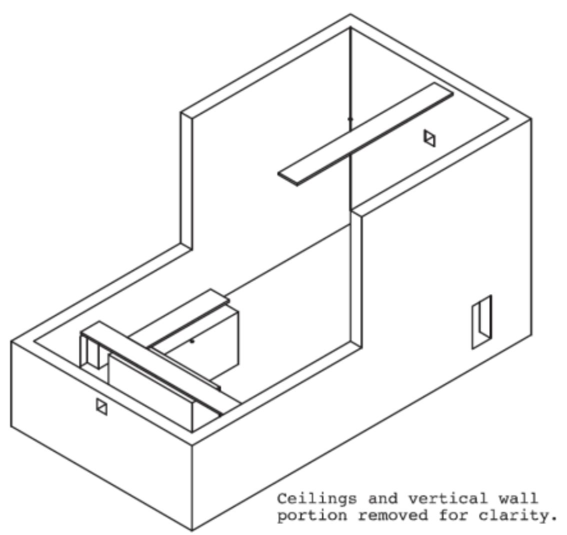
Figure B-10. FDS/Smokeview rendering of the switchgear room.

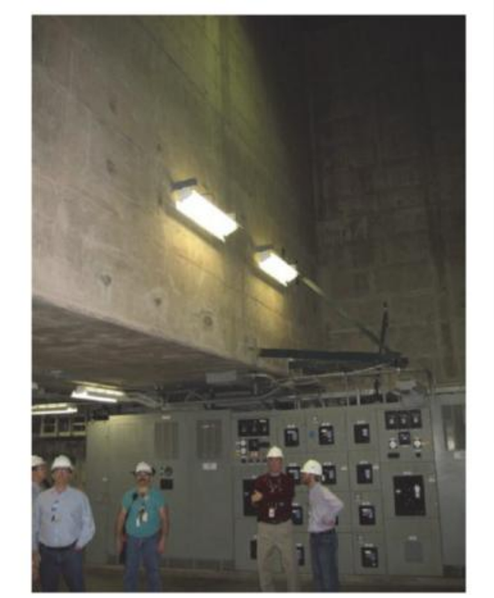
C. Lube Oil Fire in a Pump Room



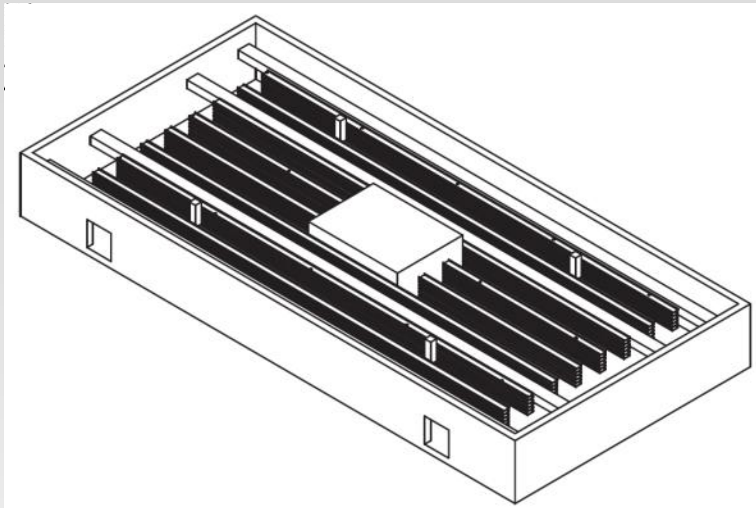


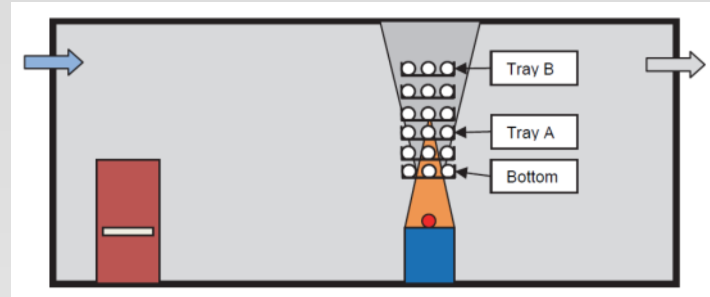
D. Motor Control Fire in a Switchgear Room

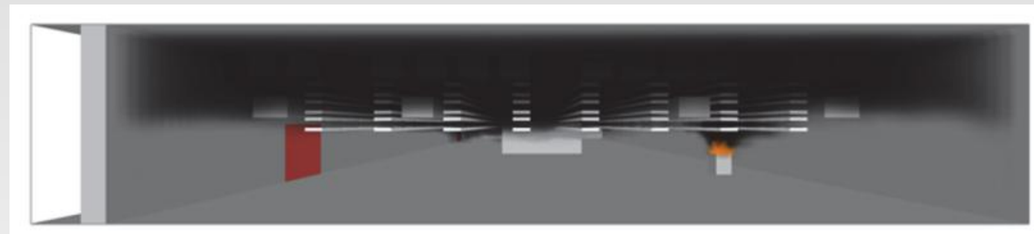




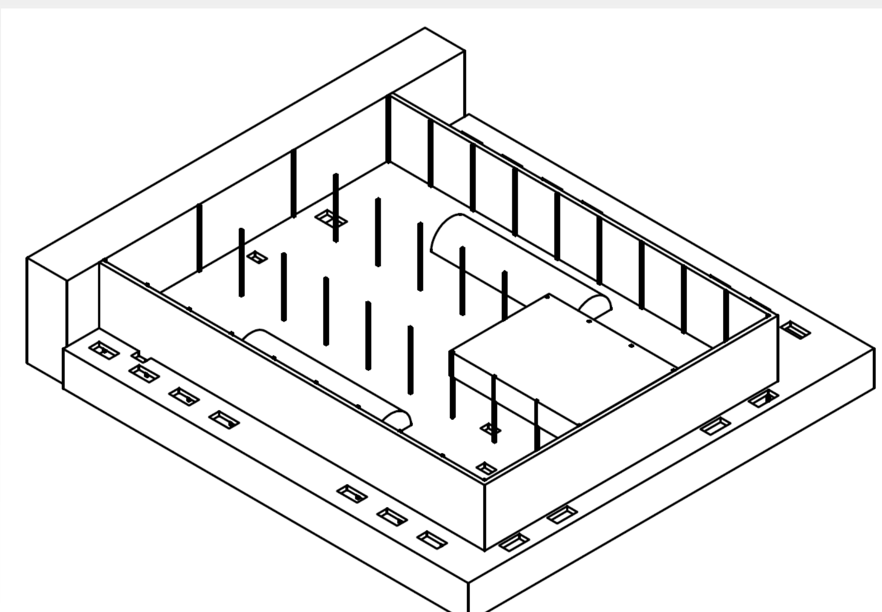
E. Transient Fire in a Cable Spreading Room



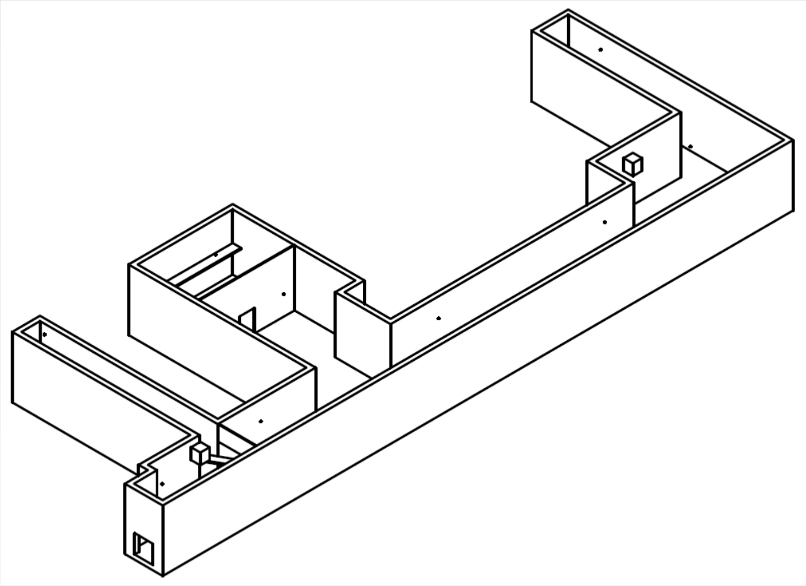


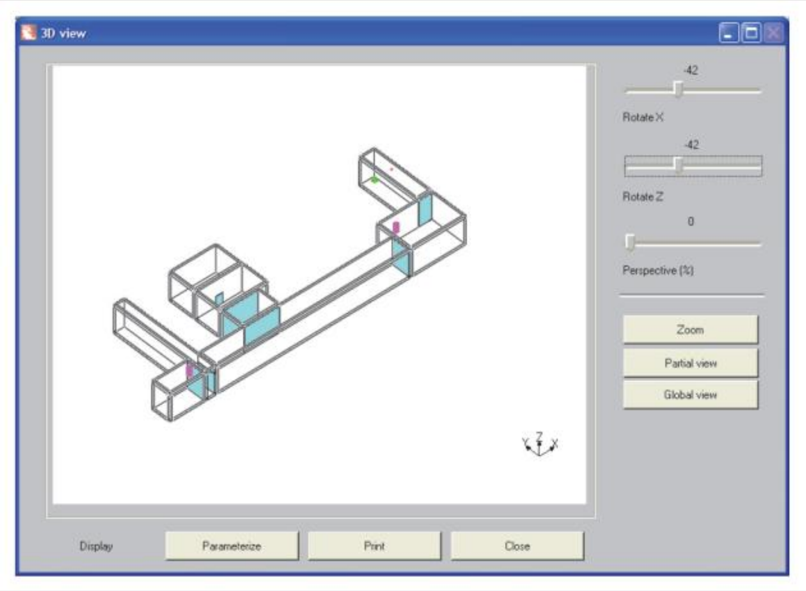


F. Lube Oil Fire in a Turbine Building

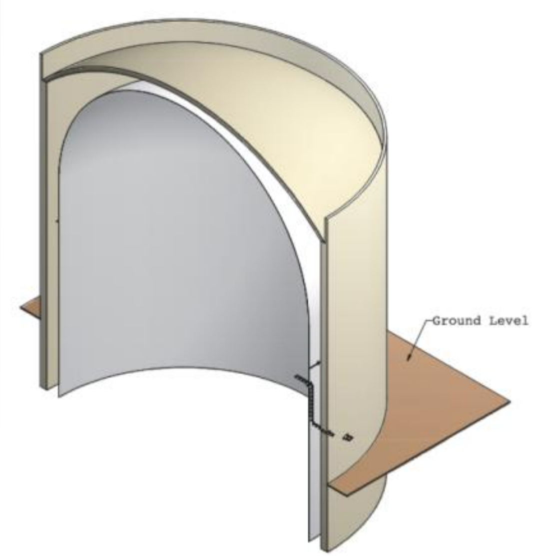


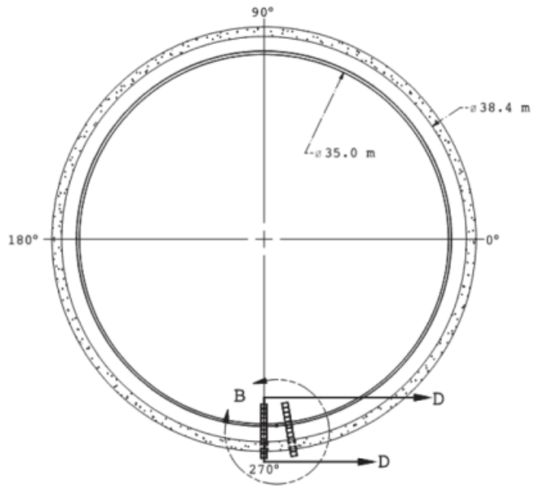
G. Transient Fire in a Multi-Compartment Corridor





H. Cable Tray Fire in the Annulus





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Example: Fire in the Main Control Room

A.1 Modeling Objective

A.2 Description of the Fire Scenario

A.3 Selection and Evaluation of Fire Models

A.4 Estimation of Fire-Generated Conditions

A.5 Evaluation of Results

A.6 Conclusion

A.7 References

A.8 Attachments

A.1 Modeling Objective

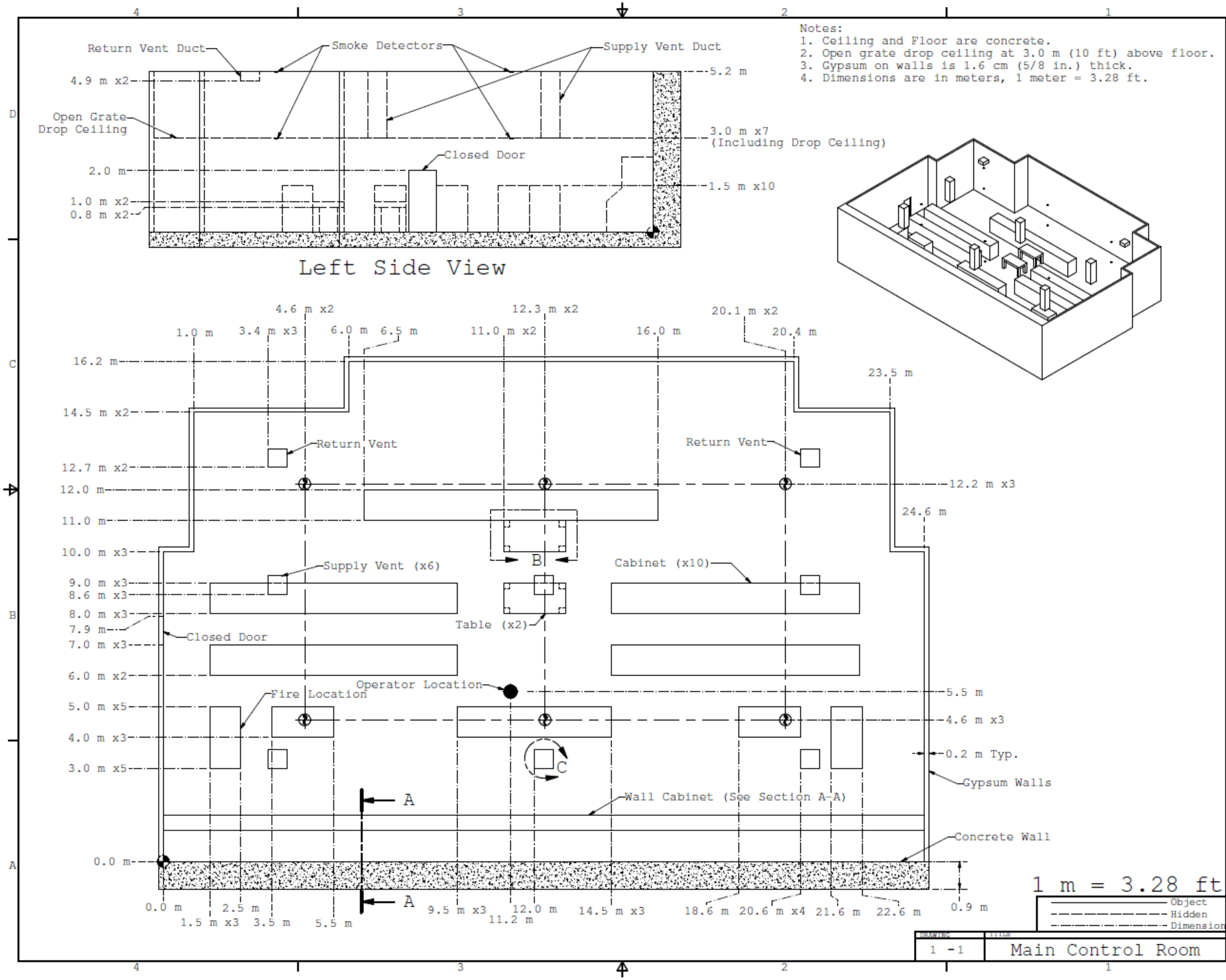
The purpose of the calculations described in this appendix is to determine the length of time that the main control room (MCR) remains habitable after the start of a fire within a low-voltage control cabinet. These calculations follow the guidance provided in NUREG/CR-6850 (EPRI 1011989), Volume 2, Chapter 11, “Detailed Fire Modeling (Task 11).” MCR fire scenarios are treated differently than fires within other compartments, mainly because of the necessity to consider and evaluate forced abandonment in addition to equipment damage.

Habitability: The MCR is manned 24 hours per day during normal plant operations. To assess habitability of the compartment, the operator position indicated in Figure A-1 is used. According to NUREG/CR-6850 (EPRI 1011989), Volume 2, Chapter 11, “Detailed Fire Modeling,” a space is considered uninhabitable if at least one of the following occurs:

1. The incident heat flux at 1.8 m (6 ft) exceeds 1 kW/m^2. A smoke layer temperature of approximately 95 °C (200 °F) generates this level of heat flux.

2. The smoke layer descends below 1.8 m (6 ft) from the floor, and the optical density of the smoke is greater[9] than 3 m^{-1}.

A.2 Description of Fire Scenario



A.2 (cont.) Description of Fire Scenario

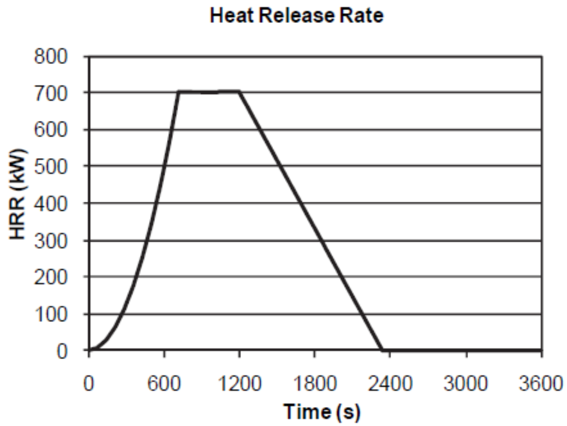
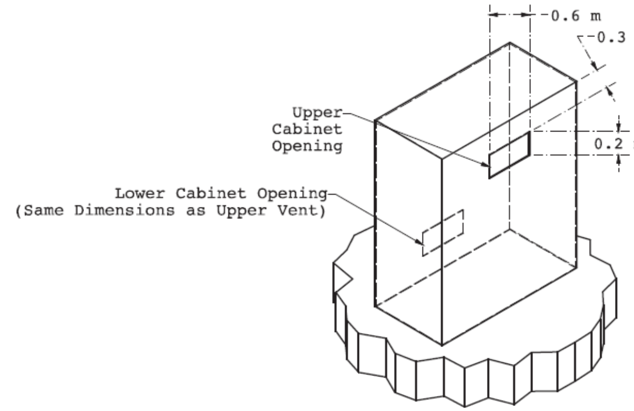


Figure A-5. Time history of the HRR used by all models in the MCR scenario.



DETAIL D, ISO VIEW
(Fire Origin Cabinet)

Table A-1. Data for MCR fire based on XPE/neoprene electrical cable.

Parameter	Value	Source
Effective Fuel Formula	$C_3H_{4.5}Cl_{0.5}$	Combination of polyethylene and neoprene
Peak HRR	702 kW	NUREG/CR-6850 (EPRI 1011989), App. G
Time to reach peak HRR	720 s	NUREG/CR-6850 (EPRI 1011989), App. G
Heat of Combustion	10,300 kJ/kg	*SFPE Handbook*, 4th ed., Table 3-4.16
CO_2 Yield	0.63 kg/kg	*SFPE Handbook*, 4th ed., Table 3-4.16
Soot Yield	0.175 kg/kg	*SFPE Handbook*, 4th ed., Table 3-4.16
CO Yield	0.082 kg/kg	*SFPE Handbook*, 4th ed., Table 3-4.16
Radiative Fraction	0.53	*SFPE Handbook*, 4th ed., Table 3-4.16
Mass Extinction Coefficient	8700 m^2/kg	Mulholland and Croarkin (2000)

A.3 Selection and Evaluation of Fire Models

Table A-2. Normalized parameter calculations for the MCR fire scenario. See Table 2-5 for further details.

Quantity	Normalized Parameter Calculation	Validation Range	In Range?
Fire Froude Number	$\dot{Q}^* = \frac{\dot{Q}}{\rho_\infty c_p T_\infty D^{2.5} \sqrt{g}} = \frac{702 \text{ kW}}{(1.2 \text{ kg/m}^3)(1.0 \text{ kJ/kg/K})(293 \text{ K})(0.4^{2.5} \text{ m}^{2.5})\sqrt{9.8 \text{ m/s}^2}} \cong 6.2$	0.4 – 2.4	No
Fire Height, $H_f + L_f$, relative to the Ceiling Height, H	$\frac{H_f + L_f}{H} = \frac{2.1 \text{ m} + 2.7 \text{ m}}{5.2 \text{ m}} \cong 0.9$ $L_f = D\left(3.7\,\dot{Q}^{*2/5} - 1.02\right) = 0.4 \text{ m}\,(3.7 \times 6.2^{0.4} - 1.02) \cong 2.7 \text{ m}$	0.2 – 1.0	Yes
Ceiling Jet Radial Distance, r_{cj}, relative to the Ceiling Height, H	N/A – Ceiling jet targets are not included in simulation.	1.2 – 1.7	N/A
Equivalence Ratio, φ, of the Room, based on Forced Ventilation of Purge Mode	$\varphi = \frac{\dot{Q}}{\Delta H_{O_2} \dot{m}_{O_2}} = \frac{702 \text{ kW}}{13{,}100 \text{ kJ/kg} \times 3.7 \text{ kg/s}} \cong 0.014$ $\dot{m}_{O_2} = Y_{O_2}\,\rho_\infty \dot{V} = 0.23 \times 1.2 \text{ kg/m}^3 \times 13.4 \text{ m}^3/\text{s} \cong 3.7 \text{ kg/s}$	0.04 – 0.6	No
Compartment Aspect Ratio	$\frac{L}{H} = \frac{24.6 \text{ m}}{5.2 \text{ m}} \cong 4.7$ $\frac{W}{H} = \frac{16.2 \text{ m}}{5.2 \text{ m}} \cong 3.1$	0.6 – 5.7	Yes
Target Distance, r, relative to the Fire Diameter, D	$\frac{r}{D} = \frac{8.8 \text{ m}}{0.4 \text{ m}} \cong 22$	2.2 – 5.7	No

Notes:

(1) The effective diameter of the base of the fire, D, is calculated using $D = \sqrt{4A/\pi}$, where A is the area of the cabinet vent.

(2) The Fire Height, $H_f + L_f$, is the sum of the height of the fire off the floor plus the fire's flame length.

Require Justification

A.3 (cont.) Selection and Evaluation of Fire Models

Justifying use of the model when the application falls outside of the validation range

For the scenario with no ventilation, the classic definition of the Equivalence Ratio does not apply because there is no supply of oxygen in the room. However, it can be shown that there is sufficient oxygen in the room to sustain the specified fire. The total mass of oxygen in the room is the product of the density of air, ρ, the volume of the room, V, and the mass fraction of oxygen in the air, Y_{O_2}:

$$m_{O_2,\text{tot}} = \rho V Y_{O_2} = 1.2\ \text{kg/m}^3 \times 1945\ \text{m}^3 \times 0.23 \cong 537\ \text{kg} \qquad \text{(A-1)}$$

The mass of oxygen required to sustain the fire is equal to the total energy produced by the fire divided by the energy released per unit mass oxygen consumed:

$$m_{O_2,\text{req}} = \frac{Q}{\Delta H_{O_2}} \cong \frac{702\ \text{kW} \times 60\ \text{s/min} \times \left(\frac{12}{3} + 8 + \frac{19}{2}\right)\ \text{min}}{13{,}100\ \text{kJ/kg}} \cong 69\ \text{kg} \qquad \text{(A-2)}$$

These calculations show that the quantity of oxygen in the room would be able to sustain the specified cabinet fire.

- The ratio of the Target Distance relative to the Fire Diameter, r/D, exceeds the range of the validation study. However, this parameter is only relevant to the point source radiation heat flux calculation, which is by definition more accurate, as the target moves further from the source. Thus, although the parameter is outside the validation range, it is not outside of the methodology's range of validity.

A.4 Estimation of Fire-Generated Conditions

<u>Start with empirical models first</u>

(Foote, Pagni, Alvarez Correlation for Closed, Ventilated Compartment)

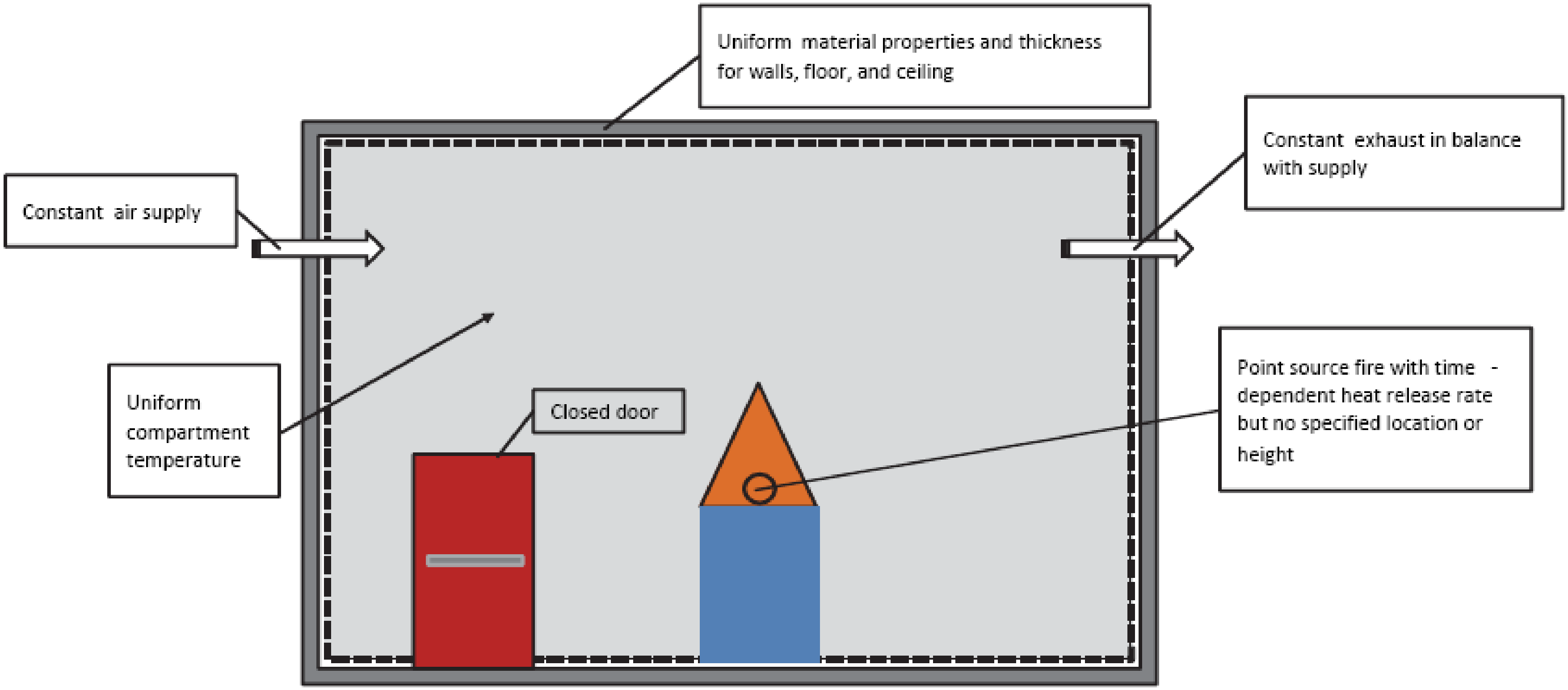
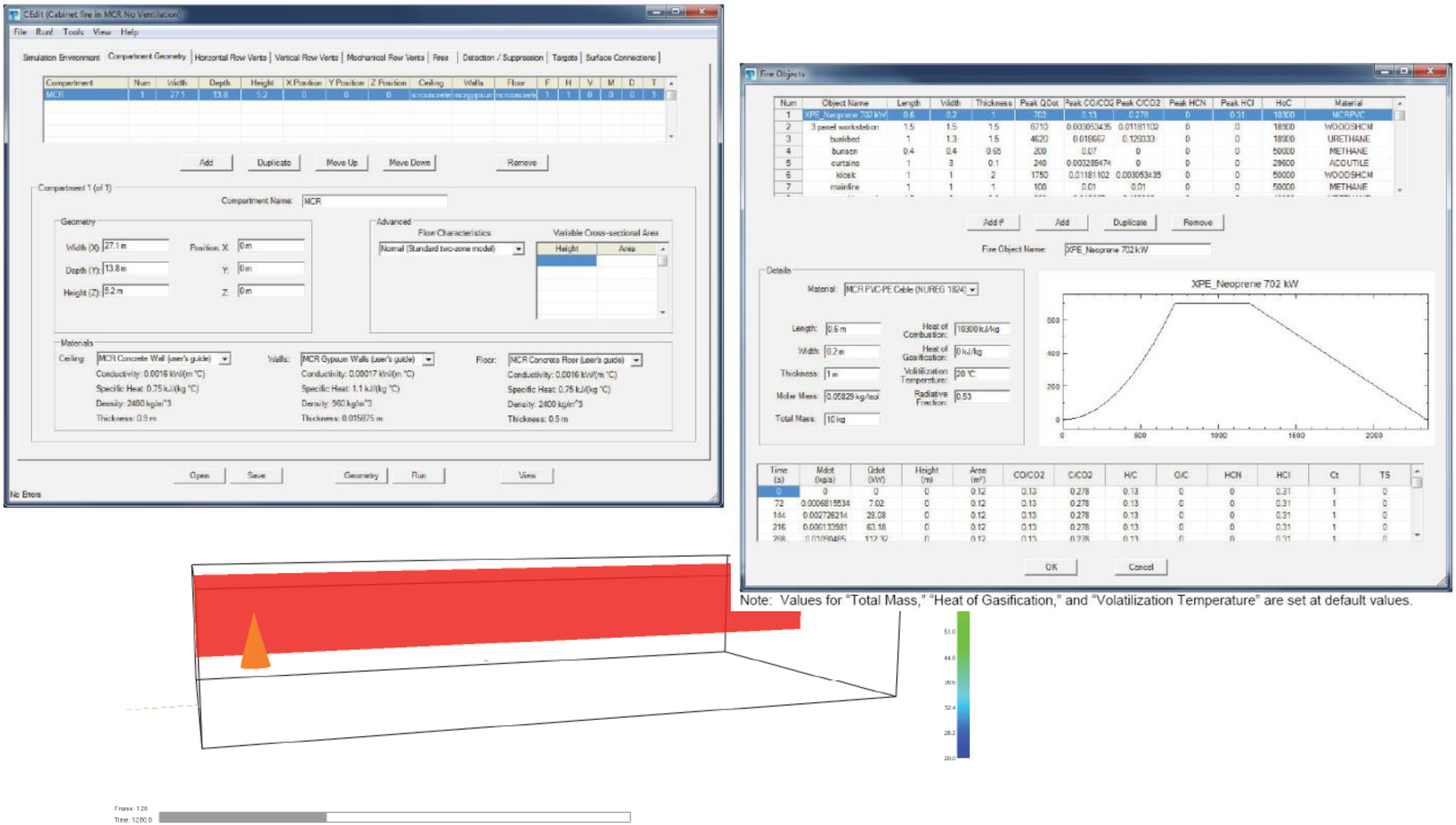


Figure A-6. Schematic diagram of the FPA calculation for the MCR smoke purge scenario.

A.4 (cont.) Estimatation of Fire-Generated Conditions

Move to next level of complexity (zone models) if empirical correlations cannot address all of the failure criteria.



Note: Values for "Total Mass," "Heat of Gasification," and "Volatilization Temperature" are set at default values.

Figure A-10. Snapshot of the CFAST simulation of the MCR fire with mechanical ventilation.

A.4 (cont.) Estimation of Fire-Generated Conditions

Move to next level of complexity (CFD model) if there is a need for a "second opinion".

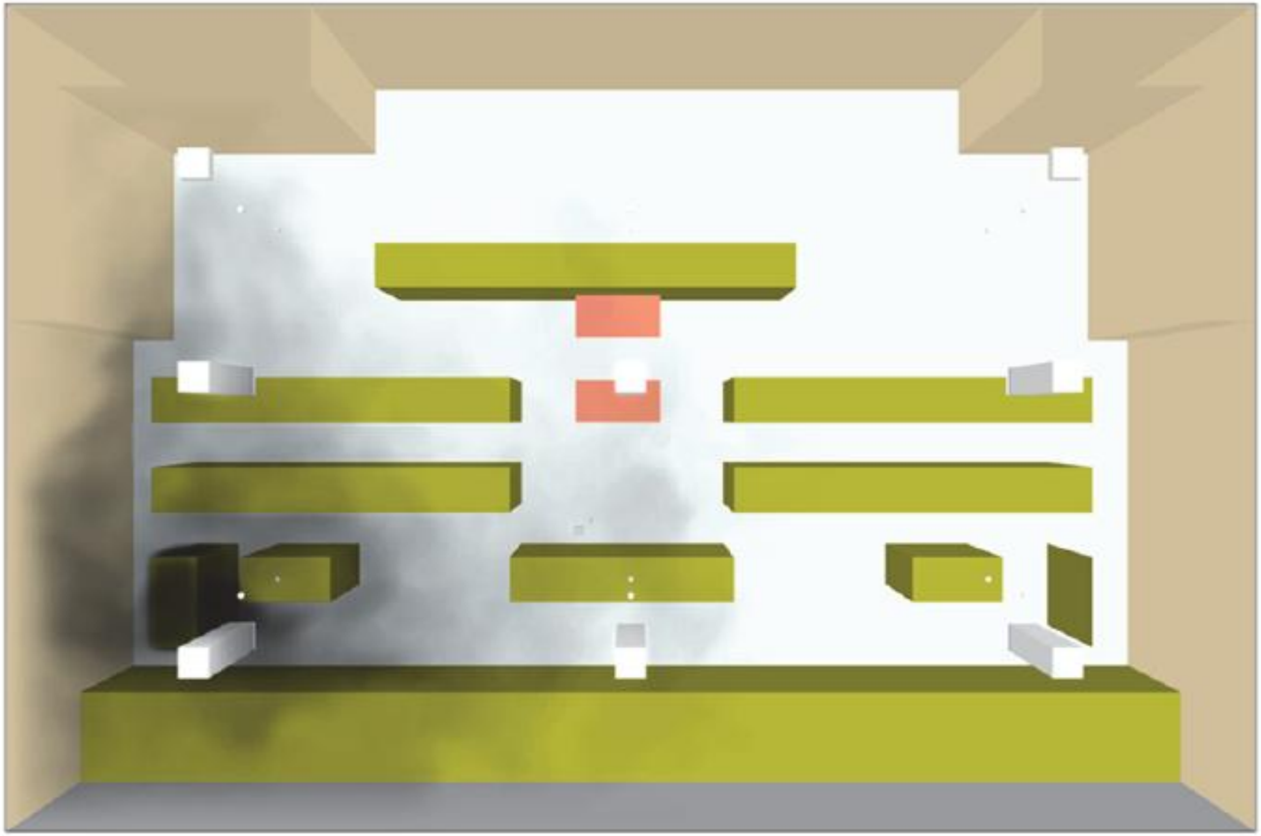


Figure A-11. FDS/Smokeview rendering of the MCR, as viewed from above.

A.5 Evaluation of Results

Table A-4. Summary of the model predictions of the MCR scenario.

Model	Bias Factor, δ	Standard Deviation, $\tilde{\sigma}_M$	Ventilation	Predicted Value	Critical Value	Probability of Exceeding
Temperature (°C), Initial Value = 20 °C						
FIVE (FPA)	1.56	0.32	Purge	70	95	0.000
CFAST	1.06	0.12		60	95	0.000
FDS	1.03	0.07		48	95	0.000
CFAST	1.06	0.12	No Vent.	82	95	0.009
FDS	1.03	0.07		70	95	0.000
Heat Flux (kW/m^2)						
FIVE	1.42	0.55	Purge	0.4	1	0.000
CFAST	0.81	0.47		0.1	1	0.000
FDS	0.85	0.22		0.2	1	0.000
CFAST	0.81	0.47	No Vent.	0.6	1	0.228
FDS	0.85	0.22		0.4	1	0.000
Optical Density (m^{-1})						
CFAST	2.65	0.63	Purge	6.5	3	0.362
FDS	2.7	0.55		0.5	3	0.000
CFAST	2.65	0.63	No Vent.	47	3	0.906
FDS	2.7	0.55		31	3	0.909

A.5 (cont.) Evaluation of Results

Focus in on the phenomenon that is most likely
to be a cause for concern.

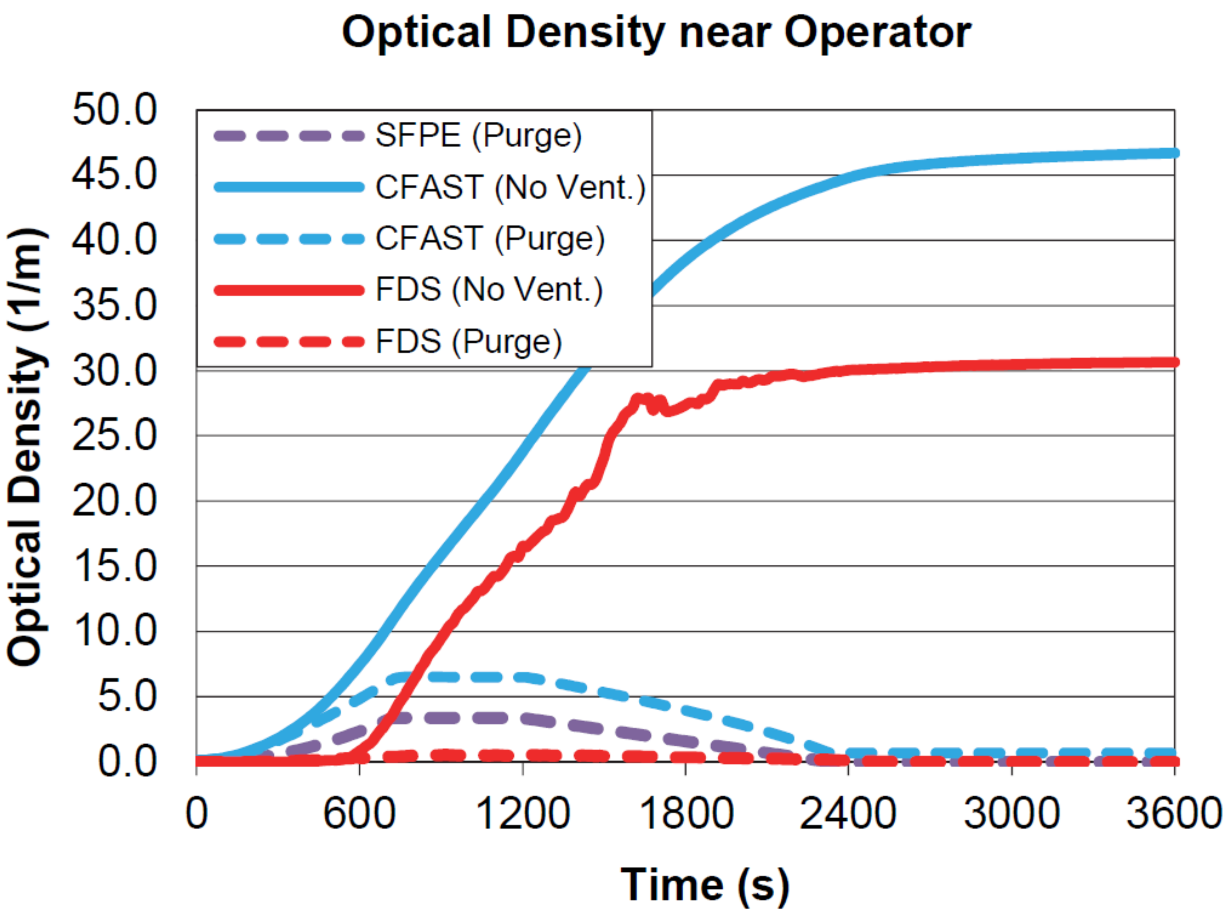


Figure A-14. Optical density predictions for the MCR scenario.

A.6 Conclusion

A fire modeling analysis has been performed to assess the habitability of the MCR in the event of a fire within an isolated electrical cabinet. The fire is not expected to spread to other cabinets. Of the three MCR abandonment criteria, it is most likely that the operators would be forced to abandon the MCR because the optical density would surpass 3 m^{-1} approximately 12 minutes after the fire ignites if the smoke purge system is not activated before this time, according to the FDS analysis. A simple analytical method and the zone model CFAST indicate that the optical density would exceed the critical value with the smoke purge system on and with the ventilation system turned off. However, these analyses are based on several important assumptions. For the smoke purge case, the analytical method assumes that the smoke fills the entire compartment uniformly, even though the FDS analysis shows that the supply vents maintain visibility in the vicinity of the operator location. CFAST reports the optical density of the upper layer, but does not predict that the upper layer would descend to the level of the operator in either the purge or no ventilation scenario based on the specified assumptions.

A.7 References

1. NUREG-1805, *Fire Dynamics Tools,* 2004.
2. NUREG/CR-6850 (EPRI 1011989), *Fire PRA Methodology for Nuclear Power Facilities*, 2005.
3. NUREG-1824 (EPRI 1011999), *Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications*, 2007.
4. *SFPE Handbook of Fire Protection Engineering*, 4th edition, 2008.
5. NIST SP 1018-5, *Fire Dynamics Simulator (Version 5), Technical Reference Guide, Vol. 3, Experimental Validation.*
6. NIST SP 1030. *CFAST: An Engineering Tool for Estimating Fire Growth and Smoke Transport, Version 5 - Technical Reference Guide*, National Institute of Standards and Technology, Gaithersburg, Maryland, 2004.
7. G.W. Mulholland and C. Croarkin. “Specific Extinction Coefficient of Flame Generated Smoke.” *Fire and Materials*, 24:227–230, 2000.

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UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

596th Meeting of the Advisory Committee on Reactor Safeguards

St. Lucie, Unit 1 Extended Power Uprate

July 11, 2012

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Protecting People and the Environment

Opening Remarks

Michele G. Evans

Division Director

Division of Operating Reactor Licensing

Office of Nuclear Reactor Regulation

Introduction

Tracy J. Orf
Project Manager
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

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Protecting People and the Environment

Topics for Discussion

- EPU Overview
- Training
- LOCA PCT Inputs
- TCD – License Condition and FRAPCON analysis
- Steam Generators

St. Lucie Unit 2
Extended Power Uprate (EPU)
ACRS Full Committee

July 11, 2012

Agenda

- **Introduction ……………………………….. Joe Jensen**
- **EPU Overview ………………………………. Jack Hoffman**
- **Discussion Topics from ACRS Subcommittee**
  - Acceptability of Single Simulator………………….. Dave Brown
  - LOCA Peak Cladding Temperature Rackup…..... Jay Kabadi
  - Steam Generators (Proprietary) ………………….. Rudy Gil
- **Acronyms**

FPL

St. Lucie

- **FPL appreciates the opportunity to discuss the EPU License Amendment Request for St. Lucie Unit 2 with the ACRS**
- **Since the ACRS Subcommittee meeting, FPL and NRC Staff worked diligently to address actions from the Subcommittee members**
- **FPL recognizes and appreciates the importance of the Subcommittee's questions, particularly those on Steam Generator performance**
- **FPL's top priority is safety; we continue to proceed with caution through the remaining steps of the EPU**
- **FPL looks forward to answering any remaining questions**

FPL

St. Lucie Unit 2

- Located on Hutchinson Island, southeast of Fort Pierce, Florida
- Pressurized Water Reactor (PWR)
- Combustion Engineering Nuclear Steam Supply System (NSSS)
- Westinghouse Turbine Generator
- Architect Engineer – Ebasco
- Fuel supplier - Westinghouse
- Unit output 907 MWe gross

FPL

St. Lucie

- **Original operating license issued in 1983**
- **Renewed operating license issued in 2003**
- **Installation of a new single-failure proof crane to support spent fuel dry storage operations in 2003**
- **Steam Generators (SGs) replaced in 2007**
- **Reactor Vessel Head was replaced in 2007**
- **Replaced 2 of 4 Reactor Coolant Pump motors in 2007 and 2011**
  - The remaining motor replacements planned for 2012 and 2014

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Agenda

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- Acronyms

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St. Lucie

- **Licensed Core Power**
  - Original Licensed Core Power 2560 MWt
  - Current Licensed Core Power 2700 MWt
    - -- 5.5 % Stretch Uprate (1985)
  - EPU Core Power 3020 MWt
    - -- 10% Power Uprate
    - -- 1.7% Measurement Uncertainty Recapture
    - -- (2700 x 1.10) x 1.017 ~ 3020 MWt
- **Grid stability studies have been completed and approved for the EPU full power output**
- **Final modifications to support EPU operation are being implemented in 2012**

EPU License Amendment Request (LAR) was prepared utilizing the guidance of *RS-001, Review Standard for Extended Power Uprates*

- **Addressed lessons learned from previous PWR EPU reviews**
- **Evaluations consistent with the St. Lucie Unit 2 Current Licensing Basis (CLB) per RS-001**
- **License Renewal evaluated in each License Report section consistent with RS-001 requirements**
- **Measurement Uncertainty Recapture evaluated the proposed Leading Edge Flow Meter (LEFM) system using the Staff's criteria contained in *RIS 2002-03, Guidance on the Content of Measurement Uncertainty Recapture Uprate Applications***

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Agenda

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- Acronyms

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A single control room simulator for St. Lucie Unit 1 and 2 is acceptable for licensed operator training

- **A single control room simulator is typical for dual unit sites**
- **St. Lucie Operator Training Programs are accredited by the Institute of Nuclear Plant Operations (INPO) National Academy for Nuclear Training**
  - St. Lucie's methods of training, including the use of a single simulator, determined to be acceptable
- **Operators are licensed and qualified on both units, and routinely operate both units**
- **Differences between the two units are emphasized in both classroom and simulator training**
- **EPU modifications will reduce the number of differences between the units**

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Agenda

- **Introduction .... Joe Jensen**
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- **Acronyms**

Large Break LOCA analysis Peak Cladding Temperature (PCT) of 2087°F meets 10 CFR 50.46 requirements

Large Break LOCA PCT
Rackup Deltas from Pre-EPU to EPU

Input Parameter Changes	Penalties (°F)	Benefits (°F)
Increase in core power	+ 54	--
Flattening of power around peak rod	+ 19	--
Decrease in maximum integrated radial peaking factor, Fr	--	- 53
Increase in RCS flow rate	--	- 17
Increase in Containment Spray flow rate	+ 23	--
Increase in ECCS Flow Rate	+ 9	--
Conservative containment passive heat sink	+ 3	--
Reduction in discretionary conservatism 1. Decrease in third reflood rate 2. Increase in two-phase mixture level	--	- 60
Total	+ 108	- 130

Integrated impact is 17°F benefit

FPL

Small Break LOCA analysis PCT of 1903°F meets 10 CFR 50.46 requirements

Small Break LOCA PCT
Rackup Deltas from Pre-EPU to EPU

Input Parameter Changes	Penalties (°F)	Benefits (°F)
Increase in core power	+ 335	--
Change in axial power consistent with blanketed fuel	--	- 81
Implementation of replacement steam generators with 10% SGTP (from OSGs with 30% SGTP)	--	- 100
Change in ECCS flow rates (Includes crediting Charging Flow)	--	- 169
Total	+ 335	- 350

Integrated impact is 40°F benefit

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Agenda

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- **Acronyms**

Acronyms

ACAD	National Academy for Nuclear Training Guideline	MDNBR	Minimum Departure From Nucleate Boiling
AOO	Anticipated Operational Occurrences	MSLB	Main Steam Line Break
AVB	Anti-Vibration Bar	MSR	Moisture Separator Reheater
BAMT	Boric Acid Makeup Tank	MSS	Main Steam System
BOP	Balance of plant	MWe	Megawatts electric
CHF	Critical Heat Flux	MWt	Megawatts thermal
CLB	Current Licensing Basis	NPSH	Net Positive Suction Head
COLR	Core Operating Limits Report	NSSS	Nuclear Steam Supply System
CVCS	Chemical and Volume Control System	OSG	Original Steam Generator
DNB	Departure From Nucleate Boiling	PCT	Peak Cladding Temperature
ECCS	Emergency Core Cooling System	PLHR	Peak Linear Heat Rate
EHC	Electro Hydraulic Control	PORV	Power Operated Relief Valve
EPU	Extended Power Uprate	PPM	Parts per Million
EQ	Environmental Qualification	PSIA	Pounds per square inch - absolute
F	Fahrenheit	PWR	Pressurized Water Reactor
F_r^T	Total Radial Peaking Factor	PZR	Pressurizer
ft	Feet	RCS	Reactor Coolant System
FW	Feed Water	RIS	Regulatory Issue Summary
HFP	Hot Full Power	RPS	Reactor Protection System
HTP	High Thermal Performance	RTP	Rated Thermal Power
HZP	Hot Zero Power	RWT	Refueling Water Tank
IC	Inside Containment	SB	Small Break
INPO	Institute of Nuclear Plant Operations	SGTP	Steam Generator Tubes Plugged
Keff	K-effective	SIT	Safety Injection Tank
lb/hr	Pounds per hour	SDM	Shutdown Margin
LAR	License Amendment Request	Sec	Second
LB	Large Break	SLB	Steam Line Break
LEFM	Leading Edge Flow Meter	SG	Steam Generator
LHGR	Linear Heat Generation Rate	V	Verlocity
LOCA	Loss of Coolant Accident	ρ	Density

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Extended Used Fuel Storage and Transportation Safety Basis

Industry Perspectives

NRC Advisory Committee on Reactor Safeguards

July 11, 2012

Rod McCullum

NEI
NUCLEAR ENERGY INSTITUTE

Extended Storage Safety Basis

- **Dry Casks are robust systems with no moving parts**
- **Extensive Operating Experience – over 1,700 casks**
- **72.42 rulemaking – license/renewal terms up to 40 yrs.**
  - **"This increase is consistent with the NRC staff's findings regarding the safety of spent fuel storage as documented in the renewal exemptions issued to the Surry and H.B. Robinson ISFSIs"** 76 Fed. Reg. 8874 2/16/2011
- **Waste Confidence rulemaking**
  - **"studies performed to date have not identified any major issues with long-term use of dry storage"** 75 Fed. Reg. 81072, 12/23/2010
- **EPRI and NRC Dry Storage PRAs conducted in 2007**
  - **Annual cancer risk between 1.8E-12 and 3.2E-14 ***
- **Opportunities to further verify performance being pursued**

* Compares to 2E-6 LCF/yr. public & 1E-5 LCF/yr . worker thresholds of negligible risk from NRC's framework for "Risk-Informed Decision-making for Nuclear Material and Waste Applications", Revision 1, February 2008

NEI

Performance Verification

- INL Dry Storage Characterization Project opened cask stored from 1985 to 1999 and verified “long-term storage has not caused detectable degradation of the spent fuel cladding or the release of gaseous fission products”
- Industry working with DOE to develop a similar demonstration program for additional data (including higher burn up fuel)
- EPRI is conducting inspections to verify canister performance in chloride rich atmospheres

Extended Storage in an Integrated System

- **An integrated system must, at a minimum, connect the following elements***
  - **Storage at reactor sites**
  - **Transportation**
  - **Storage at consolidated sites**
  - **Transportation (?)**
  - **Disposal**
- **Integration must be built on the system we have, not the one we wish we had**
- **Integration must be supported by a more efficient regulatory framework**

*The deployment of recycling technologies will not completely eliminate the need for direct disposal of at least some portion of the used fuel inventory

Conclusion

- There is a strong basis to support safe used fuel storage for extended time periods
- Industry is working pro-actively to address future challenges regarding extended storage
- Extended storage should be addressed in the context of the integrated system in which it exists
- Regulatory framework improvements will enhance our ability to address extended storage

NEI

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

Regulation of Future Extended Storage and Transportation
Technical Information Needs

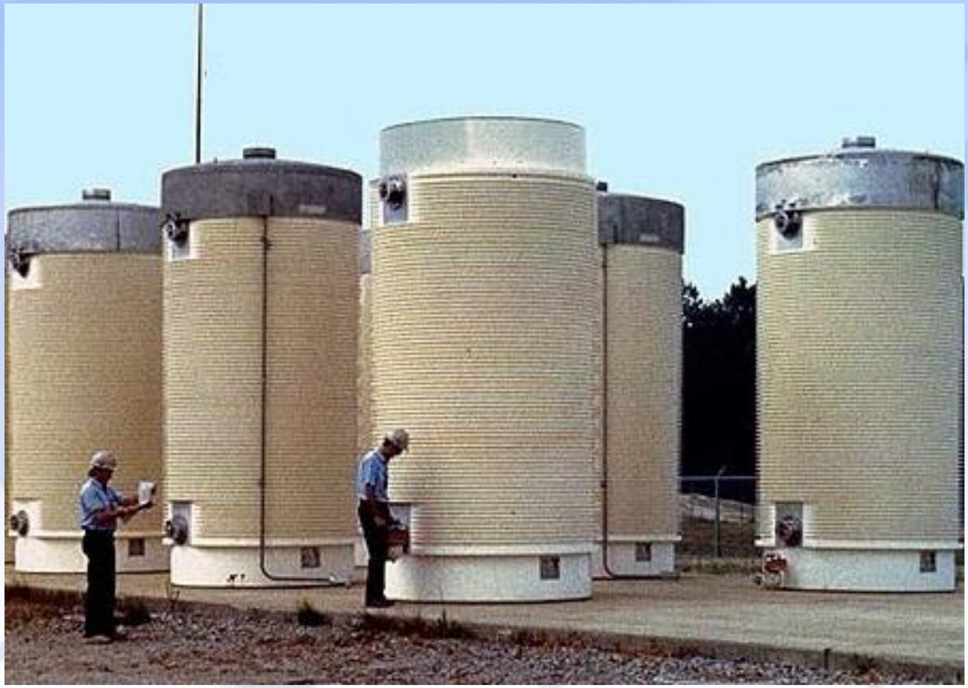
James Rubenstone
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission

Advisory Committee on Reactor Safeguards

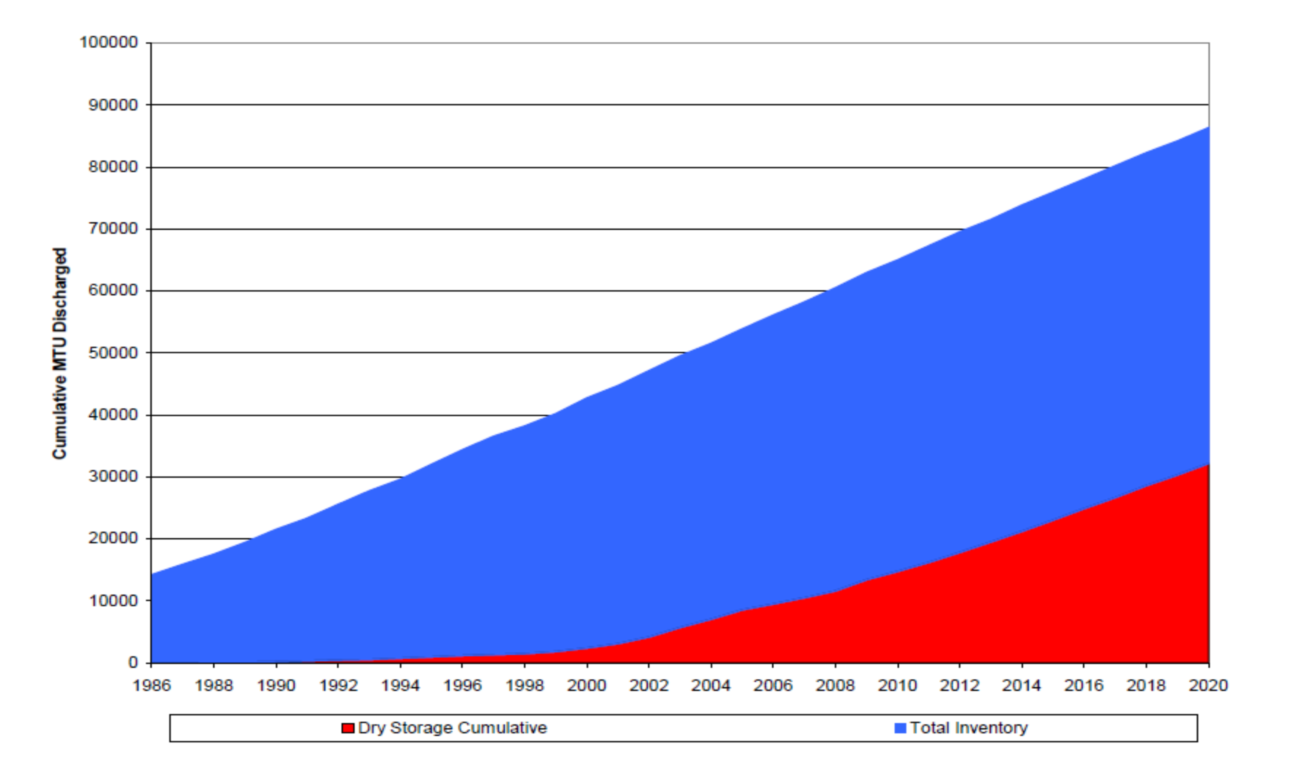
July 11, 2012

Overview

- Changing policy environment
- Regulatory framework—current and future
- Extended storage and transportation—technical information needs
- Next steps



Spent Fuel Storage: Historical and Projected Spent Fuel Discharges



Source: *Impacts Associated with Transfer of Spent Nuclear Fuel from Spent Fuel Storage Pools to Dry Storage After Five Years of Cooling*, Electric Power Research Institute, 2010

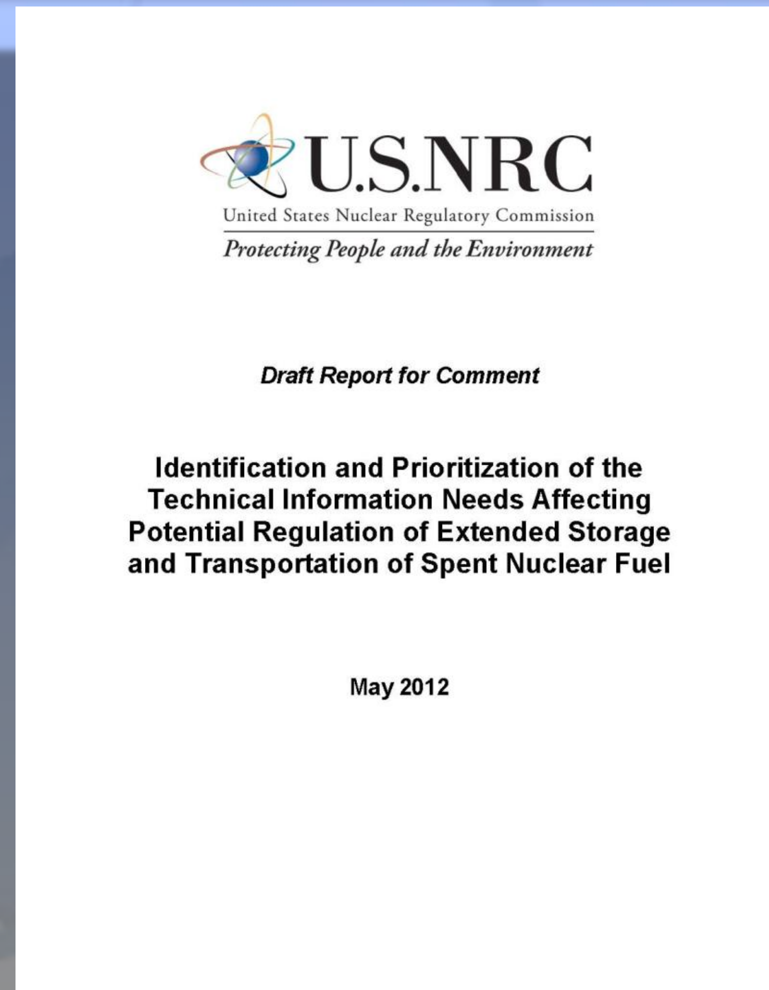
- About 18,000 MTU commercial SNF currently in dry storage
- About 1,500 casks currently loaded

Extended Spent Fuel Storage and Transportation: Needs

- **Potential changes to regulations and guidance to accommodate extended storage and transportation of long-stored spent fuel**
- **Technical information to inform potential regulatory changes and support future licensing reviews**
  - **Identify technical issues associated with long-term storage**
  - **Perform focused research on technical issues of regulatory significance**

Extended Spent Fuel Storage and Transportation: Technical Needs

- Focus on potential degradation phenomena for dry storage systems, structures, and components
- Consider impact on performance of safety functions for storage and transportation
- Consider understanding necessary for regulatory review


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

Draft Report for Comment

Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel

May 2012

Extended Spent Fuel Storage and Transportation: Methodology

- Used previous studies of technical gaps
  - NRC – Savannah River National Laboratory
  - Department of Energy
  - Nuclear WasteTechnical Review Board
  - Electric Power Research Institute
- Level of knowledge for degradation processes
  - Time and conditions of initiation
  - Rate of progression
  - End state
- Impact on meeting regulatory criteria

Extended Spent Fuel Storage and Transportation: Criteria

- Design criteria – Safety functions
  - Confinement
  - Criticality control
  - Radiation shielding
  - Structural integrity
  - Thermal control
- Ability to retrieve stored fuel by normal means
- Possible impacts for transportation of long-stored spent fuel

Extended Spent Fuel Storage and Transportation: Technical Needs

- High priority degradation areas:
  - Stress corrosion cracking of stainless steel canister body and welds in marine atmosphere
  - Degradation of cask bolts
  - Effects of fuel pellet swelling and fuel rod pressurization on cladding stress
- High-priority cross-cutting areas:
  - More realistic thermal model calculations
  - Effects of residual moisture after canister drying
  - In-service monitoring methods for dry storage systems

Extended Spent Fuel Storage and Transportation: Technical Needs

- Other (nearly as) high priority degradation areas:
  - Propagation of cladding flaws, cladding fatigue, and low temperature creep (stress dependent)
  - Fuel assembly hardware corrosion and fatigue embrittlement
  - Neutron absorber degradation
  - Microbially influenced corrosion
  - Concrete degradation in unexposed areas

Extended Spent Fuel Storage and Transportation: Active Work Areas

- Stress corrosion cracking of stainless steel canister body and welds in marine atmosphere
- Effects of residual moisture
- Improved thermal models
- Potential non-destructive methods for inspection and monitoring

Extended Spent Fuel Storage and Transportation: Current SCC Work

- Prior scoping investigation (NUREG/CR-7030)
  - Limited control of quantity of salt deposited on surface; tests used higher relative humidity than expected for facilities
  - Results showed SCC could occur at lower temperatures where salt could deliquesce
- Current NRC-sponsored investigation
  - More realistically bound conditions where SCC can occur
  - Preliminary results indicate that SCC can occur even with relatively low quantity of deposited salt, for likely temperature and relative humidity
- Industry efforts
  - Currently focusing on canister conditions, including surface temperature, relative humidity, and deposited material

Extended Spent Fuel Storage and Transportation: Regulatory Areas

- Long term cladding integrity and retrievability
- Long-term financial assurance
- Decommissioned sites
- Physical security
- Risk informed regulations
- Integration of storage, transportation, and disposal regulations
- Coordination with current licensing process improvements

Extended Spent Fuel Storage and Transportation: Next Steps

- Finalize report on *Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation* after public comments
- Complete research plan for technical investigations
- Assess potential regulatory issues
- Continue technical investigations in selected high-priority areas
- Engage industry and other stakeholders
- Monitor outside technical work

Spent Fuel Storage and Transportation: BRC

Blue Ribbon Commission proposed a national nuclear waste management strategy with eight key elements, including:

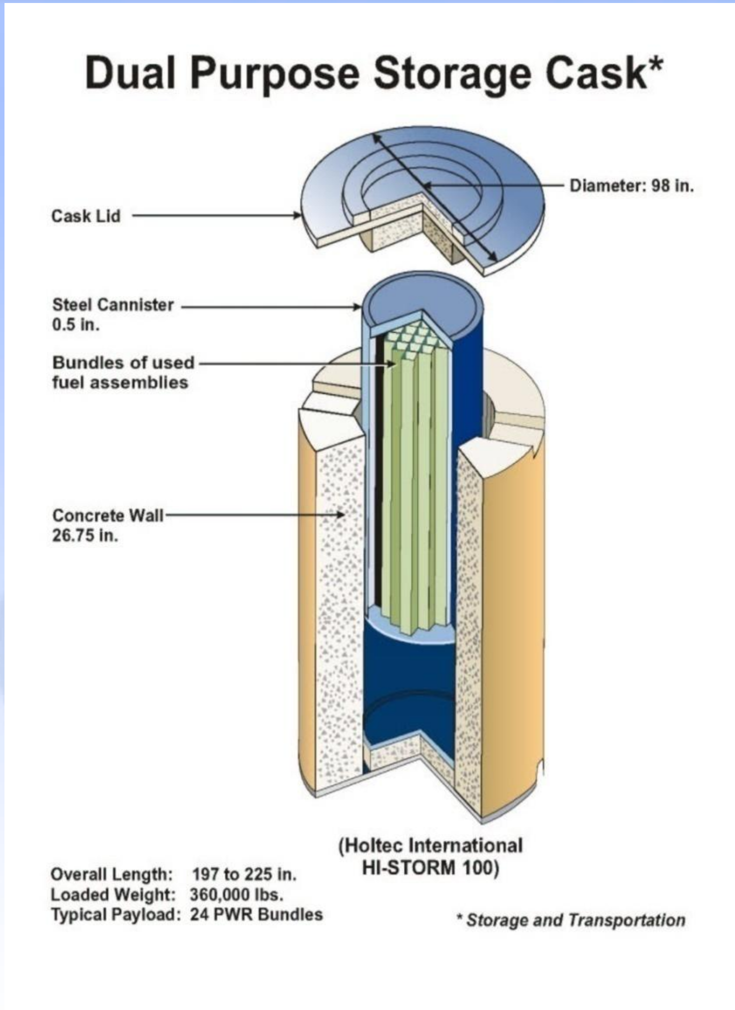
- A new, consent-based approach to siting future nuclear waste management facilities
- Prompt efforts to develop one or more consolidated storage facilities
- Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available

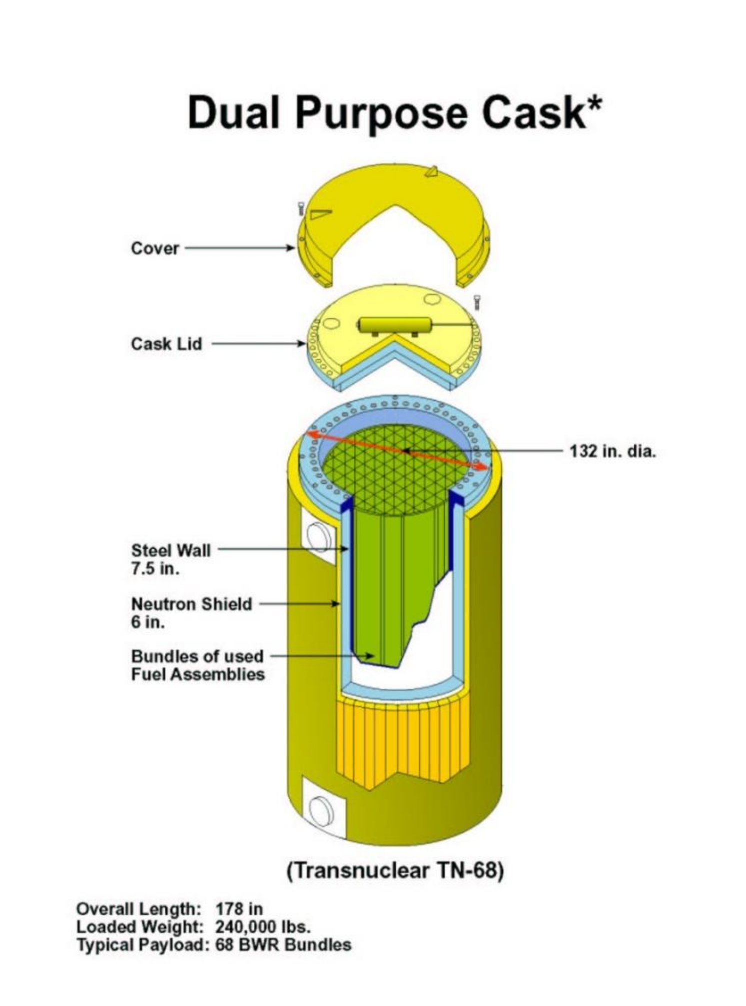
Conclusions

- NRC is continuing to perform its mission while preparing for potential policy changes
- Initial NRC staff efforts have defined tasks and developed plans and schedules
- Draft report for technical needs been issued for public comment
- Staff is completing technical work plans, examining regulatory areas, and has begun some technical work
- Staff is continuing interaction with public, industry, and other stakeholders

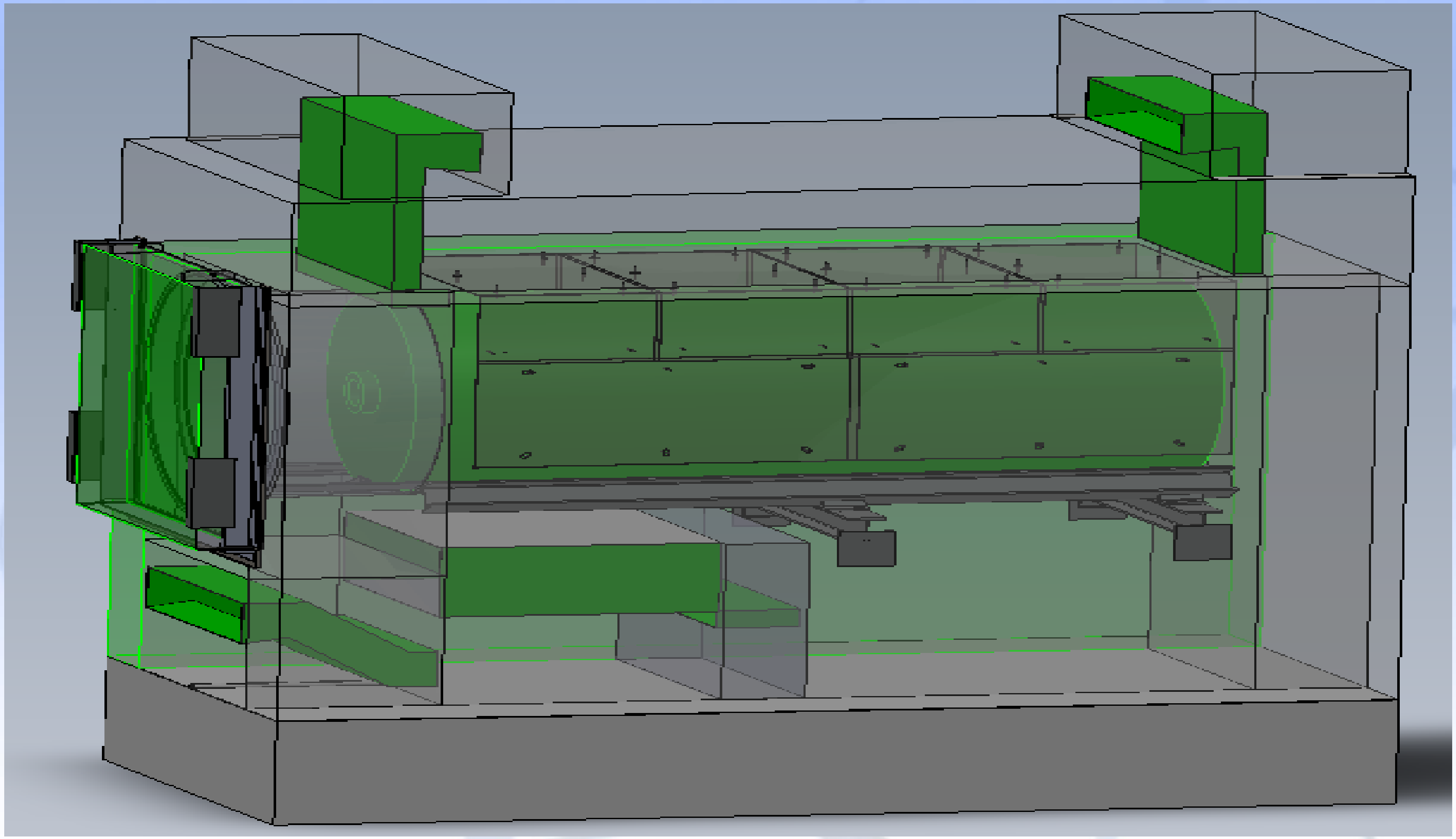
Backup Slides

Spent Fuel Storage: Dual Purpose Systems





Spent Fuel Storage: NUHOMS Canister System



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Extended Storage Technical Issues

John Kessler
Manager, Used Fuel and HLW Management Program

Advisory Committee on Reactor Safeguards
11 July 2012

Extended Storage – an International Issue

- Most "nuclear" countries face extended storage
  - No reprocessing
  - No disposal
  - Centralized (consolidated) storage is still storage

- Major need to share data and collaborate

“Extended Storage Collaboration Program” (ESCP) Launched in 2009

Bring together US and international organizations engaged with active or planned R&D

- Storage and transportation system vendors
- Regulators and their R&D contractors (includes NRC)
- National waste management organizations
- R&D organizations (includes DOE, EPRI)
- Industry (utilities/cask vendors)

EPRI Extended Storage Collaboration Program (ESCP)

- Purpose: "Provide the technical bases to ensure continued safe, long-term used fuel storage and future transportability"

✓ Phase 1: Review current technical bases and conduct gap analysis for storage systems

➢ Phase 2: Conduct experiments, field studies, and additional analyses to address gaps

- Phase 3: Long-term performance confirmation

Gap Analyses*: Highest Priority Items

- **Welded SS canisters SCC**
- **High burnup cladding**: hydride effects (reorientation, embrittlement)
- **Bolted casks**:
  - Corrosion of bolts
  - Embrittlement and mechanical degradation of bolts
- Fuel pellet swelling

*NWTRB, DOE, NRC, EPRI

Cross-Cutting Needs

- **Improved thermal modeling**
- **Degradation monitoring systems**
- Stress profiles
- Adequacy of drying
- Sub-criticality: burnup credit
- Examine casks at INL (DOE)
- Retrievability: fuel transfer options

EPRI Plans for In Situ Inspection of SS Canisters

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SCC of Welded Canisters – What Do We Know?

For stress corrosion cracking you need:

- Susceptible material (austenitic stainless steels; e.g. 304, 316)
- Tensile stress (residual weld stress)
- Corrosive environment
  - Salts in the air
  - Deliquescence
    - Surface temperature
    - Humidity

Studies have shown SCC can occur on canister materials *under lab conditions*

What we don't know …

What are the conditions on actual canisters?

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Inspection #1: Calvert Cliffs (June 27-28, 2012)

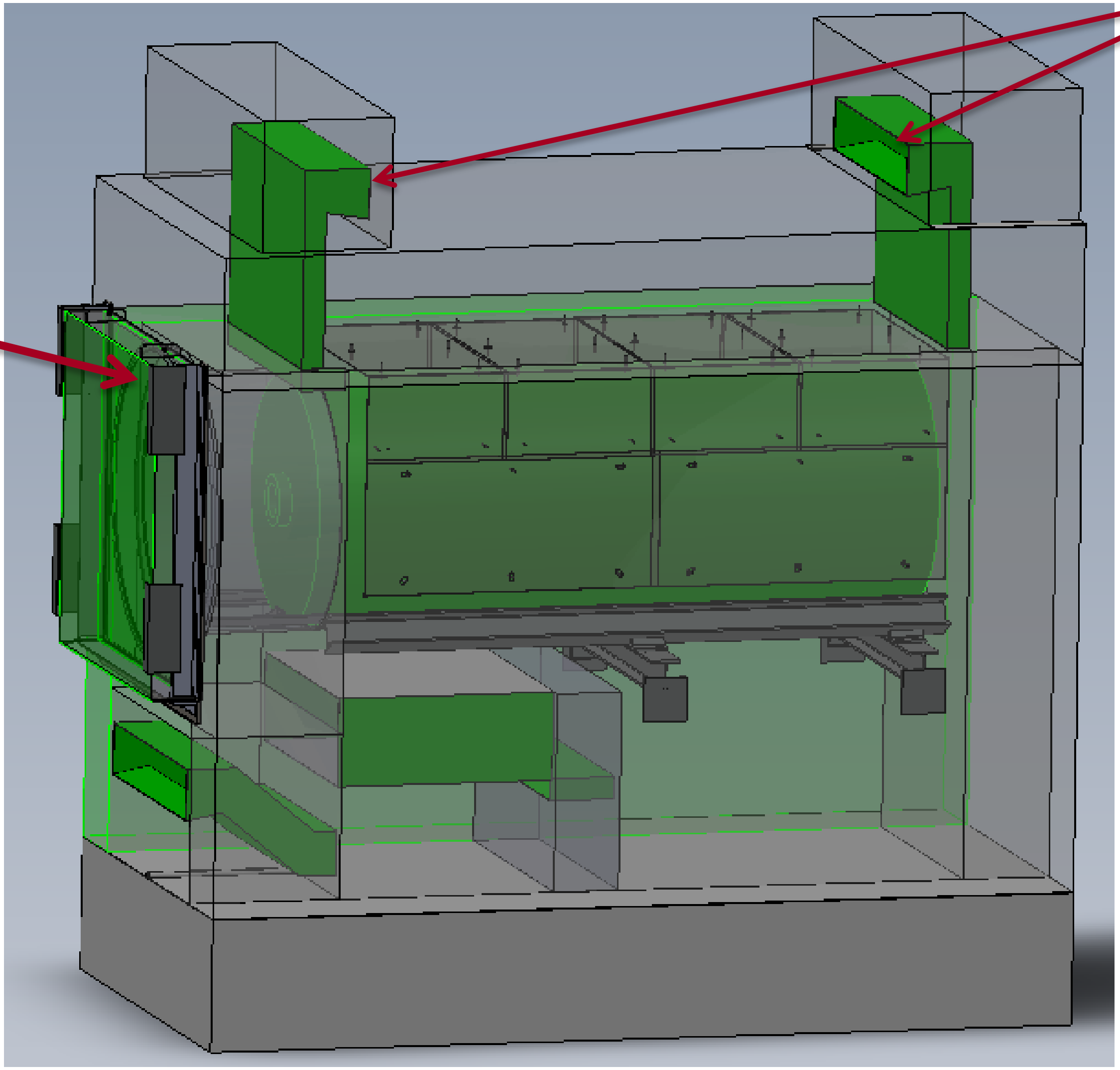
- ~ ½ mile from Chesapeake Bay
- Canisters in service for >15 years
- Two canisters were inspected
  - "HSM-15" visual inspection for license renewal
  - "HSM-1" (oldest, coldest): R&D data to evaluate SCC potential
- Constellation currently preparing report for NRC

More inspections to follow

Calvert Cliffs Inspection Entry Points

Visual

Temperature, surface contaminants



Calvert Cliffs

NUHOMS Design

HSM-1 Temperature, Surface Contaminant Data Collection: Mock-Up Demonstration, Training

Photo courtesy of

Transnuclear

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SaltSmart Deployment: Example from Mockup

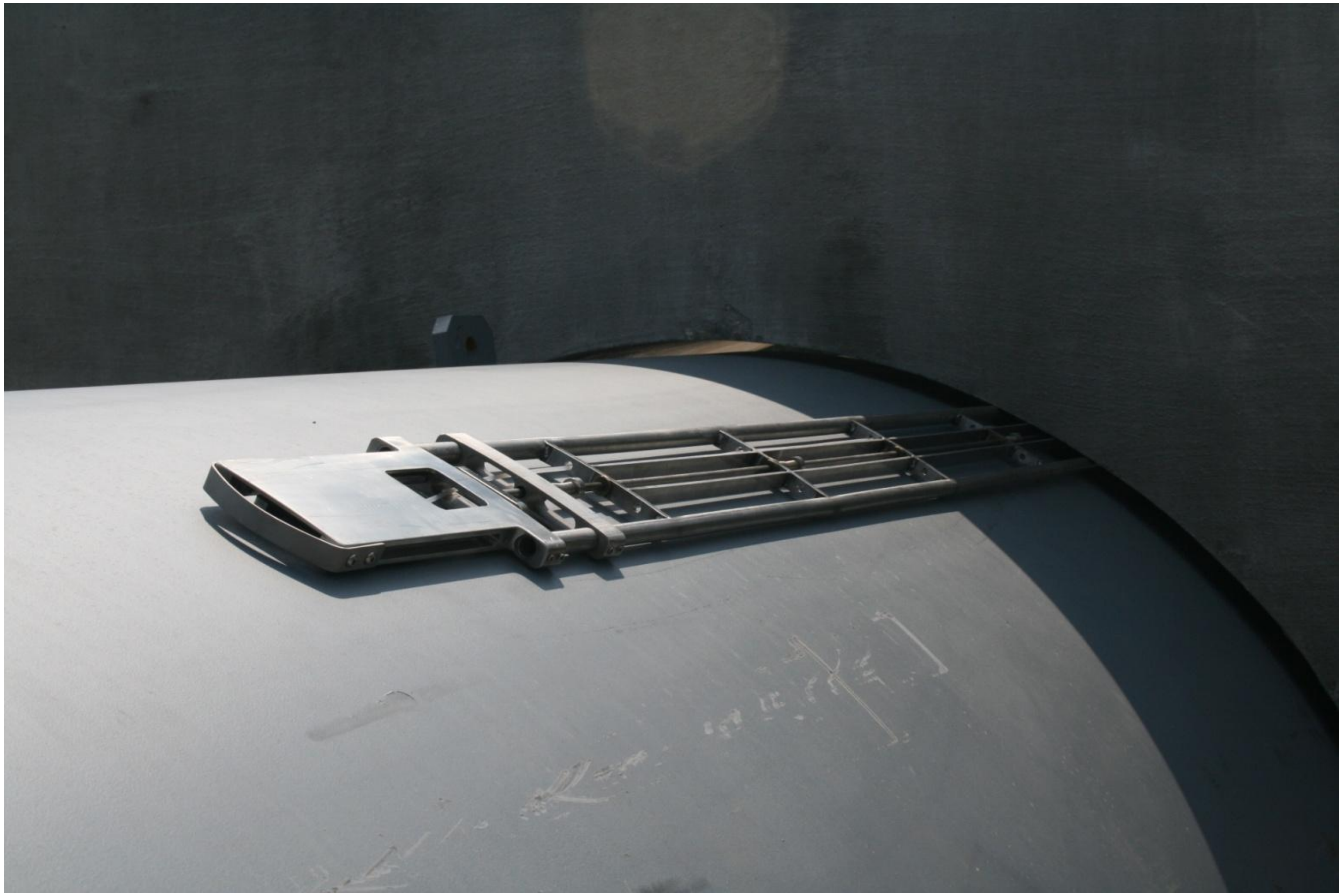

Photo courtesy of

Transnuclear

Surface Deposit Collector: Example from Mockup

Photo courtesy of Transnuclear

Ultimate Goal: Industry-wide SS Canister Aging Management Plan

- Identify potentially susceptible canisters
  - Where?
  - When?

- Inspection plans

- Mitigation plans if required

Full-scale, Long-term, High Burnup Used Fuel Confirmatory Data Collection

(“high burnup demo”)

High Burnup Demo Needs

Confidence in understanding longer-term behavior of dry storage system requires:

1. Model development and benchmarking data
2. Small-scale "Separate effects testing"
3. **Confirmatory testing under "prototypic" conditions**
   - **Full scale**
   - **Representative dry storage conditions**
   - **Prefer multiple high BU fuel types (if possible)**

Full-scale High Burnup Demo Activities

Industry need to keep this short

- Obtain “t=0” data from sister rods
- Modify existing cask with a special lid that includes
  - Thermocouples
  - Gas sampling
  - Other?
- Load cask and emplace modified lid
- ***Data collection through lid begins immediately***
  - Capture temperature and gas evolution during drying
  - Continue temperature measurements and periodic gas sampling
- After X years (TBD), re-open, remove rods, visually inspect for degradation

High Burnup Demo Option that Keeps Startup Time Short

- Initiate the demo at a reactor site
  - Avoids up-front transportation to a national lab
  - Avoids having to wait for a full-scale hot cell to be funded and constructed
  - Keeps costs lower prior to test initiation

- Dominion-TN option(start test in 3-5 years)
  - Willing host (North Anna or Surry)
  - Multiple, high burnup fuel types
  - TN to supply cask(s) at lower cost
  - EPRI providing initial funding for instrumented lid design
  - Looking for co-funding

Together…Shaping the Future of Electricity

I) The total quantity of hydrogen that could be produced in a severe accident

A) In the Three Mile Island accident, it is generally estimated that a total of 500 kg of hydrogen was produced.[1]

B) A 1988 Oak Ridge National Laboratory report states that:

> It should be noted that in an unmitigated BWR severe accident the entire Zircaloy inventory of the reactor would eventually oxidize (either in the reactor vessel or on the drywell floor), generating as much as…2722 kg of hydrogen (plant specific value).[2]

C) In severe accidents, if the total amount of the zirconium in a typical PWR's core (3600 megawatts thermal), approximately 26,000 kg, were to oxidize, approximately 1150 kg of hydrogen would be produced and if the total amount of the zirconium in a typical BWR's core (3800 megawatts thermal), approximately 76,000 kg, were to oxidize, approximately 3360 kg of hydrogen would be produced.[3] (In both of these cases, the total quantity of zirconium in the core is greater than that of 100 percent of the active fuel cladding length.)

D) In a BWR severe accident, between 100 kg and 400 kg of hydrogen could be produced from the oxidation of the boron carbide neutron absorber material.[4] And in a severe accident, "[s]teel oxidation may contribute about 10% to 15% to the total [in-vessel] hydrogen production."[5]

II) Potential rates of hydrogen production in a severe accident

In a severe accident, hydrogen generation would occur at rates from 0.1 to 5.0 kg per second; during a reflooding of an overheated core up to 300 kg of hydrogen could be produced in one minute.[6] One report states that between 5 and 10 kg of hydrogen could be produced per second, during the reflooding of an overheated core.[7]

III) The need for installing high-capacity filters at BWR Mark I and Mark IIs in addition to hardened vents:

A) The report "Filtered Venting Considerations in the United States," states that "[f]iltered venting may have positive benefits for those sequences in which the rate of containment pressure rise is relatively slow. Filtered venting is less feasible for those sequences resulting in early over-temperature or over-pressure conditions. This is because the relatively early rapid increase in containment pressure requires large containment penetrations for successful venting."[8]

B) In a December 2011 article, Saloman Levy[9] stated that in the event of a U.S. BWR Mark I severe accident, "[e]arly venting [would be] preferred, when the containment pressure and hydrogen concentration are low and not prone to explosions and fires" and that in the Fukushima Dai-ichi accident, plant operators should have "[c]onsider[ed] early venting rather than waiting for containment pressure to reach or exceed design pressure."[10] Levy does not refer to high-capacity filters in his statements; however, it could be argued that implementing a policy of early venting would require installing a high-capacity filter to help protect the surrounding population, who would not have time to evacuate and prevent becoming exposed to radioactive releases.

C) The NRC should also consider that not all severe accidents would be like the Fukushima Dai-ichi accident: "slow-moving" station-blackout accidents caused by natural disasters. Fast-moving accidents could also occur; for example, a large break loss-of-coolant accident could rapidly transition into a severe accident—a meltdown could commence within 10 minutes after an accident initiated.[11] Early venting might be necessary in a fast-moving accident scenario: a high-capacity filter would help protect the surrounding population, who would not have time to evacuate and prevent becoming exposed to radioactive releases.

[1] Jae Sik Yoo, Kune Yull Suh, "Analysis of TMI-2 Benchmark Problem Using MAAP4.03 Code," Nuclear Engineering and Technology, Vol. 41, No. 7, September 2009, p. 949.

[2] Sherrell R. Greene, Oak Ridge National Laboratory, "The Role of BWR Secondary Containments in Severe Accident Mitigation: Issues and Insights from Recent Analyses," 1988.

[3] International Atomic Energy Agency, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," IAEA-TECDOC-1661, July 2011, p. 10.

[4] *Id.*, pp. 6, 15, 16.

[5] Report by Nuclear Energy Agency Groups of Experts, OECD Nuclear Energy Agency, "In-Vessel and Ex-Vessel Hydrogen Sources," NEA/CSNI/R(2001)15, October 1, 2001, Part I, B. Clément (IPSN), K. Trambauer (GRS), W. Scholtyssek (FZK), Working Group on the Analysis and Management of Accidents, "GAMA Perspective Statement on In-Vessel Hydrogen Sources," p. 8.

[6] E. Bachellerie, *et al.*, "Generic Approach for Designing and Implementing a Passive Autocatalytic Recombiner PAR-System in Nuclear Power Plant Containments," Nuclear Engineering and Design, 221, 2003, p. 158.

[7] J. Starflinger, "Assessment of In-Vessel Hydrogen Sources," in "Projekt Nukleare Sicherheitsforschung: Jahresbericht 1999," Forschungszentrum Karlsruhe, FZKA-6480, 2000.

[8] R. Jack Dallman, *et al.*, "Filtered Venting Considerations in the United States," May 17-18, 1988, CSNI Specialists Meeting on Filtered Vented Containment Systems, Paris France, p. 3.

[9] "How Would U.S. Units Fare?" states that "Dr. Levy was the manager responsible for General Electric (GE) BWR heat transfer and fluid flow and the analyses and tests to support [GE's] nuclear fuel cooling during normal, transient, and accident analyses from 1959 to 1977." See Saloman Levy, "How Would U.S. Units Fare?," Nuclear Engineering International, December 7, 2011.

[10] Saloman Levy, "How Would U.S. Units Fare?," Nuclear Engineering International, December 7, 2011. Levy makes the point that his observations are not intended to be criticisms of the actions of the Fukushima Dai-ichi plant operators.

[11] Peter Hofmann, "Current Knowledge on Core Degradation Phenomena, a Review," Journal of Nuclear Materials, Vol. 270, 1999, p. 205.

Post-Fukushima Hardened Vents with High-Capacity Filters for BWR Mark Is and Mark IIs

By Mark Leyse, Nuclear Safety Consultant

A Project Completed for NRDC, July 2012

Acknowledgements: The author thanks David Lochbaum of Union of Concerned Scientists for reviewing this report.

I. Why Boiling Water Reactor Mark I Primary Containments have Been Backfitted with Hardened Vents

The U.S. Nuclear Regulatory Commission's (NRC) 2011 Near-Term Task Force report on insights from the Fukushima Dai-ichi accident states that NRC reports from 1975[1] and 1990[2] both concluded that in the event of a severe accident, boiling water reactor (BWR) Mark I primary containments have "a relatively high containment failure probability," because BWR Mark I primary containments have smaller volumes when compared to PWR containments[3]—about one-eighth the volume of PWR large dry containments. (BWR Mark I primary containments have a volume of approximately 0.28×10^6 ft^3; pressurized water reactor (PWR) large dry containments have a volume of approximately 2.2×10^6 ft^3.[4]) BWR Mark II primary containments also have relatively small volumes—about one-sixth the volume of PWR large dry containments. (BWR Mark II primary containments have a volume of approximately 0.4×10^6 ft^3.[5])

A BWR Mark I primary containment is comprised of a drywell, shaped like an inverted light bulb, and a wetwell (also termed "torus"), shaped like a doughnut. The

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[1] NRC, "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," NUREG-75-014, WASH-1400, October 1975.

[2] NRC, "Severe Accident Risks: An Assessment or Five U.S. Nuclear Power Plants," NUREG-1150, December 1990.

[3] Charles Miller, *et al.*, NRC, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," SECY-11-0093, July 12, 2011, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML111861807, p. 39.

[4] M. F. Hessheimer, *et al.*, Sandia National Laboratories, "Containment Integrity Research at Sandia National Laboratories: An Overview," NUREG/CR-6906, July 2006, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML062440075, p. 24.

[5] *Id.*

wetwell is half filled with water (typically over a million gallons[6])—the suppression pool. A BWR Mark II primary containment also has a drywell and wetwell—both shaped differently than their BWR Mark I counterparts.

In a severe accident, the water pumped into the reactor core to cool the fuel rods would heat up and produce thousands of kilograms (kg) of steam, which would enter the primary containment. The water in the suppression pool is intended to condense the steam and help absorb the heat released by the accident to reduce the pressure in the primary containment. Without the condensation of the steam in the suppression pool, the relatively small primary containments of BWR Mark I and Mark IIs (often termed "pressure suppression containments") would fail from becoming over-pressurized.

In a BWR severe accident, hundreds of kilograms of non-condensable hydrogen gas would also be produced (up to over 3000 kg[7])—at rates as high as between 5.0 and 10.0 kg per second, if there were a reflooding of an overheated reactor core[8]—which would increase the internal pressure of the primary containment. If enough hydrogen were produced, the containment could fail from becoming over-pressurized. To help address this problem, in 1989, the NRC sent Generic Letter 89-16, "Installation of a Hardened Wetwell Vent" to all the owners of BWR Mark Is, *recommending*[9] that hardened vents be installed in BWR Mark Is.[10] Hardened wetwell vents are intended to depressurize and remove decay heat from BWR Mark I primary containments; and the water in the wetwell would help scrub the fission products (excluding noble gases) that had entered the containment.[11]

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[6] David Lochbaum, "Fission Stories: Nuclear Power's Secrets," February 2000, p. 9.

[7] International Atomic Energy Agency (IAEA), "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," IAEA-TECDOC-1661, July 2011, p. 10.

[8] J. Starflinger, "Assessment of In-Vessel Hydrogen Sources," in "Projekt Nukleare Sicherheitsforschung: Jahresbericht 1999," Forschungszentrum Karlsruhe, FZKA-6480, 2000.

[9] Generic Letter 89-16 states that "the Commission has directed the [NRC] staff to approve installation of a hardened vent under the provisions of 10 CFR 50.59 ["Changes, Tests, and Experiments"] for licensees, who on their own initiative, elect to incorporate this plant improvement;" see NRC, "Installation of a Hardened Wetwell Vent," Generic Letter 89-16, September 1, 1989, p. 1.

[10] NRC, "Installation of a Hardened Wetwell Vent," Generic Letter 89-16, September 1, 1989, p. 1.

[11] R. Jack Dallman, *et al.*, "Filtered Venting Considerations in the United States," May 17-18, 1988, CSNI Specialists Meeting on Filtered Vented Containment Systems, Paris France, p. 5.

II. What Would Be the Features of Reliable Hardened Containment Vents with High-Capacity Filters?

It is widely known that in the Fukushima Dai-ichi accident, hardened vents did not prevent hydrogen from entering BWR Mark I secondary containments and detonating. In fact, hardened vents may have caused the Fukushima Dai-ichi accident to be worse than it would have been if such vents had not been used: "it is postulated that the hydrogen explosion in the Unit 4 reactor building was caused by hydrogen from Unit 3."[12] Unit 3 and Unit 4's containment vent exhaust piping was interconnected, so hydrogen may have been vented from Unit 3 to Unit 4's secondary containment,[13] where it detonated. Thus, one of the NRC's requirements for a new design of a hardened vent is that it "shall include design features to minimize unintended cross flow of vented fluids within a unit and between units on site."[14]

In a nuclear power plant (NPP) accident, venting BWR Mark I and Mark II primary containments could be beneficial; however, venting could also cause negative consequences. For example, a 1988 paper, "Filtered Venting Considerations in the United States" (hereinafter "Filtered Venting Considerations"), states that for some NPP accident scenarios, "venting has been postulated to increase the likelihood of core damage by causing pump cavitation[15] and the eventual loss of injection to the reactor coolant system."[16]

Given the vulnerabilities of BWR Mark I and Mark II primary containments—their relatively small volumes and dependence on suppression pools, which do not mitigate hydrogen—it is essential that a hardened containment vent be designed so that it

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[12] Institute of Nuclear Power Operations, "Special Report on the Nuclear Accident at the Fukushima Dai-ichi Nuclear Power Station," INPO 11-005, November 2011, p. 34.
[13] *Id.*, pp. 33-34.
[14] NRC, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents," EA-12-050, March 12, 2012, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML12054A694, Attachment 2, p. 1.
[15] Cavitation is "[t]he formation of...vapor-filled cavities in liquids in motion when the pressure is reduced to a critical value while the ambient temperature remains constant. ... Cavitation causes "a restriction on the speed at which hydraulic machinery can be [operated] without noise, vibration...or loss of efficiency;" see "A Concise Dictionary of Physics," Oxford University Press, 1990, p. 34.
[16] R. Jack Dallman, *et al.*, "Filtered Venting Considerations in the United States," p. 3.

would be reliable in a wide range of different severe accident scenarios. If such a vent cannot be developed,[17] the NRC should perhaps consider either shutting down or not relicensing BWR Mark I and Mark IIs.

It could be difficult to design a hardened vent that would perform well in scenarios in which there were rapid containment-pressure increases. The report "Filtered Venting Considerations" discusses the importance of considering these scenarios: "[f]iltered venting may have positive benefits for those sequences in which the rate of containment pressure rise is relatively slow. Filtered venting is less feasible for those sequences resulting in early over-temperature or over-pressure conditions. This is because the relatively early rapid increase in containment pressure requires large containment penetrations for successful venting."[18] This indicates that a reliable hardened vent's piping would possibly need a greater diameter and thickness than those of the hardened vents presently installed at U.S. BWR Mark Is.[19]

A 1993 OECD Nuclear Energy Agency paper, "Non-Condensable Gases in Boiling Water Reactors" (hereinafter "Non-Condensable Gases"), discusses severe accident scenarios in which there would be a rapid accumulation of steam in the drywell and non-condensable gas accumulation (nitrogen[20] and hydrogen) in the wetwell; in such scenarios, the primary containment's pressure could *rapidly* increase "up to the venting and failure levels."[21] "Non-Condensable Gases" states that for a 3300 megawatt thermal BWR Mark I, in scenarios in which hydrogen would be produced from a zirconium-steam reaction of 40 percent, 70 percent, and 100 percent of all the zirconium in the reactor core,[22] if the total quantity of non-condensable gases (including nitrogen) were to

[17] It is noteworthy that a 1983 Sandia National Laboratories manual cautions that "it may be difficult to design vents that can handle the rapid transients involved [in a severe accident];" see Allen L. Camp, *et al.*, Sandia National Laboratories, "Light Water Reactor Hydrogen Manual," NUREG/CR-2726, August 1983, p. 2-66.
[18] R. Jack Dallman, *et al.*, "Filtered Venting Considerations in the United States," p. 3.
[19] The piping of hardened vents currently installed at U.S. BWR Mark Is is typically 8-inches in diameter.
[20] Nitrogen is used to inert BWR Mark I and Mark II primary containments.
[21] T. Okkonen, Nuclear Energy Agency OECD, "Non-Condensable Gases in Boiling Water Reactors," NEA/CSNI/R(94)7, May 1993, pp. 4-5.
[22] Equivalent to the quantity of hydrogen that would be produced from a zirconium-steam reaction of 72 percent, 126 percent, and 180 percent, respectively, of the active fuel cladding length.

accumulate in the wetwell, the primary containment's pressure would increase up to 107 pounds per square inch (psi), 161 psi, and 215 psi, respectively.[23]

If a hardened vent were designed to have a rupture disk, the vent would work passively, ensuring that the venting of the primary containment commenced once its internal pressure reached the point at which the rupture disk was set to rupture. A reliable passive venting capability would satisfy two of the NRC's requirements for a new design of a hardened vent: 1) it "shall be designed to minimize the reliance on operator actions" and 2) it "shall include a means to prevent inadvertent actuation."[24] A reliable passive venting capability could also be advantageous in severe accident scenarios that had rapid containment pressure increases; however, there could always be other severe accident scenarios in which plant operators would want to vent the primary containment before the primary containment's internal pressure reached the point at which the vent's rupture disk was set to rupture.[25]

In a December 2011 article, Saloman Levy[26] stated that in the event of a U.S. BWR Mark I severe accident, "[e]arly venting [would be] preferred, when the containment pressure and hydrogen concentration are low and not prone to explosions and fires" and that in the Fukushima Dai-ichi accident, plant operators should have "[c]onsider[ed] early venting rather than waiting for containment pressure to reach or exceed design pressure."[27] Levy does not refer to high-capacity filters in his statements; however, it could be argued that implementing a policy of early venting would require installing a high-capacity filter to help protect the surrounding population, who would not have time to evacuate and prevent becoming exposed to radioactive releases.

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[23] T. Okkonen, "Non-Condensable Gases in Boiling Water Reactors," p. 6.

[24] NRC, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents," Attachment 2, p. 1.

[25] In a telephone conversation with the author on May 18, 2012, David Lochbaum of Union of Concerned Scientists said that there could be severe accident scenarios in which plant operators would want to vent the primary containment when the internal pressure was relatively low.

[26] "How Would U.S. Units Fare?" states that "Dr. Levy was the manager responsible for General Electric (GE) BWR heat transfer and fluid flow and the analyses and tests to support [GE's] nuclear fuel cooling during normal, transient, and accident analyses from 1959 to 1977." See Saloman Levy, "How Would U.S. Units Fare?," Nuclear Engineering International, December 7, 2011.

[27] Saloman Levy, "How Would U.S. Units Fare?," Nuclear Engineering International, December 7, 2011. Levy makes the point that his observations are not intended to be criticisms of the actions of the Fukushima Dai-ichi plant operators.

A high-capacity filter would also be needed for scenarios in which there was a reflooding of an overheated reactor core, which would rapidly generate hydrogen, thereby possibly threatening containment integrity and increasing the risk of radioactive fission product releases.[28] Additionally, a 1988 Oak Ridge National Laboratory (ORNL) paper suggests installing high-capacity filters at BWR Mark IIs because "[i]t is much more probable that operation of simple 'hard' venting systems in [Mark] II plants would result in the discharge of aerosols directly into the environment."[29]

"Filtered Venting Considerations" states that "[v]enting could be from the drywell or the wetwell, but wetwell venting is preferred to allow for fission product (excluding noble gases) scrubbing in the suppression pool."[30] However, according to the same paper there could be a wide range in the effectiveness of suppression pools in scrubbing and retaining radionuclides in the event of a severe accident. The paper states that "[t]he decontamination factor[31]...associated with suppression pool scrubbing can range anywhere from one (no scrubbing) to well over 1000 (99.9 [percent] effective). This wide band is a function of the accident scenario and composition of the fission products, the pathway to the [suppression] pool (through spargers, downcomers, etc.), and the conditions in the [suppression] pool itself. Conservative [decontamination factor] values of five [80 percent removal] for scrubbing in Mark I suppression pools, and 10 [90 percent removal] for Mark II...suppression pools, have recently been proposed for licensing review purposes."[32] Clearly, a high-capacity filter would help protect the public from becoming exposed to radioactive releases if there were venting from either the drywell or wetwell (in cases in which the suppression pool was ineffective at scrubbing and retaining radionuclides).

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[28] OECD Nuclear Energy Agency, "In-Vessel Core Degradation Code Validation Matrix: Update 1996-1999," Report by an OECD NEA Group of Experts, October 2000, p. 13.

[29] Sherrell R. Greene, Oak Ridge National Laboratory, "The Role of BWR Secondary Containments in Severe Accident Mitigation: Issues and Insights from Recent Analyses," 1988.

[30] R. Jack Dallman, *et al.*, "Filtered Venting Considerations in the United States," p. 5.

[31] The decontamination factor is "[t]he ratio of the initial amount of a nuclide in a [gaseous or liquid] stream (specified in terms of concentration or activity of radioactive materials) to the final amount of that nuclide in a stream following treatment by a given process;" see T. Chandrasekaran, *et al.*, NRC, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors: PWR-GALE Code," NUREG-0017, Rev. 1, March 1985, p. 1-4.

[32] R. Jack Dallman, *et al.*, "Filtered Venting Considerations in the United States," p. 4.

III. The Need for Installing High-Capacity Filters at BWR Mark I and Mark IIs in Addition to Hardened Vents

> The nuclear industry and NRC staff appear generally to be in alignment on a variety of issues regarding the implementation of orders incorporating safety lessons from the agency's Fukushima tack force, though some differences remain to be worked out.[33]—Nuclear Energy Institute

In October 1985, the Swedish Barsebäck Power Plant completed the installation of a hardened venting system and high-capacity filter system (FILTRA),[34] a gravel filter with a volume of 10,000 cubic meters,[35] for its two BWRs, which were constructed by Asea-Atom.[36] Barsebäck's FILTRA system was "designed so that 99.9 [percent] of the core inventory of radioactivity, excluding noble gases, [would be] retained in the reactor containment and filter system in the event of containment venting" in a severe accident.[37] Interestingly, in the 1980s, the Long Island Lighting Company had plans to install a hardened venting system and high-capacity filter system, similar to the FILTRA system, at the Shoreham Plant, a BWR Mark II.[38, 39]

The combined cost of Barsebäck's hardened venting and FILTRA systems for its two BWRs, was approximately 15 million dollars (1985 U.S. dollars).[40] In other words, Barsebäck's high-capacity filter system was not very expensive, considering that in the event of a severe accident it could significantly reduce the quantity of radioactive particulates discharged to the environment, which, in turn, reduces offsite contamination

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[33] Nuclear Energy Institute, "NRC, Industry Discuss Details of Fukushima Response," April 12, 2012.

[34] R. Jack Dallman, *et al.*, "Filtered Venting Considerations in the United States," p. 6; and Sherrell R. Greene, "The Role of BWR Secondary Containments in Severe Accident Mitigation: Issues and Insights from Recent Analyses."

[35] OECD Nuclear Energy Agency, "Filtered Containment Venting Systems," Note on the Outcome of the May 1988 Specialists' Meeting on Filtered Containment Venting Systems, CSNI Report 156, 1988, p. 17.

[36] Barsebäck Power Plant Unit 1 and Unit 2 were permanently shutdown in November 1999 and May 2005, respectively.

[37] A. H. Persson, "The Filtered Venting System Under Construction at Barsebäck," Nuclear Technology, Vol. 70, No. 2, August 1985, Abstract.

[38] Sherrell R. Greene, "The Role of BWR Secondary Containments in Severe Accident Mitigation: Issues and Insights from Recent Analyses."

[39] The Shoreham Plant never operated.

[40] A. H. Persson, "The Filtered Venting System Under Construction at Barsebäck," Abstract.

and damage to economic activity. (Barsebäck is located in southern Sweden about 12 miles from Copenhagen, Denmark.)

By the end of 1988, all Swedish NPPs had high-capacity filter systems, intended to limit the contamination of the environment to 0.1 percent of the reactor core's inventory of radioactive material in the event of a severe accident. In Sweden, the FILTRA-MVSS (Multi Venturi Scrubber System) system—designed to handle flow rates of up to 12 kg per second—was installed in seven BWRs and three PWRs.[41] An OECD Nuclear Energy Agency report states that Sweden's FILTRA-MVSS system cost less than five million dollars (1988 U.S. dollars) per reactor and opines that, because Sweden's high-capacity filter systems were inexpensive, "all criteria of the cost-benefit type are irrelevant."[42]

A number of nuclear power plants in Europe currently operate with high-capacity filter systems, including designs other than the FILTRA-MVSS system. In France, hardened vents with high-capacity filter systems were installed in *all* French PWRs in the 1990s.[43] And in Germany, *all* of the BWRs have hardened vents with high-capacity filter systems.[44] Unfortunately, U.S. BWR Mark Is and Mark IIs are *not* presently operating with high-capacity filter systems. A 1988 ORNL paper reports that U.S. utilities believe that high-capacity filter systems have "unacceptably low cost-benefit ratios."[45] And a 2005 Nuclear Energy Institute (NEI) document on severe accident mitigation alternatives analysis states that the estimated cost of a filtered containment vent would be three million dollars and that the "upper bound estimate benefit" of installing a filtered vent would be zero dollars.[46] An April 30, 2012 *Huffington Post* article, which discusses the monetary values provided by the 2005 NEI document, states that a spokesperson for NEI

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[41] OECD Nuclear Energy Agency, "Filtered Containment Venting Systems," pp. 7, 8.
[42] *Id.*, p. 4.
[43] E. Raimond, *et al.*, "Continued Efforts to Improve the Robustness of the French Gen II PWRs with Respect to the Risks of Severe Accidents: Safety Assessment and Research Activities," Eurosafe, 2011, p. 7.
[44] Martin Sonnenkalb, Manfred Mertins, "Severe Accident Mitigation in German NPP: Status and Future Activities," Eurosafe, 2011, p. 7.
[45] Sherrell R. Greene, "The Role of BWR Secondary Containments in Severe Accident Mitigation: Issues and Insights from Recent Analyses."
[46] NEI, "Severe Accident Mitigation Alternatives (SAMA) Analysis: Guidance Document," NEI 05-01 [Rev. A], November 2005, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML060530203, p. 43.

said the estimated cost of three million dollars dated back to 1994 for a filtered vent, which would not have been "seismically designed;" the article also states that Dale Klein, a former NRC commissioner, estimates that a filtered vent might now cost about 15 million dollars.[47]

When evaluating the cost of a filtered vent, it is pertinent that some U.S. BWR Mark Is and Mark IIs are located in proximity to areas with large populations. For example, the Limerick Nuclear Power Plant, which has two BWR Mark IIs, is located about 21 miles from Philadelphia. The potential impact of an unfiltered radioactive release in the event of a severe accident is quite large when considering the possible loss of agricultural economic activity and associated lands, the evacuation and suspension of industrial centers, and the cost of the decontamination of farmlands and city housing. However, even after the Fukushima Dai-ichi accident, the U.S. nuclear energy industry does not seem too keen on installing high-capacity filter systems,[48] in addition to the new hardened vents, which the NRC has required to be installed in BWR Mark Is and Mark IIs by December 31, 2016.[49]

According to an April 12, 2012 NEI article "[i]ndustry participants [in a public meeting] said that other safety modifications could result in a level of safety benefit similar to that of filtered vents."[50] And Maria Korsnick, Chief Nuclear Officer of Constellation Energy Nuclear Group, is quoted in the April 12, 2012 NEI article as stating that "[i]f you are managing a damaged core, managing containment, you are addressing the heart of the issue and there are modifications that are more beneficial than filtration."[51]

Indeed, managing a damaged core and protecting the containment would be very important in a severe accident; however, the fact that severe accident computer safety models, instrumentation, and management procedures could be vastly improved is a separate safety issue than requiring that hardened venting systems have high-capacity

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[47] Tom Zeller, "Nuclear Safety Advocates Accuse Industry and Regulators of Foot-Dragging on Basic Safety Measure," Huffington Post, April 30, 2012.
[48] Jordan Weaver, NRDC, "Nuclear Safety Deferred: The U.S. Nuclear Regulatory Commission's Inadequate Response to the Lessons of the Fukushima Dai-ichi Nuclear Accident," March 2012, p. 12.
[49] NRC, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents."
[50] NEI, "NRC, Industry Discuss Details of Fukushima Response."
[51] *Id.*

filters. The nuclear power industry's comments seem disingenuous: if the industry is confident that "there are modifications that are more beneficial than filtration," why did the industry not suggest implementing such modifications well before the Fukushima Dai-ichi accident occurred, in the 1980s and 1990s, when Europeans were installing hardened venting systems with high-capacity filters in NPPs?

The nuclear power industry's "modifications" for managing a damaged core seem to be predicated on at least three conditions: 1) computer safety models would accurately predict the progression of reactor core damage in different severe accident scenarios; 2) plant operators would know the condition of the core throughout the progression of a severe accident; and 3) there would not be circumstances in which plant operator error would make a severe accident far worse.

There is reason to doubt that these three conditions would be fulfilled in the event of another severe accident. Regarding the first condition: computer safety models under-predict the rates of hydrogen production that would occur in a severe accident, if there were a reflooding of an overheated reactor core.[52] Regarding the second condition: given the fact plant operators did not know the condition of the reactor cores during the progression of the TMI-2 and Fukushima Dai-ichi accidents, there is reason to doubt that plant operators would know the condition of the core during the progression of another severe accident. (To help enable plant operators to accurately measure a wide range of in-core temperatures, under typical and accident conditions, NPPs need to operate with thermocouples (temperature measuring devices) placed at different elevations and radial positions throughout the reactor core.[53]) Regarding the third condition: given the fact that plant operator errors made the TMI-2 and Chernobyl accidents far worse, there is reason

[52] IAEA, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," p. 14; and Report by Nuclear Energy Agency Groups of Experts, OECD Nuclear Energy Agency, "In-Vessel and Ex-Vessel Hydrogen Sources," NEA/CSNI/R(2001)15, October 1, 2001, Part I, B. Clément (IPSN), K. Trambauer (GRS), W. Scholtyssek (FZK), Working Group on the Analysis and Management of Accidents, "GAMA Perspective Statement on In-Vessel Hydrogen Sources," p. 9.

[53] In February 2012, the author of this report submitted a rulemaking petition (PRM-50-105) to the NRC requesting that the NRC require that NPPs operate with in-core thermocouples at different elevations and radial positions throughout the reactor core to enable NPP operators to accurately measure a large range of in-core temperatures under typical and accident conditions; see Mark Leyse, PRM-50-105, February 28, 2012, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML12065A215.

to doubt that there would not be circumstances in which plant operator error would make another severe accident far worse.

The NRC is presently considering if it should require high-capacity filtration for hardened vents in order to reduce radioactive releases to the environment in the event of severe accidents. The NRC staff is scheduled to prepare a policy paper on this issue by July 2012.[54] NEI's April 12, 2012 article reports that Martin J. Virgilio, the NRC's Deputy Executive Director for Reactor and Preparedness Programs, "said that NRC staff also is working on a paper on the 'economic consequences of land contamination' from radioactive materials following a reactor accident" and "that cost-benefit analysis would be one of the tools used to analyze the land contamination issue."[55]

The NRC should also consider that not all severe accidents would be like the Fukushima Dai-ichi accident: "slow-moving" station-blackout accidents caused by natural disasters. Fast-moving accidents could also occur; for example, a large break loss-of-coolant accident could rapidly transition into a severe accident—a meltdown could commence within 10 minutes after an accident initiated.[56] Early venting might be necessary in a fast-moving accident scenario: a high-capacity filter would help protect the surrounding population, who would not have time to evacuate and prevent becoming exposed to radioactive releases.

IV. Recommendations Regarding Hardened Vents with High-Capacity Filters for BWR Mark Is and Mark IIs

The author recommends that a hardened vent be designed so that it would perform well in scenarios in which there were rapid containment-pressure increases; for example, in scenarios in which there was a reflooding of an overheated reactor core. If such a vent cannot be developed, the NRC should perhaps consider either shutting down or not relicensing BWR Mark I and Mark IIs.

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[54] NRC, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents," pp. 4-5.

[55] NEI, "NRC, Industry Discuss Details of Fukushima Response."

[56] Peter Hofmann, "Current Knowledge on Core Degradation Phenomena, a Review," Journal of Nuclear Materials, Vol. 270, 1999, p. 205.

The author also recommends that the NRC require that high-capacity filters be installed at BWR Mark Is and Mark IIs, in addition to hardened vents.

To uphold its congressional mandate to protect the lives, property, and environment of the people living within proximity to BWR Mark Is and Mark IIs, the NRC needs to require that hardened vents have high-capacity filtration systems, in order to reduce radioactive releases to the environment in the event of severe accidents. (Some BWR Mark Is and Mark IIs are located in proximity to areas with large populations. For example, the Limerick Nuclear Power Plant, which has two BWR Mark IIs, is located about 21 miles from Philadelphia.)