Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Reactor Safeguards Subcommittee on Fukushima
Docket Number:	(n/a)
Location:	Rockville, Maryland
Date:	Wednesday, October 3, 2012

Work Order No.: NRC-1921 Pages 1-375

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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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SUBCOMMITTEE ON FUKUSHIMA

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WEDNESDAY

OCTOBER 3, 2012

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., Stephen P. Schultz, Chairman, presiding.

SUBCOMMITTEE MEMBERS:

STEPHEN P. SCHULTZ, Chairman

J. SAM ARMIJO, Member

SANJOY BANERJEE, Member

DENNIS C. BLEY, Member

CHARLES H. BROWN, JR. Member

MICHAEL L. CORRADINI, Member

DANA A. POWERS, Member

HAROLD B. RAY, Member

JOY REMPE, Member

MICHAEL T. RYAN, Member

WILLIAM J. SHACK, Member

JOHN D. SIEBER, Member

GORDON R. SKILLMAN, Member

JOHN W. STETKAR, Member

NRC STAFF PRESENT:

ANTONIO DIAS, Designated Federal Official

SUDHAMAY BASU, RES/DSA

JEROME BETTLE, NRR/DSA

TIM COLLINS, NRR/DSS

ROBERT DENNIG, NRR/DSA

ROBERT FRETZ, NRR/JLD

ED FULLER, RES/DRA

TINA GHOSH, RES/DSA

JOHN MONNINGER, NRR/JLD

AJ NOSEK, RES/DSA

ALLEN NOTAFRANCESCO, RES/DSA

WILLIAM RULAND, NRR

MARTY STUTZKE, RES/DRA

AARON SZABO, NRR/DPR

ALSO PRESENT:

NATHAN BIXLER, Sandia National Laboratories

PAUL GUNTER, Beyond Nuclear*

MARK LEYSE*

*Participating via telephone

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

8:30 a.m.

CHAIR SCHULTZ: Good morning. This meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Fukushima. I am Stephen Schultz, chairman of the subcommittee.

Members of the subcommittee in attendance are Jack Sieber, Sanjoy Banerjee, Dick Skillman, Dennis Bley, Dana Powers, Harold Ray, Sam Armijo, John Stetkar, Michael Ryan, Bill Shack, Charlie Brown, Joy Rempe and Mike Corradini.

The purpose of today's meeting is to receive a briefing and hold discussions with the staff on the development of a position paper addressing the value of filtered vents.

The entire meeting will be open to public attendance. Rules for the conduct of participating in this meeting have been published in the Federal Register as part of the notice for this meeting.

The subcommittee will hear presentations by and hold discussions with representatives of the NRC staff and other interested persons regarding this matter. The subcommittee will gather information, analyze relevant issues and facts, formulate proposed positions and actions as appropriate for deliberation by the full committee.

Another subcommittee meeting on the same briefing is scheduled for October 31st followed by a full committee briefing in November. The staff is currently developing a position paper that is due to the Commission by the end of November.

Antonio Dias is the Designated Federal Official for the meeting. A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice. We request that all speakers first identify themselves and then speak with sufficient clarity and volume so that they can be readily heard.

We have received no written comments from the public. We have received requests for time to make oral statements from Mr. Mark Leyse and Mr. Paul Gunter. I understand that there are other stakeholders in the audience as well as on the bridge line today who are listening in on today's proceedings and they will also be given the opportunity to address the subcommittee at the end of the briefing.

As stated we have future meetings

established for hearing additional information related to this topic. We have already had two meetings of the subcommittee, one an introduction to the topic held earlier this year and another subcommittee meeting held just recently. But this is the most developed presentation that we have had so far and so we look forward to today's discussion.

We'll now proceed with the meeting and I will call upon Mr. Bill Ruland from the Office of Nuclear Reactor Regulation to open the presentations. Bill? Thank you.

MR. RULAND: Thank you, Mr. Chairman and good morning to everyone.

The staff is here today to discuss the regulatory analysis it has prepared to inform a Commission decision on the need for additional improvements to the containment venting systems that were ordered for BWR Mark I and Mark II plants in March of this year.

The staff was directed by the Commission to provide backfit analyses under the current regulatory analysis framework for two incremental changes.

First, modify the current ordered reliable hardened vent such that the vent will be functional in severe accident conditions. The current requirements do not include severe accidents capability, only station blackout functionality.

Second, require that a high-efficiency external filter be included as part of the severe accident capable vent system.

Today the staff will provide you with considerable information gathered and the analysis performed for these options to support the Commission's decision.

As you alluded to, or as you stated, Mr. Chairman, in future meetings the staff will present its recommendations. We'd like to receive a letter of course from the committee after those meetings.

I believe it's fair to say at the outset that while the per-plant cost using available technology is not judged prohibitive the staff expected that the filtered containment venting system would not pass the quantitative cost-beneficial test under the current regulatory analysis framework. Also, a conclusive argument for adequate protection was not anticipated.

The findings that we present today are consistent with those expectations. Consequently, the staff's recommendation will depend heavily on consideration of other qualitative factors. This weighing of qualitative factors is ongoing and is the key task before the staff now.

The staff will speak today for all of the matters I've touched on in this brief introduction as well as as to how the EPRI analysis in the recently published technical report have been considered.

We look forward of course to your questions. Bob, do you want to introduce the team, please?

MR. FRETZ: Sure. Thank you, Bill, and thank you, Dr. Schultz and the committee for giving us the opportunity to brief you on this subject.

With me here at the table is John Monninger. I guess you can introduce yourself.

MR. MONNINGER: Good morning. I'm John Monninger, the associate director of the Japan Lessons Learned project director within the Office of Nuclear Reactor Regulation.

MR. DENNIG: Bob Dennig, chief of the Containment and Ventilation Branch at NRR.

MR. BETTLE: Jerome Bettle. I work for Bob Dennig in the Containment and Ventilation Branch.

MR. FRETZ: Good morning. Again as this slide suggests the purpose of our presentation is to brief you on at least the preliminary results of our regulatory analysis regarding the issue of filtered venting. And again, looking at our analysis related to the BWR Mark I and Mark II containment designs only.

And here's a slide on the proposed schedule. I understand that in order to accommodate members of the public as well as other proposed speakers we will not be following this. We'll be following the actual agenda that was published and placed on there. But again, this is our proposed schedule. It's a very challenging schedule.

Again, the outline for today's discussions is shown on slide 4. And as you can see by the materials that we handed out for today's briefing there's a lot of material to discuss.

I guess the good news is that there will be one or two speakers speaking so that we will be able to present you with the various experts from each of the areas that provided their input and expertise in the various matters.

Again, as mentioned earlier some of this material we have discussed before but we felt that it was very important to go over some of the things we talked about in previous meetings to at least provide the opportunity for just discussion on those matters. We had additional questions -- been thought of from the previous meetings.

And again, we will finalize the discussion with our next steps, pretty much where do we go from here.

And as mentioned earlier, this whole effort culminates with an IOU to the Commission to provide its recommendations by November 30th. That seems like a couple of months from now but there's a lot to do between now and then. As previously alluded, we will be coming before the subcommittee at the end of this month as well as the full committee on the following day.

And again we appreciate the coordination that we've had between the staff and the ACRS regarding scheduling of those meetings. I know it's been a challenge to make sure that everyone was available to at least hear what the staff said. So again, there's a lot to do.

The staff has a number of interactions that it will have with the Fukushima Steering Committee between now and the time we speak next.

And again it all culminates to submitting a Commission paper by the end of November. Next slide, slide 6.

Again, the purpose of the paper is known. As mentioned by Bill Ruland we are going to be looking at a number of options including whether or not to install severe accident-capable vents or filtered vents. And another option that we are looking at is a performance-based approach. And that will be discussed during the subsequent discussions today.

Our SECY paper outline essentially follows our discussion that we had today. This slide might be a little bit familiar from our previous things, but the staff -- there's a lot of information to present.

And the staff intends to provide the bulk of the details relating to various subject matters in enclosures to a SECY paper that will summarize essentially what's in the enclosures. We felt that there's a lot of information to present and we wanted to present it to the Commission in a clear way so that they can again be informed on the various aspects of it.

The first three enclosures are really

intended to provide sort of a foundation or lay a common understanding of venting and severe accident management and how they all relate.

The technical analysis enclosure will provide information relating to essentially the information that was important for coming up with this regulatory analysis and the conclusions from the regulatory analysis. Again, we will discuss an evaluation of various options that we are presenting.

And finally, we do plan to discuss our involvement with stakeholders. We felt that that's been a very important part of the process, to engage not only the regulated industry but as well as members of the public during this whole entire process.

Current status. One of the things we want to stress is that our technical and policy assessments are ongoing. We are still working on some of the results. In fact, as a bit of housekeeping, as an attachment to your slides we do have a 3-page addendum highlighting some of the latest information that we have gotten regarding the MELCOR analysis. So again, we are right now only in the preliminary stage. Again, this is what we hope to share with you today.

Again, as I mentioned earlier the staff will continue to engage the Fukushima Steering Committee on developing the path forward. And again we will be making recommendations once this assessment is complete.

I'd like to turn the presentation over to Bob Dennig who is the chief of the Containment and Ventilation Branch in the Office of Nuclear Reactor Regulation.

CHAIR SCHULTZ: Thank you, Bob. Bob, before you start I'd just like an administrative item to be handled.

Those of you who are on the bridge line, please if you have mute capability on your phones please use them. We are getting some feedback in the room from individuals turning pages. And we also get static if the phones are not on mute. So please take advantage of that and put your phones on mute until there is an opportunity for comment later today.

Thank you. Bob?

MR. DENNIG: Thank you. I'm going to move quickly through a high-level summary of basically regulatory history from Mark I's and Mark

II's. The technical implications and details of some of these aspects will be talked about by subsequent speakers from the Office of Research. First slide, please.

At the beginning, basically Mark I containments have been on the radar screen for quite some time. Probabilistically it goes back to WASH-1400. The nominal characteristics that put it on the radar screen is the inability to handle severe accident overpressure challenges and this is because of the inability to deal with gas buildup in a severe accident, and the fact that BWRs have three times the quantity of zirconium as PWRs which gives the potential for generating a substantial amount of hydrogen gas during a severe accident. Next slide, please.

All of the containments were looked at as you well know in the Containment Performance Improvement Program and the Mark I was sort of the flagship or the origin of that program. Coming out of that program the staff recommended several modifications to improve the robustness or the performance of the Mark I containment in severe accident conditions and those include the improved hardened vent.

By "hardened" we mean that -- the plants always had the capability to vent through a low-pressure standby gas treatment path, but that was judged to be unreliable and would not take the pressures post accident. And so "hardened" means that it will take higher pressures reliably.

Reactor pressure vessels depressurization system improvements. This had to do with extended dc power for operating SRVs. This has been addressed by the SBO capability that's in the new order.

Provide alternate water supply to reactor pressure vessel and drywell sprays. You'll hear later how this has been folded into the response to 9/11 and more recently in mitigating strategies. And then of course improve emergency procedures and training.

Coming out of that SECY paper was 89-17. The Commission at that time approved the hardened vent as a feature that could be put into -- be installed under 50.59 by BWR Mark I's and so that resulted in the issuance of the Generic Letter 89-16. And that gets us to where we were before Fukushima.

The other recommendations were parsed

off to be included in the IPE program which was ongoing at that time. Next slide, please.

MEMBER SIEBER: Just as a matter of clarification, this hardened vent is seismically capable?

MR. DENNIG: No.

MEMBER SIEBER: No, okay.

MR. DENNIG: No.

MEMBER SIEBER: If it's not seismically capable how capable of handling deflagration or detonation?

MR. DENNIG: The generic letter said that it should be able to deal with that. That was in the generic letter.

MEMBER SIEBER: Okay.

MR. DENNIG: So to the extent that --

MEMBER SIEBER: Were they designed that way? The ones that were installed.

MR. DENNIG: The staff's overview was to look at the responses to the generic letter following the BWR Owners Group guidance and I believe that included that factor. I don't know to what extent anybody did any check calculations or anything like that.

MEMBER SIEBER: Well, to me that's an

important factor and one that I would like to personally look into further.

MR. DENNIG: Well that currently is not part of what's in the order.

MEMBER SIEBER: Okay.

MR. DENNIG: Next slide, please. A similar accident signature profile to the Mark I. The exception that was noted is that the TW sequence was not as predominant for Mark II's. Interestingly the risk profile was dominated by early failure with a release that --

MEMBER BLEY: I'm not sure that everybody knows the TW. Could you?

MR. DENNIG: It's a loss of containment heat removal capability with not necessarily losing core-cooling capability.

Anyway, the risk profile was dominated by early failure with release that bypasses the suppression pool. For that reason at that time the venting that was being considered for the Mark I was considered for the Mark II but it was not brought forward because it would require, in the view of the people doing the analysis it would require an external filter similar to the one that was being -- that had just been installed in all the Swedish plants which is the MVSS, Multi-Venturi Scrubbing System.

So one aspect of this is we have an order out there that has a vent that's not filtered for Mark II's so there's some need to revisit this observation with regard to filtering for Mark II's.

Again, we didn't go forward with the generic backfit hardened vent. It was spun off into the IPE program. Next slide, please.

With regard to -- this is a very quick, breezy summary of filtered containment vents here. You can track back to a TMI action item that was enshrined in 50.34(f) that provided one or more dedicated containment penetrations sized to a single 3-foot, et cetera, et cetera, et cetera. So there was some provision going forward for filtering.

Shoreham submitted a supplemental feature for their containment that was basically the Barseback filtration system which is -- Jerry will talk later about this. It's a very large, large, large, large containment cylinder of gravel.

I've mentioned that the possibility of filters came up during the CPIP. It wasn't pursued at that time. There wasn't any detailed cost-benefit analysis done. The filters that were available included Venturi scrubbers but that wasn't looked at. We were still looking at large, large gravel field-bed sand beds as a primary concept.

MEMBER CORRADINI: Just an information question. So all these various designs you're speaking about have tested decontamination factors? There is data out there to look at if one were to install it the decontamination factor would be X, Y or Z?

MR. DENNIG: The ones that are installed elsewhere and are available now, yes. Jerry will talk about that when we get to his presentation. You notice that anything I don't want to talk about is Jerry's.

(Laughter)

MEMBER POWERS: Well, I think it's important to understand, Mike, that when they say a decontamination factor of so much -- and depending on what you're putting into this.

MEMBER CORRADINI: Well, I was going to say it depends on the input, the input isotopes.

MEMBER SIEBER: And physical forms.

MEMBER POWERS: Well, I mean most of these things depends actually on the particle size. If I put marbles in I'd probably have very high decontamination factors for most filtration systems. If I put atoms in I don't have any decontamination factor at all. So these have been tested against some --

MEMBER SIEBER: Input distribution and flow.

MEMBER POWERS: -- input material. I mean, we have not -- I keep hoping for a RAND but apparently we don't have any filtered vents hooked up to reactors that have accidents. So we don't really have a test on the actual material going in.

And what goes into the filtered vent depends on everything that's occurred before it gets to that filter. So, you've got to put a codicil on all these decontamination factors that people quote because kind of the way people in the business of marketing filtered systems tend to quote rather high decontamination factors and they're absolutely accurate given what they put into it.

MR. DENNIG: Next slide, please. Just a recap of the order that was issued in, what was it, February? EA-12-050, Reliable Hardened Vent Capable of Performing During Prolonged SBO. And it is designed for use prior to onset of core damage designed for the prevention of core damage, to remove heat from the containment and depressurize the containment.

Severe accident conditions were not folded in. We did ask that they be designed to minimize operator actions but we didn't do anything by way of making sure that they would be protected from post-accident high radiation and could perform those operations. And we did stipulate that it would discharge at a release point above the main plant structures.

The installed vents in some cases did not do that so we made sure that that was covered in the current order. But again, hydrogen is not part of the mix there. Next slide, please.

I think we've spoken with the committee on a number of occasions on our foreign information-gathering and the report. The paper will have an enclosure that talks about all that and seeks to summarize it, pull it all together.

One I guess general observation was that what we heard in talking to regulators and licensees overseas was basically what one could find in the 1988 CSNI report, "Specialist's Meeting on Filtered Containment Venting Systems." Again, that was from 1988.

And I would direct your attention to that. It does talk at length about submicron particles and testing for efficiencies with submicron particles. I'm pretty sure that the data to independently confirm that isn't there but it at least gives you a sense that the topic was addressed.

The other insight was that the filtered containment venting system is considered as part of a severe accident management system that is there to as passively as possible control containment pressure while you are trying to restore containment flooding and core cooling. And so they see it as a suite if you will of capabilities. Get water in, make sure that the containment takes care of itself, we don't have to manage that.

MEMBER BANERJEE: Is that CSNI report available?

MR. DENNIG: Oh, sure.

MEMBER BANERJEE: Relatively readily?

MR. DENNIG: Yes.

MEMBER BANERJEE: Could we get hold of it?

MEMBER POWERS: There is that report, but there's also a specialist report on the status of aerosol science. And there's an appendix on filtered vent in that. And it's actually pretty decent, more of a status report than it is, you know, here's how these things work and here's how well they work. But it updates.

MEMBER BANERJEE: Any experimental results?

MEMBER POWERS: There are lots of various things. Is there an experiment on a full-blown filter system? Well, there's some on a Venturi system, a scrubber, Venturi scrubber, especially water-injection Venturis were done at SKI but not as much as you would like.

There are lots and lots of issues on how well these perform, especially with radioactive materials.

MEMBER BANERJEE: So most of the tests, Dana, were done with surrogates?

MEMBER POWERS: Technically, yes.

MEMBER BANERJEE: Thanks.

CHAIR SCHULTZ: Is the timing of that report that you mentioned about the same?

MEMBER POWERS: No, no, no, it was written --

MR. DENNIG: 2009 I think is the --

MEMBER POWERS: Yes, in the two thousands or something, and it updates.

MR. DENNIG: I think it's 2009, CSNI something something.

MEMBER POWERS: It has a superb discussion of aerosol physics. Truly insightful.

MEMBER STETKAR: Did you write that part?

(Laughter)

MEMBER BANERJEE: I presume that we know the author.

MEMBER CORRADINI: I'm glad there's no pride of authorship. Let me ask a different question. So, taking away the experimental data for -- I think I had asked this when I think you guys were here in July. I don't remember exactly when you were talking about foreign experiments. But I thought it was asked at that time that you were going to check into whether we pick any of these in Sweden for example. Do they at least go through a consistent set of calculations with their dominant sequences --

MR. DENNIG: Yes.

MEMBER CORRADINI: -- that show the performance?

MR. DENNIG: Yes.

MEMBER CORRADINI: So that you actually see differences with and without?

MR. DENNIG: They are currently requiring their plants that are being uprated to perform a full, I think all the way at level 3 PRA to confirm that with the 3 it will operate as a standard.

So, and at the time that this was done there was a program called the MITRA that was a joint program with industry and the Swedish regulator in which all these kinds of calculations were done. One of the prescriptions in the 1980-81 government order was that they would examine all overpressure sequences probabilistically and also that if there was any alternative to using a filter that that would be brought forward as this program went on. So that was written into the law. So yes, they have done all this.

MEMBER STETKAR: Do you know the results of those comparative studies?

MR. DENNIG: In the sense of -- well, the bottom line was there wasn't -- I don't have the details of what they looked at and what they found, but the outcome was that they didn't find an alternative. That much we were told.

MEMBER CORRADINI: I guess what I'm asking --

MEMBER STETKAR: Release categories with and without the filter is what I was asking about.

MEMBER CORRADINI: Right.

MEMBER STETKAR: Right.

MR. DENNIG: Yes.

MEMBER STETKAR: With and without a filter what is the profile of their release categories?

MR. DENNIG: Those calculations were done and they are available and we can get them from the regulator but we have not scrutinized them.

MEMBER STETKAR: Why not?

MR. DENNIG: As a matter of time I suppose as much as anything else, plus they pretty much run the same codes as we do and they do the same kinds of analysis. A lot of their work was based on NRC work.

MEMBER CORRADINI: I mean, I don't know where John is going with this but where I'm going with it is if there's not data as Dana said based on some sort of surrogate set of materials with the sur inventory and distribution that you can -- I was just at another meeting yesterday that some people were really worried about surrogates.

MEMBER BANERJEE: Why is that, Mike?

MEMBER CORRADINI: Well, I'm saying the inherent data in this case, I'd want to see a consistent calculation. I guess staff would -- I would have expected staff to look at a set of consistent calculations. Because with these calculations you can run a computer program but these computer programs, you can get almost anything you want out of it if you tweak the knobs a certain way. So I'd like to see --

MR. DENNIG: Well, you'll from Research we have done calculations with and without filters here that you'll be able to scrutinize.

MEMBER CORRADINI: Okay. But just to summarize, you know that these exist but you haven't looked at the details of them is I think what John -- was your answer to John. Is that correct?

MR. DENNIG: Right. We have not read the MITRA report or pulled the addendums and appendices thereto. We have gotten some analyses of recent uprates that include filtering and passed those onto Research for scrutiny at like the MELCOR MAAP-level analysis. So there has been some of that.

Some of the calculations are done, you know, done by the licensee and the authority is not eager to put them out in the public domain so there's that issue all the time. So, for a variety of reasons we haven't been at that level but Research will talk about how they have modeled things and the results they've gotten with and without filters.

MEMBER BANERJEE: Is it the general feeling that sufficient data and validation exist so that these things can be designed properly?

MR. DENNIG: Well, I think that's the consensus of folks outside of our realm. I think that's the consensus.

MEMBER BANERJEE: And that would be something Research will address for us today?

MR. DENNIG: They're going to talk about how they've modeled DFs and calculated decontamination factors within MELCOR.

As far as the testing that's been done the -- like I said, the CSNI report talks in detail about high-efficiency scrubbing of submicron particles and alludes to having to address that problem. The Venturi scrubbing system is specifically selected as having the capability to do that where other systems, other approaches do not. Coolants and sprays will not do that.

So, in consequence of that the -- and the Swedes are the ones that started it. They went off and looked at particulate-scrubbing technology that came out of air quality which is wet Venturi scrubbing. It was an old technology when they looked at it but they adapted it to the purpose of capturing submicron particles to the degree that they needed to whereas other processes would not. It was a specific design requirement for this.

MEMBER BANERJEE: So the pools would not. If you had bubbles --

MR. DENNIG: In some cases to some degree they will and Dana knows more than I do. But I think when we look at the research results later you will see that, if they show that, that the large things drop out. If you look at it by particle size class the large things drop out and the smaller things tend to go through. So it makes sense.

MEMBER POWERS: What happens in nearly all filtration systems is the big stuff is pretty easy to do. Very, very tiny stuff is very easy to do because it diffuses rapidly. And there is a minimum. If I plot the filter efficiency as a point -- size there is a minimum. It is not zero, okay. So that you, if you make your pool deep enough you'll get everything. But they can be very, very deep.

What the -- what we observed in sprays is that minimum shifts with the droplet size. So that by using a distribution of droplets you do better than you do with a single droplet size.

What the Venturi does is it creates a little bit of droplet mist in there that is a particularly good size for getting the aerosol particles that are most difficult or have the minimum kind of efficiency of capture.

MEMBER CORRADINI: So it basically creates what it needs to remove some class of size.

MEMBER POWERS: That's right. Now, if you plot the efficiency of a water-injection Venturi as a function of particle size there's still a minimum in the efficiency. That's almost unavoidable, okay, and it's just how shallow that minimum is. And it happens to be less shallow than passive kinds of systems.

MEMBER BANERJEE: It also creates turbulence. That helps.

MEMBER POWERS: These particles that you're worried about, it takes awfully intense turbulence to get them to cross stream lines.

MEMBER BANERJEE: What is the typical size, Dana?

MEMBER POWERS: Typically around 0.1 micron, 0.1-0.2 microns are the problem particles.

MEMBER BANERJEE: Okay. Thank you.

MR. BASU: Bob, can I clarify one thing just in my mind?

MR. DENNIG: Please.

MR. BASU: Sud Basu from the Office of Research. In MELCOR we do calculate DF of whole scrubbing, we do calculate the capture efficiency of spray, so on and so forth. We don't calculate DF of external filter.

So what I understand, most of the discussion if not the entire discussion is centered around the DF of external filter. We actually use a number in MELCOR for external filter, a preassigned or prescribed DF number. So, just for clarification.

MR. DENNIG: This is -- the slide's up there now. It's just illustrative of the general statement about the reason for pursuing Venturi scrubbers for submicron particles, one of the things that it does if you can't do electrostatic removal.

And at the point where Sweden was deciding how to pursue this, there are two tacks basically. One has to do with sands and gravels, large-bank filters that comes out of like a defense establishment filtering production plants and reprocessing plants. And the other branch goes off into wet Venturi scrubbing. And we didn't follow the former branch to any great degree. And others followed the Venturi scrubbing branch, and that's what's developed at the present time. So you can take that down.

MEMBER SKILLMAN: Bob, in your answer to Dr. Banerjee's question relative to is this notion going to work or is it going to be successful you answered those outside of this community think so, or words to that effect. May I ask you to expand on that answer a little bit, please?

MR. DENNIG: As I'll talk about later the majority of other countries have installed Venturi scrubbing systems either after TMI, after Chernobyl, after Fukushima. They all have requirements for minimum DFs. They all scrutinize and accredit the designs that their licensees have put in as meeting those criteria and believe that that is an effective answer to -- if you're going to have to vent a containment that is an effective answer to minimizing the release in a practical way at a practical cost. And so that's where things have settled.

MEMBER SKILLMAN: Okay, I understand that. So, that is those outside the community. Now, what's the thinking of those inside the community?

MR. DENNIG: Well, the basic -- how shall I characterize this? There's skepticism about two things, the capability that's being promoted by vendors, DFs of 10,000 or so.

MEMBER SKILLMAN: This is technical skepticism?

MR. DENNIG: Technical skepticism. And I think we had PSI in here talking to you about what they did and how they did it and where they came out on it. So that's their perspective. And we don't have any firsthand -- PSI has not given us their data, okay. AREVA has not given us their data. But they do want and they have been accepted by the regulators as doing the job.

MEMBER BANERJEE: PSI is the Paul

Scherrer Institute?

MR. DENNIG: Paul Scherrer Institute.

MEMBER SKILLMAN: Thank you, Bob. That explained what I was asking for. Thank you.

MEMBER BANERJEE: But they didn't give you the data because it's sponsored by some subgroup?

MEMBER STETKAR: It's actually CCI. It's a private company.

MEMBER BANERJEE: Oh, that's completely different from PSI.

MEMBER STETKAR: Right. And apparently PSI -- PSI I think has been contracted by them to run some tests. But it's CCI for whoever they --

MEMBER BANERJEE: PSI is a fairly reliable organization.

MEMBER BLEY: But they're together. PSI came to talk to us.

MR. MONNINGER: This is John Monninger from the staff. I think there's a lot of good questions here on the experiments that have been done, the data that has been collected as a prototypical, as a representative, et cetera.

You know, one of my thoughts is thinking of the other things that we do within -- to address severe accidents is the state of technology in filters much, you know, is it significantly different from how we have addressed disposition or resolved other severe accident issues out there? Whether it's decisions the staff has made from vendors submitting a corium debris cooling systems within the lower cavity, whether it's the installation and testing of PARS, passive autocatalytic recombiners. You know, whether it's the external reactor vessel cooling system that Westinghouse has.

I think this is not within the design basis accident spectrum, this is within the severe accident spectrum. And from the meetings I've been involved in, you know, we can't say it's a complete suite of testing but it appears to be comparable to the other state of knowledge and testing that the staff has looked at in resolving and addressing other types of severe accident issues.

That's just meant to put it in some level of perspective. And the Agency has proceeded with rulemakings and to impose requirements based on that state of knowledge.

MR. DENNIG: Okay. Next slide, please.

MEMBER BANERJEE: If I interpret what

you said it means that you're willing to proceed with less complete knowledge than you would have for certain design basis accidents.

MR. MONNINGER: I think the staff does do that. I think, you know, with the validation of our severe accident codes, our models, the level of completeness of our PRAs, our risk assessments, yes, I do believe that's true. And that's, you know, an accepted regulatory practice. Whether it's good or not is different.

MEMBER BANERJEE: Yes. I mean you're stating a fact.

MR. MONNINGER: Yes.

MR. DENNIG: Next slide, please. I want slide 16. I've touched on this already. The installation of filtered containment venting systems has largely been in response to operating experience from large accidents. You can see that it was done after TMI is the earliest and that's Sweden and they did the earliest after Chernobyl. And now after Fukushima there are commitments to install filtered containment venting systems.

The -- some plants, if you look into it, the commitment is from the industry and voluntary to the extent that we understand voluntary.

MEMBER ARMIJO: Strange word.

MR. DENNIG: One of the consistent things though is that the way it usually proceeds is that there's a decision that's been made that since the containment has to be vented it has to be filtered and that decision gets made, and then the regulator works with industry to develop the specifications and the approaches. So the decision comes early and then the effort to come up with a feasible solution follows.

Some countries have done this, put in filters as part of their periodic backfit reviews. But again, my sense is that it was driven by operating experience, in response to operating experience.

And at the time that these decisions are made it is highly likely that severe accidents were not part of the design basis, that they were going beyond the design basis and later would incorporate it, pull it into the design basis. But at the time it was decided to have a filtered release that was not the case. Next slide, please.

MEMBER ARMIJO: Before you do that, Bob, are these systems that have been installed seismically qualified?

MR. DENNIG: Yes.

MEMBER ARMIJO: And so, the last bullet I'm trying to understand. Severe accidents were not part of the design basis for the filter? I mean, or --

MR. DENNIG: For the original plant.

MEMBER ARMIJO: For the original plant.

MR. DENNIG: Right. They had the same thing as --

MEMBER ARMIJO: So as far as --

MR. DENNIG: -- design basis accidents, you know, and successful if late recovery of ECCS and stopping the accident process, the same thing as we had.

MEMBER ARMIJO: Okay.

MR. DENNIG: Next slide, please. The technical bases are to a great extent qualitative. The regulators assert that it's -- FCVS is needed to manage a severe accident with pressure challenges.

For example, the Finnish regulator, their position is that a filtered containment venting system is useful for anytime there are fission products in the containment to manage the accident.

Defense-in-depth to address

uncertainties associated with severe accidents. This was the point that was emphasized to us by the Swedish regulator.

And then obviously it significantly reduces offsite release and land contamination. And they do -- except for Sweden who actually has a criterion for that contamination.

The other countries have adopted an achievable DF approach, available technology. They specify that you have on the filter, for the filter a DF of 1,000 for aerosols and 100 or so for iodine. And that's where they pick it up. That's the requirement. It's stipulated.

MEMBER CORRADINI: And then when they -- because I guess Dana's going to help answer this one. When you give a specification like that it must be some average by some test? In other words, because it is particle-dependent and you do get a minimum. I remember some slides that Dana sent to all of us kind of ahead of time on this. So, how is the DF computed? Is it the minimum DF or is it some integrated that takes account of particle size?

MR. DENNIG: The general assumption is that the filters that are installed at the moment, the technology at the moment, the DF is not sensitive to particle size to any great degree. That is the representation.

MEMBER BANERJEE: Are these for the Venturi scrubbers?

MR. DENNIG: Yes.

MEMBER BANERJEE: There is a minimum but it's fairly flat.

MR. DENNIG: Well, you can -- well.

MEMBER CORRADINI: Well, I guess what I was asking is when you said if, you know, you said 1,000 for particles and 100 for iodine. The question that went through my mind is is that the minimum? Is that some sort of computed average based on a test?

MR. DENNIG: No, that's a minimum. That's a greater than or equal to 1,000 for aerosols. That's a minimum. I'm sorry, I misunderstood.

MEMBER BANERJEE: So physically suppose you had these Venturi scrubbers. How big are they?

MEMBER CORRADINI: They're big.

MEMBER SKILLMAN: They're huge.

MR. DENNIG: Did we bring the comparative slide?

MR. BETTLE: Yes, there's some backup

slides.

MEMBER BANERJEE: You brought some pictures?

MR. DENNIG: We'll show you that, yes. We'll show you that. Do you want to put it up? We have a slide.

MEMBER BANERJEE: Whatever you're comfortable with.

MEMBER CORRADINI: Just tell us the number and we'll look at it.

MR. DENNIG: It's in the backup slides.

MEMBER CORRADINI: Oh, it's not in this. This is just the main slides, sorry.

MEMBER STETKAR: This is just a high-level summary.

MR. BETTLE: This is Jerome Bettle. The Barseback filter was a large seismic reinforced concrete cylindrical structure about the size of their primary containment is like 65 meters high. The -- when they reduce the size down with the water bath multi-Venturi filters those are about I believe 21 meters. And a lot of the current designs are 9 meters and less.

MR. DENNIG: So it's evolved over time.

MEMBER BANERJEE: I'm glad I asked that

question.

MR. DENNIG: Well, and there is a design that's being put on the Chinese plants that splits the scrubber section from the after-particle removal, the metallic filter section. And they do it in two pieces and it fits inside the reactor building.

MR. BETTLE: For more constrained installation locations.

MEMBER CORRADINI: What Chinese plants are these?

MR. DENNIG: There are two PWRs that I know of that have the AREVA filter installed on it, and they're putting it on all their PWR forward builds. And the last time --

MEMBER CORRADINI: Not on their construction, on their planned.

MR. DENNIG: Under construction. Planned and under construction. They're putting that system on their PWRs.

MEMBER BANERJEE: The AREVA plants.

MR. DENNIG: No, this is Chinese, China's plants. They're using the AREVA design.

MEMBER CORRADINI: So let's just make sure I'm clear. They have four AP1000's going up.

Are they on the four AP1000's?

MR. DENNIG: I don't have any information about that.

MEMBER CORRADINI: There's four -- I mean, there's 26 plants in construction. When you say they're on all the plants, that's an awful lot of plants to put them on. So I just want to make sure I'm clear on what they're doing.

MR. DENNIG: I can give you the list. It does not include -- well, I don't know. I have the list of names of PWRs.

MEMBER CORRADINI: I was figuring that would be the answer I would eventually hear.

(Laughter)

MEMBER CORRADINI: Okay, fine. Thanks.

MEMBER BANERJEE: And are they backfitting any or it's just going forward?

MR. DENNIG: The words are new builds.

MR. MONNINGER: Well, throughout the world or within China?

MEMBER BANERJEE: Within China.

MR. DENNIG: I haven't heard backfit. I've heard going forward.

Okay. Barseback was a one-of-a-kind and it was obsolete pretty much by the time it was installed. And the period of 1980-ish to 1986, the filter MVSS was developed in Sweden. And that's the eighties technology and at that time that was fairly expensive and the cost has gone down.

The people we talked to considered the cost low to modest. The idea is that -- best expressed by there's a reasonable solution, a reasonable cost that can be implemented in a reasonable amount of time is pretty much the way this has worked.

MEMBER BANERJEE: Do you have any idea what the cost is?

MR. DENNIG: Yes.

MEMBER BANERJEE: Could they give you some idea?

MR. DENNIG: Yes. We think it's about $15 million for the filter and the appurtenances.

MEMBER BANERJEE: That's installed cost?

MR. DENNIG: Yes.

MEMBER BANERJEE: And roughly how long does it take to do it?

MR. DENNIG: The -- 2 years. It takes, what, two outages. And you can do this without stopping production. You can do it in a way that doesn't impact production and tie it in during an outage.

MEMBER SIEBER: And this is big enough to actually perform its function?

MR. DENNIG: Everybody uses 1 percent license power as the beginning point of the size and then the things about how much fission product loading and so on and so forth. Those are worked out in designing a system for a specific customer.

CHAIR SCHULTZ: Bob, it would be a two-outage schedule following design?

MR. DENNIG: Yes. Having the design in hand from -- between `86 and `88 Sweden installed MVSS's on all of their plants. On 10 units.

MR. MONNINGER: So that would be the foreign experience. Now, if the NRC was or wasn't to do something doesn't necessarily mean that that would be the schedule here.

CHAIR SCHULTZ: I understand. Thank you.

MEMBER BLEY: Bob, when you said the Barseback filter was obsolete shortly after it was installed, commercially obsolete or functionally obsolete?

MR. DENNIG: Both. Thank you.

MEMBER BLEY: How far functionally

obsolete?

MR. DENNIG: It was designed and tested to achieve 1,000 I think was the spec for that, and it could -- I'm sure it could continue to achieve that. It was in large part that size for heat capacity considerations.

MEMBER BANERJEE: Was this that gravel bed or something?

MR. DENNIG: Yes. This is just a huge, huge, huge, huge building of gravel.

MEMBER BLEY: You didn't finish saying --

MR. DENNIG: Oh, it was just too expensive and too large.

MEMBER BLEY: It would still do --

MR. DENNIG: Oh, it would still perform its function.

MEMBER BLEY: It was functionally obsolete, it was just -- it was commercial.

MR. DENNIG: Oh, no. Okay, yes. There were better solutions.

MEMBER BLEY: Fair enough.

MEMBER REMPE: In addition to subsequent filter -- or replacement filter costs, are there like testing costs? Like when we have a HEPA filtration system we do testing. And are those things very expensive?

MR. DENNIG: Yes. In other countries these systems are -- they're not single-failure proof but they are pretty much safety grade. They have tech specs and they are tested periodically and we do talk to the owners and operators about that subject. And it's -- they characterize it as minimal.

MR. MONNINGER: So, operational cost once it's put in place?

MEMBER REMPE: They actually test how good the filter is working at least with our system in the lab and I just was wondering if that cost very much.

MR. DENNIG: Oh, no, no, that's not done.

MEMBER STETKAR: They do more like valve cycling.

MR. DENNIG: Right, no, that's the way it is.

And some of the -- well, they all have chemistry, they all have iodine chemistry to one degree or another so there's testing of that. There's testing of the chemistry.

MEMBER BANERJEE: You mean they add something to the water.

MR. DENNIG: Yes.

MEMBER BANERJEE: Like thiosulfate.

MR. BETTLE: And sodium hydroxide, thiosulfate in the PSI system.

MR. DENNIG: Okay, next. As I mentioned Sweden did develop subsequent to their decision to put filters on their plants a land contamination goal. And it is related to the dose received in the first year from people returning to the site following an accident assuming poor weather conditions that concentrate the release in a small area.

And the way they term it is that they expect that with this filter they will have less than 100 square kilometers of highly contaminated property that would give somebody more than 5 rem in the first year after they return to their homes.

MEMBER CORRADINI: I guess I didn't appreciate how you said that. So maybe, can you say it again? So they developed the goal after they had the filter vent?

MR. DENNIG: They had decided to -- since the containment had to be vented and it had to be filtered that much they knew. At that point they worked out --

MEMBER CORRADINI: The effect on land contamination.

MR. DENNIG: What -- yes. What was achievable, what could be accomplished, and did that meet their needs.

MEMBER CORRADINI: Okay. And the last part, "meet their needs," means they have some sort of performance goal about land contamination?

MR. DENNIG: The Swedish have -- no, they don't have a contamination number, amount per acre or square meter or anything like that. They have this dose criterion that is going to be calculated that pertains to the dose that would return in public 1 year -- remaining in place 1 year after the accident that they won't get more than 5 rem. They will get less than 5 rem in limited areas.

MEMBER BLEY: Not to have this go on forever but I'm a little confused by that because from the way you stated it they've evacuated and now they come back at some point in time and yet we still have an area 100 kilometers square where they get over 5 rem. So what determines that time between the accident --

MEMBER CORRADINI: Less than.

MEMBER BLEY: No, he said there would be an area --

MR. DENNIG: So, there's a limited area. Yes, there are areas that you could return 100 --

MEMBER BLEY: Less than 100 kilometers --

MR. DENNIG: -- you would get less than 5 rem, yes, that's correct.

MEMBER BLEY: Over 5 rem.

MR. DENNIG: That's correct, yes. There would be limited areas --

MEMBER BLEY: Why would you put them back if --

MR. DENNIG: Well, that's -- they would --

MEMBER BLEY: What is that delta time that they use to apply that? I'm just curious.

MR. DENNIG: Oh, it's a couple of weeks.

MEMBER BLEY: So it's real fast. You're returning them back pretty fast.

MR. DENNIG: Yes.

MEMBER BLEY: Okay. After the emergency is over essentially.

MR. MONNINGER: A lot of the criteria were driven by the need for no long-term condemnation of the land. They wanted to ensure that the populations could come back.

MEMBER ARMIJO: So it's temporary, a very short period of evacuation for the bigger area and no long-term condemnation for the more contaminated area.

MR. MONNINGER: Right.

MEMBER ARMIJO: Okay.

MEMBER SIEBER: The driving nuclide for the evacuation is iodine?

MR. MONNINGER: It's not my expertise but I mean, it's all -- I think the rehabilitation is the cesium within the soil for the long term. But the actual evacuation --

MEMBER CORRADINI: I just wanted -- I had a follow-up question. Since you used Sweden as an example at least this kind of illustrates. So, just to repeat what I thought you said is they decided to do it, they did it. They estimated or computed with the effect of it that connected to their land contamination goal.

So, when this thing fails what do they calculate to be the probability of failure of this filtered vent in containment? Do they have a performance goal for that?

MR. DENNIG: One chance in 1,000 is what they said. If it was called upon to work it would be 1 time in 1,000 that it wouldn't work.

MEMBER CORRADINI: So that is part of their PSA analysis.

MR. DENNIG: Yes.

MR. MONNINGER: And they use passive rupture disk in the line with manual valve bypasses.

MR. BETTLE: Yes, yes. First 24 hours no operator intervention.

MR. DENNIG: The Swiss, and there's a paper, they have looked at with the installation of a scrubber that has the 1,000-100 combination, the effect on emergency measures and zoning and so on and so forth. And they have a system where they postulate, one, you've got your standby gas treatment system and that works and they give that 1,000 and 100. Then they've got it's worse than that, you have to go to then venting containment, controlling containment pressure. The filter gets 1,000 and 100. And then they have another scenario where that fails. And so they analyze all that stuff to help refine their evacuation strategies.

MEMBER BANERJEE: They can get -- what factor do they get on the iodine with these scrubbers?

MR. DENNIG: It's 100 is what's assumed. Again, the testing that's presented that you can get your hands on is higher than that, but as far as --

MEMBER BANERJEE: That has to assume some organic iodides.

MR. DENNIG: This is elemental iodine.

MEMBER BANERJEE: Elemental.

MR. DENNIG: Right.

MEMBER BANERJEE: What happens if there's a lot of organic iodides?

MR. DENNIG: I think that's where Paul Scherrer's approach comes in. They feel that they've taken care of the iodine question with the chemistry to a great degree.

MEMBER BANERJEE: That would be interesting to know.

MEMBER SIEBER: Could we postulate that if somebody installs a containment filtered vent and they have a severe accident and they use the vent and it actually works, is the vent and all of its appurtenances shielded sufficiently so that people can still get around the plant to do emergency work?

MR. DENNIG: Yes. All the things that would occur to you --

MEMBER SIEBER: What dose will the operators get?

MR. DENNIG: -- in terms of the practical engineering of the system have been done and implemented. The shielding, the access, how you drain the stuff out of the tank at the end.

MEMBER SIEBER: It would take a lot of shielding because you basically moved a good part of the radioactive part of the core into this filter.

MR. MONNINGER: Yes. Well, they utilize existing plant structures. You know, you have walls that are 4-feet reinforced concrete. You have -- and where it would be, let's say the pipe would run past equipment that you might want to have access to post accident, they put up shielding. So they --

MEMBER SIEBER: It would have to be massive shielding.

MR. MONNINGER: Oh, yes. And as you see on the original MVSS filter that the Swedish plants have, you know, they started out with a reinforced concrete vessel that has a liner in it so that portion of it provides the shielding. And like what Bob said, they have either the capability of the filters located high enough they can, you know, after the vent gets under control and you get containment cooling back they can either gravity-drain, open a valve and gravity-drain it back in the containment or you can pump it back. You know, they have installed pumps there behind, you know, some pretty massive lead shielding bore areas. So, they've considered the shielding needs.

MEMBER SIEBER: Thank you.

MR. DENNIG: Okay. I think I've covered the points I wanted to make on this slide. Next slide, please.

This is a preliminary rack-up of installations outside of the U.S. The green is the committed or installed, white is we're not quite sure, red is we know they're not going to. And so we're continuing to update this. We're interested in Mark I's and Mark II's but that distinction is not being made.

MEMBER CORRADINI: Maybe you said it and we just didn't ask it. So, since Canada is so close what's their regulatory basis for this?

MR. DENNIG: Okay. Back up to slide --

MEMBER CORRADINI: I mean, you don't have to -- unless you --

MR. DENNIG: I'd like to.

MEMBER CORRADINI: What I'm noting is what I remember from China is that only the heavy water reactors there are vent. That was because they essentially adopted them from the Canadian design which all their reactors are.

MR. DENNIG: Right.

MEMBER CORRADINI: But there is a regulatory difference in Canada is my memory.

MR. DENNIG: I do not know the Chinese regulatory basis.

MEMBER BANERJEE: The regulatory difference in Canada to some extent is they look at impaired emergency cooling as part of their regulatory basis.

MEMBER CORRADINI: Right.

MEMBER BANERJEE: They require it.

MEMBER CORRADINI: Essentially it's not a single-failure criterion. They actually assume failure of the --

MEMBER BANERJEE: Impairment of the --

MEMBER CORRADINI: -- core cooling.

MEMBER BANERJEE: Yes, emergency cooling. It's required.

MR. DENNIG: This is a quote that

succinctly summarizes. This is for Point Lepreau for the decision. They have installed a filtered vent outside their containment and they put in some walls to shield it. And so this is the best statement that I've found of their regulatory basis, just exactly what it says.

MEMBER BROWN: Did they actually cost $14 million?

MR. DENNIG: That is the number that I was given by the plant people.

MEMBER BANERJEE: This is a 600.

MEMBER CORRADINI: This is a CANDU 6. Is this -- I mean, just a little more detail. Is this part of the vacuum building design? Or is the newer one with a large dry containment over the --

MEMBER BANERJEE: Point Lepreau doesn't have a vacuum. Bruce and Darlington do.

MEMBER CORRADINI: So this is an add-on to their large dry.

MR. DENNIG: Yes.

MEMBER ARMIJO: Could you leave it up just a little bit more? I just want to read that last sentence.

MR. DENNIG: Well, we should provide the backup slides that got used.

MEMBER ARMIJO: Yes, if we could have the backup slides.

MEMBER CORRADINI: And last question since -- did the Canadians do a PSA, some sort of PRA in terms of the performance of this system?

MR. DENNIG: Yes.

MEMBER CORRADINI: Was it similar to what you quoted for the Swedes? Or the Swiss. I can't remember which one you said was 1 in 1,000. I guess the only reason I'm focused --

MR. DENNIG: Yes, the reason why they can say that it lines up well with SSG-3 and SSG-4 is that they did the level 2 PSA. And there are guidelines in those guidance documents that they stated that they met. I have another slide that has the numerics on it I think. But it fits in well with the criteria for large-release frequency and the severe core damage frequency based on certain plant damage states following the IAEA guidance. And so they did that study and everybody was happy with how that turned out.

MEMBER BANERJEE: Can you leave that on for just a second?

MR. DENNIG: The Canadian one?

MEMBER BANERJEE: No, no. So with China

you're saying 13 are unknown status basically.

MR. DENNIG: Yes. That number is -- I'm not quite sure where we got that number from that's up there. I have to square that with my analyst, get his laboratory to look at the Navy stuff. So we'll clean that up. But since it was not BWR we weren't particularly concerned about that aspect of it.

MEMBER BANERJEE: Okay. Thank you.

MR. DENNIG: I think that's the end of my -- thank you very much. Oh, I have one more? Oh, okay. Here's the -- this is the distillation. The boilers. And Mark I's and Mark II's, the lion's share are here in Japan. The Mark I/Mark II no FCVS decision, that is India and Mexico -- Mexico, yes. The considering line, the Mark I is Spain and that plant's shutting down in 2013. So I would guess that they're not going to. And the Mark III is still under scrutiny. And again that's Spain. But they have PWRs and they have decided to put them on PWRs.

But the regulatory authority's words were they encourage everybody to have this. And the PWRs apparently volunteered to do it. And there are two BWRs that haven't. Like I said, one of them is a Mark I that's being retired in 2013 and the other one is -- it's a Mark III. I'm sorry, Mark III.

MR. MONNINGER: So approximately 90 percent of the boilers in the world either have them or are committed to filters outside the U.S.

MEMBER ARMIJO: Could you go back to that slide 19? The large number of PWRs that are going to install them or have already installed them, those include large dry containment systems. So the issue of containment size wasn't -- really wasn't central to their decision. They just said -- could you explain why -- what their reasoning was?

MR. MONNINGER: We believe the majority of the decisions are based on land contamination, evacuation, large population zones. So that's generally the worldwide experience is based on what happens to the land and to avoid any type of long-term evacuation.

MR. DENNIG: Now, they do differentiate in the accident progression between the one and the other and the way the containment behaves. And the acknowledgment is that the large dry, it's going to be a long time and it's going to be laid over pressure. And they acknowledge all of that. Nonetheless --

MEMBER ARMIJO: They put in the same size system to handle the --

MR. DENNIG: One percent.

MEMBER ARMIJO: Yes.

MR. DENNIG: One thousand.

MR. BETTLE: Some of them require somewhat less. Because if they assume that because it's going to handle the pressure for awhile it may be 24-48 hours before you need the vent. So they could have it sized for like one-half a percent. So some of them are designed for lesser.

MEMBER SHACK: And the French ones wouldn't be Venturi filters, right?

MR. BETTLE: The French are the sandbed.

MEMBER SHACK: They will be.

MR. BETTLE: They will be.

MR. DENNIG: They will be.

MEMBER SHACK: They're changing them?

MR. DENNIG: Yes. For a long time we've been told that they were swapping out and going to a scrubber system for a number of reasons. One of the reasons is that the sandbeds are on tops of buildings and are not seismic. So they're going to have seismic scrubbers installed.

And I think EdF. EdF is putting --

they're putting a scrubber on the English plant, on -- Sizewell.

MR. MONNINGER: So currently the staff, our assessment is just limited to the Mark I's and Mark II's. So once we come up with our recommendations, whether it's no action or whether it's something else, following that we would look at other designs.

And right now we believe the focus should be on the Mark I's and II's predominantly due to the regulatory technical issues associated with the Mark I and II containments.

MEMBER ARMIJO: But if the driver is land contamination it really doesn't really matter whether it's Mark I or BWR.

MR. MONNINGER: It could depend. It could depend upon your decision, and the releases, and the frequency of the releases and the vulnerabilities in the particular containment designs.

You know, we are -- the Commission may decide wherever and whatever basis the Commission would like to decide, up or down, left or right, but the staff is looking at the technical aspects of the design of the Mark I's and II's and how that plays into potential offsite releases, et cetera. So we believe there are technical issues associated with the Mark I's and Mark II's and you could potentially differentiate them from the rest of the fleet.

MR. DENNIG: There is a history of concern especially about the Mark I's that led to venting. And so the obvious question is, okay, how about, you know, what do you want to do with retaining fission products. And this, the technology has advanced in the last 20-25 years to the extent that you'll hear. And so it's time to, you know, revisit that decision.

As I said, when it was first made here the focus was on concepts that involved large sandbeds, underground large sandbeds. And to my knowledge we never did any particular research on Venturi scrubbing. Although it was mentioned a couple of times I'm not aware of anything that we've done.

We participated in the ACE program testing and there were Venturi scrubbers tested there, but the vendors brought those in and --

MEMBER BANERJEE: Hyped them. Did they hype them up?

MR. DENNIG: Oh, of course. Of course.

Sure.

MEMBER BANERJEE: That's really the problem we face.

MR. DENNIG: Right, well sure.

MR. MONNINGER: It's not just the vendors. I mean, any presentations we get from, you know, not just the vendor filters but any presentations. And we have to do the technical question. Again, they've got to back it up with the data and if they can't back it up --

MEMBER BANERJEE: Look at them with a very cold eye I think, a lot of these claims.

MEMBER POWERS: That's strange, isn't it?

MEMBER SIEBER: In the --

MEMBER POWERS: Well, let me interrupt Jack to just reemphasize this. As far as I know I have never seen a detailed wet Venturi scrubber technology analyzed in a nuclear context. There have been studies in connection with conventional power plant dust removal things. But I've never seen one in a nuclear context. That, you know, I would say is at -- real academic study. The best was done by the Swedes at SKI.

MEMBER SIEBER: I've not heard of any

modification of emergency planning tactics or organization or warning devices or anything else associated with whether you have a filtered vent system. That will continue to be the case, right? You'll still evacuate even though --

MR. DENNIG: Oh yes. Yes. That goes over to the local authorities and whatever federal authority oversees that process and that goes on.

MEMBER SIEBER: Right. Okay.

MR. BETTLE: They don't take the position that, hey, we have filters so there's no need to evacuate.

MEMBER SIEBER: Right.

MR. BETTLE: They're still going to all evacuate.

MR. MONNINGER: But the Commission could at any time reopen it. And there are other EP issues associated with Tier 3. There's the issue with expanded use of KI. There's also an issue out there with expanded EPZ.

So when you look at some of these issues and we've had discussions back in the past about how could a filtered vent or severe accident capable vent help address hydrogen issues. Could a filtered vent potentially help address these other issues out there? Potential EP issues.

MEMBER SIEBER: I think that it needs to deal with the hydrogen issue to some extent, at least be able to withstand it.

MR. DENNIG: Right. And what we've been talking about has been designed to -- with the hydrogen threat in mind. And in cases where the containment is inerted then the system or filter system is inerted prior to operation.

MEMBER SIEBER: Okay.

CHAIR SCHULTZ: I'd like to move to the next presentation. Thank you, Bob, for yours.

We are behind our advertised schedule by about 20 minutes. I'm not encouraging that we complete the next presentation in a very short time, but rather just draw attention to that. We will have an opportunity to address the issues that I'm sure continue to be on everyone's mind in subsequent presentations and discussions.

Jerry, why don't you proceed.

MR. BETTLE: Okay. Yes, my name is Jerome Bettle. I want to continue on. There's a section there titled "Filtered Containment Vent Systems in Severe Accident Management."

Just to get back to a little bit of the

nuts and bolts out at the power plants, we took a look at some of the plant procedures, the emergency operating procedures, severe accident management guides and the extreme damage mitigation guides.

After 9/11 the order EA-02-6 for the interim compensation measures had a Section B.5.b discussed injection into the reactor pressure vessel and drywell. The follow-on in 10 C.F.R. 50.54(hh)(2) puts at a high level, made a requirement and then there was endorsement of some NEI document.

And more recently along with the order for the reliable hardened vent was the EA-12-049 order for mitigating strategies which also included a requirement for injection capability.

Nothing in our discussions so far have said that we didn't think that water injection into the drywell into containment wasn't needed as a companion severe accident mitigation action, that somehow just venting alone was going to save the day.

Most of the procedures, they started out on venting. A lot of this is from the emergency operating procedures. There's some level of assumption that standby gas treatment is going to work. You're going to vent out, and the first line is you go out through your normal vent purge pathway to the standby gas treatment filtration system, and they'll operate. Since that's not rated for much of a pressure, containment pressure, it has to be like 1 to 2 pounds or less.

The other pathways that they then drop down to, some plants maintain a line out for depressurizing from integrated leak rate tests. They say we've got a pipe we can use for that. There's a couple other pathways some plants use, but a lot of those are going to wind up basically venting into the reactor building, other than the Mark I's with a hardened vent. And in their case that would be the one that would be the first line if containment pressure was high.

Most of the venting for the design basis accidents considers for eliminating the hydrogen-oxygen mixture that might develop from radiolysis, you know, many days after a DBA LOCA.

And again with that, if you have an unfiltered vent the procedures, you know, you certainly don't want to vent out radioactive material to the environment, to the plant, to the reactor building. You know, so there's plenty of cautions along that line, but then there's others. You're not going to allow a structural failure of containment. So it's kind of a back-and-forth.

MEMBER ARMIJO: So if -- I'm trying to follow that. So if you have this vent capability, filter capability, then you are not encouraged but -- you're not discouraged from venting.

MR. BETTLE: There would be less hesitation and less discouragement from going to a vent, especially from going to a vent early. The consequences are likely to be fairly minimal.

MEMBER STETKAR: Jerry?

MR. BETTLE: Yes.

MEMBER STETKAR: Bob gave us an overview of the hardware experience looking at the foreign plants.

MR. BETTLE: Yes.

MEMBER STETKAR: Did you look at all at their experience in rewriting their severe accident mitigation guidelines, because they have them in Europe, and their emergency operating procedures to see how their philosophy preventing it, if I can call it that, has changed or will change?

MR. BETTLE: No, we didn't read into --

MEMBER STETKAR: Because that strikes

me, rather than looking at what our procedures look like today with no filtered vents and trying to divine what they might look like with a filtered vent, it would be useful to look at people who have installed them and see how their procedures are changed. Recognizing that unfortunately a lot of them were installed at the time, the ones that are installed in Europe were installed at the time when they were developing severe accident mitigation guidelines. So they're developed in parallel.

However, the plants that are now committing to install them will need to change their severe accident mitigation guidelines appropriately and one would presume that they're doing that. So that would seem to be good experience to look at to see how their philosophy is changing.

MR. DENNIG: We saw the time line at the sites. Where in conjunction with installing the filter did they revise their procedures.

MEMBER STETKAR: Right.

MR. DENNIG: But we never pulled the string on that.

MR. BETTLE: And getting that, that's an excellent suggestion. The only -- of those documents that I saw on the table while we were over in Europe weren't in English and I didn't think to ask for translated copies. So maybe that's something we can take a look at.

Going onto slide 23, the drywell -- using drywell sprays for contamination. The existing spray hose were designed for DBA purposes, pressure control and heat removal. For the BWRs Mark I's and Mark II's the original design was typically from like 2,500 to 10,000 gallons per minute for drywell spray. And even with that the estimation was DFs might not be much more than 10.

We did give some credit for the design spray scrubbing at at least one plant for when they did their alternative source term license amendment request. And pretty much they calculated down that they had to take only 50 percent of the flow rate as far as the input for the scrubbing. And from header to floor, a 61-foot drop, you know, they would only get credit for 8 feet of that because there's just so many interferences with the spray flow inside the Mark I and Mark II containments.

The portable pumps that have been discussed are in the low one hundreds. You hear that the absolute minimum would probably be about 100 gallons per minute to achieve boil-off of decay heat. Other flow rates, the one that you saw from the B.5.b stemming from that is 300 unless you can justify less. EPRI has done some study assuming a portable pump flow rate of 500 gallons per minute.

On those plants that would have headers and spray nozzles arrayed for 10,000 gallons per minute it's thought that if you're down in that 500, 300 range --

(Laughter)

MEMBER ARMIJO: The spray is not going to ignite.

MR. BETTLE: It's going to be more of a number of garden hoses coming out in containment effectively. Although it is --

MEMBER POWERS: I mean, some of the plants -- I mean, the original designs on the Mark I's had this 10,000 gallon per minute kind of flow rate and so they chose a particular nozzle.

MR. BETTLE: Right.

MEMBER POWERS: Some of the plants have gone to a nozzle that didn't give you the 10,000 gallons a minute but it ignites at very low flow rates.

MR. BETTLE: Usually for a lot of them you consider if you have even 50 percent of the design flow rate they'll still be almost, you know --

MEMBER POWERS: All of them should work at 50 percent.

MR. BETTLE: Right.

MEMBER POWERS: It's the 10 percent that's going to be --

MR. BETTLE: They're down in the 5-10 percent range.

MEMBER POWERS: They just won't be a spray. I mean, it'll be a --

MR. BETTLE: However, you know, there would be a good line for flooding inside containment because you're getting a distributed flow coming in. A lot of it's going to come down from the outside. On the Mark I's especially it's going to hit the -- a lot of it is going to drain down the outside to the floor.

It's going to help you with keeping any molten core that comes down from getting to the drywell wall. So it's an excellent entry point for the drywell injection. However, you know, we don't think that you can really take a whole lot of credit for decontaminating the atmosphere.

Slide 24. Suppression pool has been

talked about earlier. If you start out with 75 degree water and you're running down the T-quenchers, you know, in 9, 10, 12 feet of submergence in cold water you're probably getting a DF of 1,000 or better. It's going to be excellent. I think later on in our Office of Reactor Research discussion they're going to talk about DFs of 100 to 300.

However, when the core comes out the flow is going to be down the downcomer pipes. And there's typically 80 to 100 of those and 20-24 inches of diameter so it's a very large area. The injection of the water might be 4 or 5 feet. Then if you flood up, you know, you might get 8 or 10 feet before you have to transfer to the drywell vent. In that case if the water has come up to about saturation your DFs with the downcomers is probably no more than 10 either.

MEMBER POWERS: That's the decontamination that you get in the pool itself?

MR. BETTLE: Yes. It's coming through the pool.

MEMBER POWERS: When we looked at this we got a lot of decontamination. When you come down those big downcomer pipes the bubble comes out and detaches and does its thing.

MR. BETTLE: Right.

MEMBER POWERS: The water surges back up. And we got a lot of decontamination actually in the pipe itself. You do this water surging back and forth. I don't know that any of the codes actually take account of that.

MR. BETTLE: Yes, that's probably some element of uncertainty.

MEMBER POWERS: Well, you know, just how you calculate it is kind of interesting. But it's a classic moving boundary problem.

MR. BETTLE: Right.

MEMBER POWERS: Flow's coming down, water's coming up and it's kind of a surging flow. And you know, the DFs you're going to get are not going to be heroic but 10 is going to be a very feasible thing.

But I don't -- I don't actually know but I don't think that the SPARK code or any of those classic codes take into account that. And I know of absolutely no experimental studies of big pipes putting out bubbles and decontaminated. Everything's been for the T-quenchers. Nothing's been for, you know.

I mean even pipes like this, I don't think anybody's ever done them. I mean, the problem is one of bubble dynamics.

MR. BETTLE: T-quencher flow, those holes are generally about 1 centimeter.

MEMBER POWERS: Easy to work with.

MR. BETTLE: And you're going to get considerable velocity of the flow coming into the water whereas you're not going to get a very energetic discharge when you have the, you know, after the cores come out, coming down through all those downcomers. It's not like an initial LOCA blowdown situation.

MEMBER POWERS: It's a nice, gentle flow. But it's fairly dynamic in those pipes. And I don't know whether anybody's ever.

MR. BETTLE: Okay. Onto slide 25. EPRI has provided us some briefing. They have a report that's available on their website for public consumption that details their investigation using the computer codes they use.

They use a portable pump for flooding the drywell cavity or some flow path or the spray header. They run with 500 gallons a minute. That helps, I don't know, in terms of the spray for scrubbing effect. But that's considerably more than you would need for decay heat to boil off so it maintains -- really helps to maintain suppression pool -- cooling to give you some pool DF.

They do control containment pressure that's near the design value. It gives them fold-up, settling, plate-out. Helps out with the spray effect even though it's relatively small. If you just let it sit there and continually spray the environment that's in containment it's going to extract a lot of the aerosol.

And you also get a high velocity discharge into the suppression pool when you depressurize. They'll run 40 to 60 pounds. It gets to 60, they'll open the vent line, drop it to 40 and close the vents.

So they have to maintain let's say a good indication and more or less continuous on containment pressure and containment water level. Because at some point they have to make a swap from the wetwell vent to the drywell vent because at 500 gallons per minute you're going to flood up the -- and seal off the wetwell vent line in somewhere around 20 hours.

Slide 26. The EPRI report does mention

the fact that if you don't put water in the containment it's going to heat up and temperature is going to get up to 1,000 degrees and that's going to compromise penetrations.

They really didn't have any discussion that if you're maintaining the pressure with the spray flows that you have coming in or the flooding especially on the Mark I's up in the top of containment, it's almost the cylindrical section. Unless you have something with momentum forcing up there it seems that the heating from the residual hot stuff in the vessel is going to come out the top of the vessel and keep the top of the containment a lot hotter than down at the bottom where the water's introduced.

MEMBER POWERS: And it gets very hot up there.

MR. BETTLE: Yes. They didn't really talk about the fact of the high reliance on instrumentation procedures and the human performance. And just taking a look at what they had on the graphs of the pressure it appears that the vent valves would be cycled between 15 and 22 times in a 72-hour period that they analyzed.

So that's quite a few cycles and you

know, there's I'd say a considerable dependence on knowing exactly what the pressure and the temperature is, and fairly accurately too. So you're putting a lot of reliance on the instrumentation there to gain a substantial decontamination factor from containment.

They're showing values that if you use the regime that they assume that you can get -- the containment itself will give you an effective -- the pool and the spray will give you an effective decontamination of anywhere from one to three thousand. However, if you drop off of that regime you can quickly fall back to the low hundreds and even more so.

One other thing I didn't mention.

MEMBER POWERS: One hundred is a lot, by the way.

MR. BETTLE: Pardon?

MEMBER POWERS: One hundred is a lot.

MR. BETTLE: Yes, yes.

MR. MONNINGER: Some of that is based on the venting through the wetwell. And there is a potential concern with venting through the drywell also.

MR. BETTLE: Right. As the procedures

would say if you need to vent you vent from the wetwell, but if that's not available then you go to the drywell vent. In that case there's, you know, there's much -- that early in the event there's a lot more that's going to come out if you have to vent from the drywell.

One other thing they didn't talk about that would seem to be a potential problem. They didn't talk about inerting the vent line. If you're going to cycle the vent line it's going to have a large composition of steam most of the time. So if you close the valves it's going to start cooling off and you know, the air from outside is going to rush back in and meet with the residual hydrogen that might be in the pipes. So you may be repeatedly giving yourself a combustible atmosphere inside that pipe.

MEMBER POWERS: Do you have any ignition source?

MR. BETTLE: No you don't, but coming up near the top it doesn't take much to ignite a hydrogen mixture. Just the static charges from a flow of air will ignite them.

MEMBER BLEY: You used to get that in the offgas system.

MEMBER STETKAR: I had a melted hard hat trying to put one of them out.

MR. BETTLE: So yes, that is a possibility. There's experience with it.

In developing this paper for the Commission we're presenting a number of choices for action or options. Of course option 1 is the no-action option, the no-action action. That's to sit with the -- at least for the time being with the current order as far as reliable hardened vents, the Order EA-12-50.

The second option would be to have an increase where we -- the requirements we would have to work it so that it was fully reliable and capable for a severe accident environment.

The third option would be installing that external filter on this vent line.

And the fourth option would be a performance-based which we really haven't explored, but that would get down to more of a plant-by-plant evaluation.

Slide 28. Option 2, severe accident capable vent. Some of the considerations there is higher temperatures and pressures, especially if you're going to have to vent off the drywell. The temperatures up there could be considerably higher than let's say containment design pressures.

If you're coming out -- a lot of these hardened vents for the Mark I's tapped off -- one of the inboard vent purge line valves. Typically they have soft seats. I don't know what the containment temperatures might be coming out of that line, whether they would be suitable. You'd have to make some changes in that hardware.

Again, the hydrogen issue that I was talking about earlier, that you'd have to have -- if you just open a vent and left it open, and you've got the heat source in there and stuff's coming out is there's a constant push going out that pipe. So you're not going to have air and oxygen coming back in that's going to maintain it inerted.

You know, whether it's your, you know, hydrogen or carbon monoxide, as long as there's just steam in there with it and no oxygen it's not a problem. And when you vent it out the venting clear of any building or any restriction to expansion you'll have a small zone of combustible gas. You know, you could have a flare going on there but it's not going to impact anything.

Also, the shielding that you would need

in the current order, it's not anticipating a significant source term or radioactivity coming off this -- the vent line when it's in service. So, you know, I guess it could essentially run almost anywhere. As long as people didn't have to squeeze past it, touch it and get burned it would be okay for the current order.

If it is going to be severe it can't be going anyplace that you're going to need access to, you know, to try to mitigate the event, operator recovering equipment locally or you're going to have to put shielding up to enable that to occur.

One of the discussions about early venting is to -- after the core damage starts to occur in the vessel to vent a lot of the generated hydrogen out before the core comes out of the bottom of the vessel. That would allow you to maintain the vent closed for a considerable period of time.

And one of the things about being able to use the vent and maintain the low pressure is that whatever developing or existing leakage that you could have out of the containment into the reactor building would be minimized to keep not only the combustible gases from potentially leading to burning or explosion but also the steam environment, the contamination that would be there, the airborne makes it extremely difficult for anybody to access the building to do anything good, you know, regarding terminating the event or stabilizing the conditions inside containment.

In talking about a wetwell vent, only the existing order can specify whether there's wetwell and drywell. As long as you don't have a damaged core that means you've been able to inject water into the vessel which means that the discharge is coming out the SRVs to the pool. It's getting scrubbed. And even if you have a vent off the drywell it would come back up through the vacuum breakers and go out the vent. So you'd be getting the scrub.

In post accident of course -- or severe accident the core could be coming out of the bottom in which case if you're flooding up you're going to seal off your wetwell vent path eventually. And when you go to the drywell you don't have any -- you're going to need to have a drywell path but it's not going to -- not going to be nearly so good. So the existing order didn't really consider the venting location because drywell/wetwell doesn't really make a difference until the core comes out of the vessel.

Okay. Given the accident it's going to be very uncertain how it progresses, you know, whether you get some water injection, you slow it down. Core damage starts, you arrest it, it starts again. The suppression pool, the drywell sprays, how much injection you have there, how much subcooling you can maintain is all going to make for a high -- let's say a considerable uncertainty as to what actually is going to be able to get out of containment, or how much you're going to be able to reduce the radioactivity leaving containment.

And in consideration of where the pipes that are currently routed it may be that rerouting the pipe would turn out to be more of a concern than with the -- just having the pre-severe accident. You know, if you go out one side of the building or if you run it out through the turbine building to get to your elevated release point you may wind up just reorienting the pipe and running out a different side of the building up to the roof line.

MR. DENNIG: The point here was that it's not entirely clear that you're incrementing what you've already got from 89-16. That may not be the best engineering solution or the least expensive engineering solution.

MR. BETTLE: Okay. Option 3, the filtered vent.

MEMBER ARMIJO: Just before we leave. Now, would you have to do these same things, many of the same things from option 2 to make option 3 work?

MR. BETTLE: Yes.

MEMBER ARMIJO: So option 3 includes many of the elements in option 2.

MR. BETTLE: Yes.

MEMBER ARMIJO: Okay.

MEMBER STETKAR: In fact, the last bullet on that option 2 slide, if you decide to put a vent in that may have a bigger influence on the routing of your pipe. That's what I've seen in Europe. Just because of space for your filter or structural capability, you know, to handle the filter.

MR. BETTLE: That will dictate the layout of the vent system.

Okay, option 3. We consider that to be -- it would be a significant enhancement in severe accident containment performance. You get the capability of option 2 plus, you know, it kind of extends the containment function and you preserve the defense-in-depth.

So far in discussing with the Europeans and in looking through as much literature as we can nobody has really identified a technical or safety issue with putting filters in a vent system.

MR. DENNIG: It doesn't introduce any new accidents or problems in coping with -- as long as it doesn't interfere with the existing systems. As long as it's not intertwined in some way with the existing systems. If you do that things get a little confused. But as long as you keep those things fairly separate you can manage it.

MR. BETTLE: And for the most part the Europeans have come out of separate penetration and they keep it totally separated from any of the systems. It's essentially a stand-alone. They don't tie in with, you know, have just a valve barrier to standby gas treatment or other ventilation systems on the way out to the vent point.

If you have a filter, however much you have coming out it's going to be much smaller than without a filter. And it's been implemented in a number of countries. It's proven in the sense that nobody's come up with a reasonable way it's a bad idea. And it's certainly a technology that is available.

You can construct this with brass from a wetwell with normally closed valves. And this would be coming out to a filter. It would give you the maximum amount of belt and suspenders reduction in anything being released. It would be more conducive to early venting, reduce the stress or any delay in consideration of the potential releases.

And you can have one of the European designs, a vent line from the drywell with one branch, one with a rupture disk and the other with a normally closed valves that you can open it up.

What you see there on slide 33 is what you would have on a Mark I with this full-feature vent system coming up, both the wetwell and the drywell.

Okay, the external filter system. I guess the staff would develop some sort of a technical basis for requiring a minimum DF. There's been some discussion before, there will probably be some discussion later today. The Europeans for the most part had a requirement of a DF of 1,000 for aerosols and 100 for iodine.

We would engage all the stakeholders to

develop appropriate performance criteria for the filters if it was made a requirement. And other features that would be under consideration, if you do have a filter it makes more sense in terms of having a passive actuation through let's say an open or exposed rupture disk.

MEMBER SKILLMAN: Jerry, what is the assumption relative to the fission product inventory or to, if you will, origin run for the core under consideration? How did -- 2,500 megawatt cores around 15 "B" billion curies, fission products plus actinides plus transuranics. In your earlier slides I don't think you were being slick, I think you were being accurate, but it sounded like slide 28, not too hard to put this plumbing experiences. You get any number of those curies, you've got thousands of R per hour on the interior coating of the piping, and approaching that piping is deadly.

MR. BETTLE: Yes.

MEMBER SKILLMAN: So I'm wondering on your slide 32, what is the assumption regarding the original isotopic inventory? Where do you start?

MR. MONNINGER: I think, you know, from other countries and from our internal discussions, you know, from the fission product at the end of life it would decay some. But there's a general thought that somewhere around 10 percent of the source term would then be hitting the filter.

MEMBER SKILLMAN: Would leave containment.

MR. MONNINGER: That would potentially be the expectation, 10 percent of the source term would be available to the filter and a decontamination of approximately 1,000 is ballpark of what has been considered internationally. So it's not the entire core, it's probably a release somewhere on the order of 10 percent or so. And we would look at various calculations to see the amount and quantity of core debris released to the containment, and what happens with a body of water on top of that, et cetera.

MEMBER SKILLMAN: We're talking about severe accident management.

MR. MONNINGER: Yes.

MEMBER SKILLMAN: And that suggests to me actions in maybe the 72-hour to 120-hour range, not in the 30-day to 90-day range. This is suggesting to me something that is unfolding and individuals are taking action right now. And that would say your isotopic burden is on the greater side than 10 percent, it's up in the 50 percent, 60 percent, not at the 10 percent level.

MR. MONNINGER: We have done some of the calculations in looking at what is available for release within the drywell in particular.

MR. DENNIG: I think that question will fit in well with the Research presentation on their MELCOR runs.

MEMBER CORRADINI: They've passed it down the chain.

MR. DENNIG: I mean, we can wing it here or let them answer.

MEMBER SKILLMAN: I know what it looks like when you're up close and personal and I know what those levels look like.

MR. MONNINGER: So the other thing to keep in mind is, you know, the concern potentially with the filters and the plate-out of the fission product and sources.

I think the other thing to keep in mind is without the filters they are directed to vent the exact same source term and you will have the same plate-out within these pipings. And if you don't do the venting there are also procedures for sprays and recirc and pumping from the suppression pools to the sprays.

So I think irregardless of the filters there could be considerable source terms throughout the entire reactor building. Whether it's just shine through the reactor or whether it's the filter in which they would do with the unfiltered vent, or whether it's taken recirc from the suppression pool of highly contaminated water throughout the reactor building to inject into the spray.

So you know, I think we appreciate the concern but we think there are also many other scenarios that represent that same concern.

MEMBER SKILLMAN: Thank you.

MR. FULLER: This is Ed Fuller from the Office of Research. You'll see later some discussion of not only filtering or venting I should say but also putting water on top of the core debris that might exit the vessel.

And if you look at core melt progression analyses you see that the preponderance of the fission product releases that are coming out during the period where the vent paths would actually be effective, you would pretty much have the volatile fission product inventory.

Any of the less volatile material would

be not tending to come out until you had core debris-concrete interactions. And if you had such core debris-concrete interactions the chances are pretty high that you would have bypass pathways develop and that would render the venting or filtered vents ineffective, relatively ineffective.

So in terms of the inventory that one would expect to go through the vent pathways I think it's not 10 percent of the entire fission product inventory in the core, it's a lot less than that. Granted there's still a lot of decay heat that you need to deal with, a lot of radioactive material that you would need to deal with, which suggests to me at least that you would need some sort of shields around these pipes going to the -- toward the stack or wherever.

MEMBER SKILLMAN: Thank you.

MR. BETTLE: Okay, onto option 4.

MEMBER ARMIJO: Jerry, before you leave that. Just go back. If that same system had been at Fukushima and those plants, I'm trying to think faced with the same challenge how much better off would we have been? It would have encouraged earlier venting, at least I think it would, but if the valves didn't have power, couldn't be opened.

MR. BETTLE: Then the rupture disk would relieve and --

MEMBER ARMIJO: Set the rupture disk at a low enough pressure.

MR. BETTLE: Yes. And there seems to be some variance.

MEMBER ARMIJO: It would be totally passive then.

MR. BETTLE: Yes. Anywhere from, what do you say, containment design pressure to 120-140 percent is typically what a lot of them --

MEMBER ARMIJO: Set it to zero. Anyway, you can go low pressure so it would just take care of itself.

MR. BETTLE: Yes.

MEMBER ARMIJO: And you didn't need any power.

MR. BETTLE: Right. And that's where you get into the, you know, the rupture disk opens and it just carries on for 24 hours without any operator action.

MEMBER STETKAR: I mean, if you look at the European designs they --

MEMBER ARMIJO: You don't have to do any flow or any chemistry inside that tank, or anything has to be activated?

MR. BETTLE: Not to that point. Beyond that eventually because of the heat and the decay products you're going to steam off a little bit more of that water. Initially you'll start out cool, you'll condense some of the steam coming in. The level will rise a little bit and it'll start essentially boiling off and the level will drop.

And you can size depending on how big you want that tank to be, or you can stand it to be, you get at least, typically at least 24 hours but you could go longer. You'll have separate tanks on the side that you can open a valve and replenish the water that's been steamed down and also the chemicals that were in there, kind of like recharge it. And subsequent to that time it probably will be good for several more days without further intervention.

MR. DENNIG: A general criteria is that it will be passively operable for 24 hours without active --

MEMBER STETKAR: General criteria where?

MR. DENNIG: In the foreign reactor.

MEMBER STETKAR: Not necessarily all of them. They have manually isolated, at least the designs, some of the designs I've seen they keep the rupture disk manually isolated. They have local manual mechanical reach rods such that you don't need either ac or dc power to operate the valves but they have procedures about when to un-isolate the rupture disk. Because it's not clear --

MR. DENNIG: Point Lepreau doesn't have a rupture disk.

MEMBER STETKAR: That's --

MR. DENNIG: -- running with the valves closed.

MEMBER STETKAR: But I mean you're -- the point is that they've designed the system so that they don't require electric power. They can be, you know, they're motor-operated valves but they've put long reach rods out through the shield so operators can actually get there and control the release, you know, mechanically, manually.

MR. MONNINGER: If you look what the NRC did for the ABWR, the advanced boiling water reactor, there's a rupture disk there. There also is a valve and that valve is normally open. And it's designed to be operable to be closed following severe accidents. So for what it's worth that's what we did for the ABWR.

MEMBER ARMIJO: Yes. So my question was really based, you know, don't give yourself credit for the improvements that we're trying to put in through the orders. With this system it's passive enough that it would still have worked even with all the things that didn't work at Fukushima. And I guess it's the rupture disk and you don't have to do anything actively to make the filter continue to work for the duration that's important.

MR. MONNINGER: I think the notion is if those two valves from the drywell were normally open and then it's the rupture disk then yes.

MEMBER ARMIJO: And there's no rupture disk on the wetwell vent?

MR. MONNINGER: No.

MEMBER ARMIJO: Just there.

MR. MONNINGER: Yes. But then you've got, you know, if this did rupture you would have -- you've got your vacuum breakers that go back through. You have a pathway from your suppression pool --

MEMBER ARMIJO: But you get no scrubbing in from the wetwell though.

MR. MONNINGER: Well, it would blow down through the SRVs into your suppression pool, come up and then this goes back to the vent pipe, right. Your vacuum breakers allow the air to transfer back from the suppression pool atmosphere to the drywell and then you can go out through your rupture disk.

MR. BETTLE: Until the core comes out of the bottom of the reactor.

MEMBER ARMIJO: Okay. So it would have done some good had it been at this -- something like this at Fukushima without any power would have done some good.

MEMBER STETKAR: I think, yes, mechanical reach rod depending on, you know. Incentive to vent earlier, basically, I think is the thing that it would have.

MR. MONNINGER: You could argue either way. You could argue because you hear about some of the political considerations in venting. Who knows, maybe they would have gone in and tried to close one of these valves. Who knows what they would have done? You can argue it.

MEMBER STETKAR: Well, but that's what I'm talking about in terms of the philosophy of once you install one of these things how does the basic accident management philosophy change, or does it? Because if there's an overriding political consideration that thou shalt not release a single microcurie then it doesn't make any difference because the operators will not do that.

MR. DENNIG: If you have an exposed rupture disk pretty much everybody has come to terms with the fact that that's the pre-approved relief pressure. You know, everybody knows it's going to go at that point.

MR. MONNINGER: There's also a notion that the release through the filter is more or less equivalent to what you would have from leakage through penetration seals, et cetera.

MEMBER BANERJEE: This filter is just a pool, right?

MR. BETTLE: It's a very engineered pool. That's why you have the multi-Venturi or the nozzle baffle plate, impingement plate system that's supposed to be much more effective for removing the --

MEMBER BANERJEE: But it just makes smaller bubbles.

MR. BETTLE: Yes, higher velocity smaller bubbles.

MR. MONNINGER: And tortuous pathways.

MR. DENNIG: There are two things that

happen in the Venturi as I understand it. Number one, you use a rectangular throat in the Venturi, that seems to be the best way to do things. You have multiple levels of injection in the Venturi on all sides. And what it does is -- and the other thing that's important is the relative velocity of the fluid into the gas as far as -- the idea is to have something that will under most conditions maintain that coverage of that throat while the gas is going through.

And there's also a phenomenon that is in the literature and is talked about by AREVA where there are like films that break off. It forms liquid films as opposed to a droplet for trapping particles.

And then the last thing is that in both the Paul Scherrer design and the AREVA design, the AREVA design ends in like a ram's head. It comes up and hits a surface and goes down, and in the PSI design it has a series of plates like an impactor for taking things out. So that's another part of it. So that whole regime, that whole thing, that's how it's supposed to work.

MEMBER BANERJEE: So the gas goes up this baffle pathway.

MR. BETTLE: Yes. That way it allows you to have a much more compact filter because the bubble rise, a very -- so it makes sure all the bubbles are small and they have a very tortuous path up, to wend their way up through.

MEMBER BANERJEE: And the flow comes in into a manifold with multiple Venturis on it?

MR. BETTLE: Yes.

MEMBER BANERJEE: This is an old chemical plant design then?

MR. BETTLE: Yes, yes.

MEMBER BANERJEE: Okay. I know how it -- yes. They use exactly these systems for emergency release of chemical reactors.

MEMBER CORRADINI: That's what I was going to say, it's a loss prevention design, right? Off of a reactor.

MEMBER BANERJEE: I have a picture in my book.

MR. MONNINGER: The thought would be that the staff, if this was one of the recommendations, we would not specify the particular design. You would specify the performance attributes and however the industry wanted to design or meet those performance attributes, that would be up to them to propose and demonstrate.

MEMBER BANERJEE: But you would --

MEMBER ARMIJO: Isn't there a philosophy that goes with this equipment of early venting that you would kind of push in the management guidelines? That says -- that really makes people rely on that thing.

MR. DENNIG: The virtue I guess, one way to put it is that it is not very sequence-sensitive. So whatever is happening, this is outside the containment and it will do its thing. And you don't have to worry about where you are even in terms of -- if it's passive even in terms of the pressure.

MR. MONNINGER: Regarding early venting there is a proposal in to the staff from the BWR Owners Group to explicitly look at that, to look at changes to the emergency operating procedures/the SAMGs. If you look at the current EOPs, you know, Rev 4 in the staff's evaluation, the notion of venting is at a last-ditch resort. So it's, you know, and the venting pressure shall be at the highest, highest, highest possibly ever allowed. So that is the mentality.

MEMBER ARMIJO: That's what worries me, that whole mentality with this system.

MR. MONNINGER: Right, but you can change the framework. Industry has proposed to change that framework for early venting but the filter isn't part of that currently.

MEMBER ARMIJO: Right. Okay.

MEMBER POWERS: When you think about these designs, mitigate releases during a severe accident such that we're thinking about here, do you think about a heat load on that upper head still and the failure of your seals for the upper drywell head? Or maybe more generally just the whole possibility of bypass through penetration in the containment.

MR. MONNINGER: I think you would have to. I think one of the things -- not to talk about MAAP analysis but to talk about the MAAP analysis, they would postulate the one containment failure, then the second, then the third. You know, starting with liner failure and eventually the upper seals going away or penetrations, et cetera.

Dependent upon how you operated this thing if it was open and kept open your forcing function, your driving pressure would essentially be limited to the head of water there versus a strategy that is keeping your containment pressure between 40 and 60 pounds, you know, and the degradation of the seals associated with that versus the head of water there. I think it would be different.

MEMBER POWERS: I mean, I personally have no idea what actually fails in the seals, whether it's a dose embrittlement or actual squeezing amount of pressure, something like that. It strikes me that that's the tradeoff that you -- you kind of have a baseline release going on because of those seals and the penetrations. Mark I's tend to be very good. Mark III's tend to be very horrible and things like that on those baseline releases.

But I mean, Sam asked you how this was going to behave in the Fukushima accident. I think the seal would become problematic and in looking at the Fukushima accidents really had this. That's one of the great auxiliary benefits of drywell sprays is that you can get cooling up in there and push things down and stuff like that.

MR. DENNIG: That's one of the reasons to have the drywell vent is because it's the advantageous location to remove heat from the upper vent area.

MEMBER POWERS: Yes, that's true.

MR. BETTLE: Once you're venting through the top head of containment, you know, you're not at the absolute best position for taking heat out of containment. But you know, you could have points that are at least mid or above the fuel zone in the reactor. So you take that kind of heat off of a lot of the penetrations in there. Maybe not the head itself. You know, it would help, it would seem to help.

Slide 34. Option 4, performance-based. This would be each plant performing a site-specific cost-benefit analysis. You come up with a defined source term for the plant and a defined decontamination factor and go through what their PRA and event frequencies are and DF. It would all be custom for each individual plant.

MEMBER CORRADINI: Would you have requirements in terms of a diversity of approach? In other words, the one you -- I was reading these kind of ahead of time and the one you highlighted was the third one. Would you consider then they would have to define a large release and then also some sort of frequency with it and a diverse approach to handle it? I'm trying to understand what this means.

MR. DENNIG: I think it would start from the presumption of core damage. You wouldn't --

MEMBER CORRADINI: So given the presumption of core damage. Then it would be what? A definition of a large release over a cumulative time period and some sort of reliability that -- or some sort of demand you don't exceed it with some frequency?

MR. MONNINGER: I don't think we've fully worked it out. One of the potential outcomes of this is, you know, if this was stylized according to our current framework would you really come up with any different result than your SAMA analysis. I mean, essentially this is what your SAMA analysis does, it look at the plant risk profiles. You cost it out, it's site-specific, et cetera. Would this result in anything different unless we went in with some new type of deterministic criteria?

MEMBER CORRADINI: Like it must be diverse.

MR. MONNINGER: Right. Or you know, some criteria for defense-in-depth, some different type of criteria for containment performance.

MEMBER CORRADINI: So, can I say it differently? What you're saying is this sounds good but once you defined it it would probably be status quo. It would essentially degenerate to option 1. That's what I heard you just say.

MR. MONNINGER: If you follow the current regulatory process it could easily turn into SAMA analysis option 1 status quo.

MEMBER CORRADINI: Should it be site-dependent?

MR. MONNINGER: Well, the SAMA is site-dependent to the extent that they do it for the wind patterns, the people that live there, the source terms, the release pathways, et cetera. You know, we could potentially in this approach come up with different types of metrics, et cetera, but then we would be in that type of battle also.

MR. DENNIG: And this would be, in talking about the EPRI insights report this would be the place where you would entertain those sorts of things as part of the mix.

MEMBER REMPE: You're thinking of using the existing cost-benefit criteria? Are you thinking of another one?

MR. MONNINGER: We use -- and this will be a good discussion for this afternoon, the reg analysis. We do use our existing tools, you know.

So until we change the tools we crank it through and what comes out comes out. And it's not acceptable to be using it in other regulatory applications. If we think a different regulatory analysis approach is needed here we should be using that in the other approaches. So we would have to use our current approaches. Unless we justify and the Commission approves some other approach.

MR. DENNIG: But the variable is the -- what's the term. The other considerations that --

MR. MONNINGER: Qualitative arguments?

MR. DENNIG: Yes, that the Commission has directed that you consider when doing the cost-benefit analysis.

MR. MONNINGER: When we do our regulatory analysis.

MR. DENNIG: Regulatory analysis.

MR. MONNINGER: And that will be discussed this afternoon too, the qualitative part.

MEMBER STETKAR: Is there some subtlety in option 4 that I'm missing? This strictly says performance-based. I noticed it doesn't say risk-informed performance-based. And you were careful to say that you would presume core damage. So you're presuming that option 4 has no information about frequency or --

MEMBER SHACK: Makes the cost-benefit analysis a lot easier.

MR. MONNINGER: I don't think we've gone that far in our thinking on it. I think we would be challenged, you know, to do that.

MEMBER POWERS: It looks to me like the DFs selected for the foreign filtered vent systems, 1,000 for the aerosol and 100 for the iodine is based on what you can do reasonably in engineering the system. When you say plant meets a defined DF or a defined source term is that what you're talking about or would you be looking for something more closely tied to the Part 100 kinds of thinking?

MR. MONNINGER: You know, and I wouldn't say the group has consensus because we haven't had that level of discussions. I don't think we would necessarily tie it to Part 100. I think it would be more on the lines of what is traditionally looked at in PRAs risk assessments, severe accidents.

MR. DENNIG: The underlying idea is to set up a target, talk about how you're going to meet it. That's the basic concept. And we start with specifying a decontamination factor and that would apply to the -- presumably to the whole plant. And the filter --

MEMBER POWERS: I mean, that aspect of it I like.

MR. DENNIG: And we go from that.

MEMBER POWERS: I'm including applying it -- treating the plant as kind of a black box and saying this is the DF I want. I would say that's more consistent with the Part 100 philosophy than coming in and saying your filter has to get a DF of 1,000 on aerosols. Because you get into --

MR. DENNIG: Yes.

MEMBER POWERS: You put a constraint on design and you disallow certain -- or disincentivize certain activities that might be beneficial when you do that.

I love Part 100 because it is really a technology-neutral kind of regulation when the regulators played the role of here's what I want. I don't care how you get it, give me this. And in the sense that you can get that idea. And certainly saying I want a DF of this much for the plant and I don't care what the individual parts are is consistent with that.

MR. MONNINGER: So one of the thoughts, if we've done 90 percent of the work in looking at options 2 and 3, you know, it would be more on the order of 10 percent for option 4. One of the thoughts was it would be some type of rulemaking activity, maybe some type of ANPR or proposed rulemaking.

It's sort of a different type track that we would pursue option 4 versus -- and you'll see it within the reg analysis. We haven't tried to cost out option 4 at all. It's if you want to do something different, you're not comfortable today making a decision for options 2 and 3, should we do something at maybe a slower pace through rulemaking and get, you know, consider plant-specific factors. So it's not as comparable to options 2 or 3.

The thought is if options 2 or 3 were potentially supported by the staff or the Commission they would more likely be orders. Option 4 would, if it was supported by the staff or the Commission be more in line of a rulemaking.

MEMBER POWERS: Always in these filter systems, I mean just knowing how people design filter systems they get very focused on the system itself and they forget that there are many slips `twixt the release and the outlet there. And there are lots of potentials for bypassing filter systems and things like that. So a more comprehensive examination embodied in a performance-based approach always looks much more attractive to me than looking at a pipe and a filter no matter how good I think that filter is.

MR. DENNIG: Again, without introducing some additional factor the subject of putting filters on plants has come up before. And if the technology and the cost doesn't factor into things then we're doing, you know, we're back at looking at concepts of internal mechanisms and external mechanisms. So we're kind of back there in looking at the whole picture.

MR. BETTLE: And when you look at the plant-specific, you know, there's some other factors. Is this something that's just a one-time shot evaluation or over time if you're doubling the population or the value of the property around the plant, or you add another operating unit there, you know, and you have to assume simultaneous severe accidents is that going to change what you need to have? Put a second unit there, that puts you over the line and you've got to put filters on both of them. Those would be some of the stuff that I think you'd have to consider with a site-specific analysis.

Okay. Slide 35. Office of Reactor Research has performed some modeling. We need to look at some representative cases to see what kind of releases we get to evaluate the options. They did a number of cases. We didn't look to explore, you know, worst case or best case, just that we had some representative scenarios. And also there were some additional cases run as sensitivity to get a little bit better understanding of what we were getting for results.

We used MELCOR calculations. These were used in SOARCA and they also have done some modeling of the Fukushima situation to see how well it would track with what the MELCOR would give you.

And then they did the MACCS calculations for venting with and without a filter for what you'd get offsite. So I guess at that point the Office of Reactor Research will continue.

CHAIR SCHULTZ: Thank you, Jerry. At this time I'm going to call a break for the meeting. I would like to warn everyone that we are well over schedule.

We had scheduled a long lunch break to accommodate a separate meeting that the committee has. I'm going to see if we can shorten up that lunch break so that we can accommodate more for the presentations in the next session because I don't want to take away time that we've scheduled for that.

Can we just hold the slide that we just presented on the screen rather than this one during the break? Because this is an excellent introduction to the next phase.

With that I'll call a break. I'm going to make the break until 10 past, 15 minutes because it's been a long morning already but please be back. We will start at 10 past 11.

(Whereupon, the foregoing matter went off the record at 10:53 a.m. and went back on the record at 11:11 a.m.)

CHAIR SCHULTZ: I'm calling the meeting back to session. I did want to make one comment. For the benefit of the recorder and for the benefit of an accurate transcript the recorder would like to let everyone know that we're having trouble with people talking over each other and hearing that properly so it can be properly transcribed. So please pay attention to that over the next few hours. We have many people in the room and in this room voices carry and can conflict the transcript. So please pay attention to that for the afternoon, the rest of the morning and the afternoon.

With that I'll turn the discussion. Bob, why don't you introduce this next session and then Sud can begin.

MR. FRETZ: We have Sud Basu from the Office of Research and Allen Notafrancesco. They are to talk about the MELCOR analysis they performed.

Again, as the slide shows or at least what we tried to depict with the slide was the MELCOR analysis was used to help us I guess begin the process of informing our regulatory analysis. And so Sud would like to talk about some of the cases that they ran to help us in that aspect.

CHAIR SCHULTZ: Thank you. Next slide.

MR. BASU: Thank you, Bob, and thank you, Mr. Chairman. In fact, if we can go back to the slide that was projected I can cut back on a couple of slides after that. That'll work, right?

So I want to show you MELCOR calculations that were informed by SOARCA insight and Fukushima insight. And these calculations involve a number of prevention and mitigation features and measures, a combination thereof that are actually involving the options, the four options that you had seen earlier in previous slides.

So with that I'm basically going to skip to the -- skip to slide 38, talk about what analyses we have performed and what -- a subset of which we're going to show you here.

So filtered vent MELCOR analyses. We looked at accident sequences that were informed by SOARCA and Fukushima. Specifically we looked at the long-term station blackout.

By the way, most of these slides are repeat slides from the September 5th meeting so I'm going to go through as quickly as I can. And if you have questions by all means interrupt me and I will respond.

MEMBER SHACK: Isn't the 16-hour battery life a little generous?

MR. BASU: Yes, it might be thought that way. Now, if you look at the SOARCA we used very conservatively 4 hours battery life. In Peach Bottom though the battery emission time is actually 8 hours.

We have reason to believe that with the new mitigation measures and severe accident measures that may be coming out it may be amenable to a longer battery life, battery emission time. And 16 hours was picked by us as the best case but we showed you in the September 5th meeting that the RCIC sensitivity with 4 hours and 8 hours really, you know, does not change the overall bottom line of our calculation and insights therein.

MR. MONNINGER: This is John Monninger. Maybe I could throw something in.

One of the things we are looking at is the timing and what is necessarily more bounding. Is it a shorter RCIC time or is it a longer RCIC time? Or is it a longer time to core damage?

You know, one of the thoughts is if the time to core damage, core ex vessel, et cetera, is earlier the suppression pool maybe isn't at as high of a temperature versus, you know, putting until you drain the RWST and then you have 12 hours of decay heat into the suppression pool and you have less scrubbing by the time it hits it.

Other issues that impact for the long term are the longer term your transient is out you also have the potential that you have added more and more water to your suppression pool. And as the level goes up eventually you lose that wetwell venting capacity. So it's not quite clear in terms of looking at filtered vents, in terms of looking at the potential impact on the environment or land contamination whether it's better or worse to look at early severe accident or a later severe accident.

MR. BASU: So we kind of bounded within a range from 4 hours to 16 hours. We looked at that. That's in terms of the battery time of the RCIC.

We did look into other sensitivities like the flow rate and timing and the wetwell versus drywell. In fact, two cases that I'm going to show you this time, they were not elaborated in the last presentations of the drywell venting cases.

So, going into 39, giving you the punch line. And I'll sort of show you some thoughts to support these. Basically what it says is the water on the drywell floor is needed to prevent liner melt-through.

This is not a new finding. We have actually concluded this back in the early nineties in connection with the liner melt-through failure or liner melt-through study. The MELCOR calculations that we have presented and are going to present here basically confirms this, that you need water on the drywell floor to prevent liner melt-through.

And incidentally if you have water on the floor it does scrub the fission products and reduces the drywell temperature at the same time. So there is some beneficial effect of that.

Venting on the other hand, this is the other mitigation measure if you will. It prevents overpressurization failure. And we're making a statement here. And you'll see later on why this is -- wetwell venting is preferable to drywell venting. Wetwell venting of course gets the benefit of full scrubbing whereas the drywell venting doesn't. So that way it is more preferable.

However, you need a combination of both. If you do not have venting you are going to then -- that's going to result in overpressure failure. If you do not have water on the drywell floor it's going to lead to melt-through. So you need a combination of both and that's what basically we concluded through our analysis.

So the nodalization, the MELCOR nodalization that we have and you have seen this as well, it comes from the Peach Bottom SOARCA study. There's nothing new there. If you look at the containment nodalization that shows you the various flow paths, particularly for venting through drywell and through wetwell.

I think there was a question in the last session about what if we have different nodalization and particularly in the reactor building nodalization. If you look at the reactor building nodalization these are high volumes so, you know, I'm really not sure where the nodalization is going to affect the overall outcome in an appreciable way.

So looking at the -- going to slide 41, looking at the results. Again, these were shown in the previous meeting. There's nothing new there on slide 41.

I had an IOU from the last meeting about why the venting cases are leading to early reactor pressure vessel failure. And if you look at also the hydrogen production in the next slide -- not the next slide, slide 43 -- you'll see early venting cases are producing also high quantity of hydrogen.

And these are related. What's happening with the early venting, you are actually decreasing the drywell pressure and that's going to impact the accident progression in the vessel to increase steaming. That's going to then lead to clad oxidation and hydrogen production, higher melt temperature and consequently the higher the vessel temperature leading to earlier failure. So that's --

MEMBER CORRADINI: So that's a detail that's important. Just so understand. So, the communication between -- in the calculation, the communication between the vessel and the drywell is such that because of the venting you're lowering the pressure.

So what's the flow path -- what is the flow path out of the vessel? What is the -- I don't want to say assumed. What is the model flow path between the vessel and the drywell in that case? It's not through the SRVs. It is? It is the SRV?

MR. BASU: Yes, that's correct. Okay, so the two cases that I want to spend a little more time on, these are the two cases that I did not elaborate on in the last presentation, last meeting, case 12 and case 13. Both are drywell venting cases. Case 12 is only drywell venting whereas case 13 is the drywell venting with drywell spray.

The way we did these two calculations in the MELCOR space is we actually disabled the SRV's stack-open mechanisms so as not to route the flow through the wetwell vent path. So that should have led to main steam line rupture ahead of the vessel failure. And this is what you will see in the -- I'm sort of going all the way to slide -- while I don't have the slide number here printed I think it's the second plot of drywell pressure. Okay. No, next one, next one.

Okay, so you see for case 12 and 13 we're getting the main steam line creep rupture ahead of the vessel failure. So that's the difference between the two cases, the drywell venting cases versus the wetwell venting cases.

Now, we could have actually simulated the drywell venting cases in a manner similar to the wetwell venting cases but that would have required a much more involved workaround with MELCOR and some of the models in MELCOR.

And again, at the end it would not have made any difference in terms of the overall findings. So, if I can go to the next slide that shows you the -- and I'm talking cesium release as just an indicator.

MEMBER CORRADINI: Sud, why don't I just stop you because I'm trying to take your four tables with your two figures. So can I just say it back to you? I'm still back on your first observation, or the question that was asked of you and you're explaining which is hydrogen production goes up and vessel failure time goes down.

MR. BASU: A couple of hours.

MEMBER CORRADINI: A bit.

MR. BASU: Yes.

MEMBER CORRADINI: Yes. And they -- hydrogen production is connected because you're getting more steam flow out of the core through the hot cladding. And one more time, the vessel -- I'm still trying to understand why you get more steam flow but that's my problem at this point.

And then the vessel failure is due to what? You said it and I didn't catch it, I apologize. The change --

MR. BASU: Early vessel failure --

MEMBER CORRADINI: Yes, earlier.

MR. BASU: -- is due to increased oxidation of cladding raising the melt temperature higher.

MEMBER CORRADINI: And then when it slumps it slumps --

MR. BASU: It slumps and because the vessel head failure is, you know, the creep rupture failure so it depends on the temperature and pressure.

MEMBER CORRADINI: Right. Thank you.

MEMBER REMPE: Why don't you explain about the steam flow, that there's more steam flow going through. What you said was why you have more oxidation.

MR. BASU: Yes.

MEMBER REMPE: Could you -- is there -- is the pressure in the vessel still at full pressure because you just are lifting the relief valve, right?

MR. BASU: Yes.

MEMBER REMPE: So why is it --

MR. BASU: But it's the delta between the drywell and the vessel.

MEMBER CORRADINI: But isn't it choke flow? So it wouldn't matter what the downstream pressure is for the flow rate.

MR. BASU: Why is it choke flow?

MEMBER CORRADINI: Well, because we're at very high pressures inside the reactor vessel and we're only about tens of psi.

MR. BASU: But you're tightly coupled.

MEMBER CORRADINI: Well, that's what I was trying to get at. I was trying to understand why they're tightly coupled versus I would think they were uncoupled.

MR. BASU: In the Mark I configuration your containment is tightly coupled with your vessel, SRVs and others.

MEMBER CORRADINI: But we're still at what pressure is inside the vessel. Very high pressures, yes?

MR. BASU: It's at high pressure, yes.

MEMBER CORRADINI: So then it shouldn't be affected by the downstream pressure. We're around 1,000 psi in the vessel and only less than 100 psi in --

MR. BASU: In the drywell.

MEMBER CORRADINI: Right. That's above a choke flow limit so it should be just the upstream pressures determining the flow rate. That's what I'm -- what I guess I'm asking is are the SRVs -- maybe I should ask the question. Are the SRVs opening more frequently when you're venting than when you're not venting?

MR. BASU: If SRV stack-open mechanism is disabled.

MEMBER CORRADINI: So they're always opening and closing, opening and closing. Right, I'll think about it some more. Thank you.

MEMBER ARMIJO: Sud, just before you -- could you go back to 44, slide 44?

MR. BASU: Forty-four, yes.

MEMBER ARMIJO: I'm trying to understand. The case 15 is --

MR. BASU: Is a drywell spray, wetwell venting.

MEMBER ARMIJO: Right and RCIC. So that's about the best you can do, right? You're doing everything right. You're spraying your wetwell vent and everything.

Then case 14 you don't vent at all.

MR. BASU: Right.

MEMBER ARMIJO: But the head fails, or the head flange fails. But yet you get much more iodine release --

MR. BASU: And cesium release.

MEMBER ARMIJO: -- in the case 15. Am I reading this wrong?

MR. BASU: Yes, and the question came up.

MEMBER ARMIJO: Why is that? And the benefit from cesium isn't that much better with a wetwell vent.

MR. BASU: No.

MEMBER ARMIJO: A factor of 3.

MR. BASU: So what's happening is remember the spray is coming on at 24 hours whereas the head flange is opening before that. So, about an hour or so before that in the case of --

MEMBER ARMIJO: So, but my question is why don't we get a lot more release, both cesium and iodine, in case 14 than in case 15.

MR. BASU: Okay, so if you go back to slide 42. So for case 14 you do not have any venting, correct?

MEMBER ARMIJO: Right.

MR. BASU: So, the head flange is going to open up at about 26 hours. Right?

MEMBER ARMIJO: But it's still bottled up.

MR. BASU: Yes, it's bottled up. And you're getting a couple of hours' of benefit of drywell spray there. Whereas in case 15 you are actually opening the vent an hour before the drywell spray is coming on. So you're not having the benefit of any scrubbing for about an hour.

MEMBER ARMIJO: That may be true but it sure does not satisfy. Okay, I understand what you're saying.

MR. BASU: Okay? So if I can get the cesium release to environment plot. Next one. So these are the cesium release and you have seen these. After 48 hours. And basically what it says there, if you have a case where there's no venting, no spray and that's case 2 with just RCIC it is going to lead to liner melt-through and sort of leading to pretty high cesium release to environment, fairly high in relative terms, relative to the other cases that are shown there. But it is still on the order of, you know, between 1.2 to 1.4 percent.

CHAIR SCHULTZ: So Sud, did you -- you're not presenting case 13 here.

MR. BASU: No, that's the next slide.

CHAIR SCHULTZ: Okay. I'll wait. Thank you.

MR. BASU: So we want to compress now this here with the next slide.

MEMBER CORRADINI: Before you do that.

MR. BASU: Yes.

MEMBER CORRADINI: I'm sorry. So, was this what Sam was asking? Maybe I was still on my first question. So, for the figure you have up there the purple is case 14 where I don't have a drywell vent and yet the cesium release is low. Is that what you were asking, Sam?

MEMBER ARMIJO: Yes, I didn't understand.

MEMBER CORRADINI: I guess I'm slow to pick up your question. I'm still scratching my head on that one.

MEMBER ARMIJO: It may be true but it sure isn't satisfying that the lowest release is when you don't --

MEMBER CORRADINI: Is when it's bottled up.

MEMBER ARMIJO: Yes, when it's bottled up and you're putting the containment at risk. The spray is helping.

MEMBER CORRADINI: But -- I agree with you. But just since Dana is thinking what I was thinking, I was comparing the purple guy to there -- where the hell is he.

MEMBER ARMIJO: To the best case is black.

MEMBER CORRADINI: To the case 7 which is a wetwell vent and spray in it.

MEMBER ARMIJO: Yes.

MEMBER CORRADINI: Is 7 the black?

MEMBER ARMIJO: Seven is case --

MR. BASU: Fourteen.

MEMBER CORRADINI: No, that's the drywell vent. I'm looking at -- where I'm going with this is in my mind the optimal case of all would be eventually that I would vent through the wetwell and I'd try to moisten up the drywell which is essentially case --

MR. BASU: Fifteen.

MEMBER SHACK: Fifteen is a wetwell vent.

MEMBER CORRADINI: I read that as a drywell vent.

MR. BASU: No, no.

MEMBER CORRADINI: I'm sorry. Excuse me. I'm sorry.

MR. BASU: I apologize. The vent, when it says vent, that's wetwell vent.

MEMBER SHACK: But I think the price you're paying for that lower release is that you're pressurizing the drywell head. You're getting your drywell head failure in 14. So you know, you're trading off a release.

MEMBER CORRADINI: In 14 you're not

venting at all.

MEMBER SHACK: That's why you're losing the drywell.

MR. BASU: That's why you're losing the drywell head.

MEMBER CORRADINI: I understand. So you're making a trade here. So then, just so we're clear, so why is the black higher than the purple?

MEMBER ARMIJO: Exactly.

MEMBER STETKAR: Is there no release through the --

MEMBER ARMIJO: The drywell head has to release.

MEMBER POWERS: My understanding is that --

MEMBER CORRADINI: We're picking on you because we can't get the Sandia people in front of us.

MEMBER POWERS: My understanding is that they're venting prior to spraying for an hour.

MEMBER CORRADINI: Okay.

MEMBER BLEY: So really we need all these scenarios laid out.

MEMBER REMPE: Yes.

MEMBER STETKAR: Would anybody actually

do that if they had sprays available?

MEMBER POWERS: Would anybody allow the drywell pressure to go over the ultimate before they opened up the wetwell vent? Yes.

(Laughter)

MEMBER ARMIJO: I think it's been done.

MEMBER CORRADINI: So then, that's fine. Dana alerted me to my lack of memory.

So now I'm opening up the vent early. I have the drywell spray. And therefore the reason I'm not getting more decontamination through the wetwell is simply this pressure well by that time is saturated?

MR. BASU: No, you are actually venting without the benefit of drywell spray for about an hour.

MEMBER CORRADINI: Okay. And that's why I'm getting most of the black. Okay. Okay, I'll stop for now. Sorry.

MR. BASU: So what we want to do is contrast that with the cesium release for the two cases that are here this time to the drywell venting cases, case 12 and case 13 which is in the next --

MR. FRETZ: There's an updated slide in your packets.

MR. BASU: So I think --

MEMBER ARMIJO: That's the one in this little supplement?

MEMBER BLEY: Two updated tables.

MR. BETTLE: This is Jerry Bettle. As a point of clarification. When you show this as being a release to the environment that's outside the reactor building, right?

MR. BASU: Yes.

MR. BETTLE: So when they talk about the releases are lower, you're just loading up the reactor building with the release if it's coming out the head. Is that a correct statement?

MR. BASU: Say that again?

MR. BETTLE: That when you're showing releases to the environment that means outside the reactor building.

MR. BASU: Outside the reactor building, that's correct.

MR. BETTLE: So when you have a low release coming out of the head you'd be loading up into the reactor building and should that disintegrate later then you'll get the release at that point.

MR. BASU: Yes, but any release numbers

that you see here are releases to the environment.

MR. BETTLE: Right, which is external of the reactor building.

MR. BASU: External of the reactor building.

MEMBER STETKAR: So the reactor building is perfectly tight.

MEMBER BROWN: No, this is outside the reactor building.

MEMBER STETKAR: I'm still trying to rationalize why a release from the head to the reactor building isn't a release to the environment.

MEMBER BLEY: But what's in the model about the reactor building?

MEMBER STETKAR: That's what I thought I just heard him say.

MR. BASU: I'm saying that these releases that you see here are releases outside.

MEMBER BROWN: Outside the reactor building?

MR. BASU: Outside the reactor building.

MEMBER BROWN: So the reactor building is open now, it's busted.

MR. FRETZ: If you go back to slide 40 you can see the flow path from the seals to the control volume. Go back to slide 40. You see flow path 903, the seals there. That's the flow path through the seals to that control volume, and then it'll migrate to the other control volumes, you know, the spent fuel pool and then out the reactor building.

I think what Jerry was trying to highlight, if this is the release to the atmosphere there's a significant source term and operator action issue within the reactor building. Is that the point of?

MR. BETTLE: Yes. Plus it's going to be loading up in the reactor building --

MEMBER STETKAR: You have to come to the microphone.

MR. BETTLE: Yes, if it's leaking out into the reactor building it's going to be loading up in the reactor building. If something happens to the reactor building later that's when the release to the environment will occur. And this graph really doesn't show that.

MEMBER BROWN: So this, the graph is representative of the reactor building not being closed up.

MR. BETTLE: Exactly.

MEMBER BROWN: It's open. The roof blew off or whatever.

MR. BETTLE: It's --

MEMBER BROWN: If it's outside how does it get out?

MEMBER ARMIJO: I mean it's not tight in a typical analysis --

MEMBER BROWN: Yes, but that's got to -- you've got to have some -- I mean, if it's not tight that's different than having total access. I mean, does that model the reactor building to get it out? Is that what this does?

MEMBER POWERS: In a typical analysis when you release that high in a Mark I you typically get a DF of about 2 in the -- from what gets released to what actually escapes into the environment. Around number 2.

MEMBER BLEY: And that's sort of what they're showing.

MEMBER POWERS: And if you go lower you can get a much higher DF. But typically up around the head at that level you come up with the combination of interception and gravitational deposition release and that gives you a DF of about 2. That is about half of what your release goes to the environment.

MEMBER BLEY: So the reactor building is treated like a filter.

MEMBER POWERS: It has a very substantial leak rate and I can't remember. I mean, I don't know what they did in these calculations at all but typically I think the -- without blowing out the blowout panels which clearly happened at Unit 1 at Fukushima. If you don't blow out the blowout panels I think there's a circulation in there of about 1 volume per hour. I think. But I don't know what you did in these calculations.

MR. BASU: Well, it's the same set that was used for Peach Bottom.

MEMBER POWERS: Peach Bottom has been analyzed with every code and every approximation since 1974.

MR. BASU: We're talking about Peach Bottom --

MEMBER BLEY: At least from your results a fair amount's leaking out.

MR. BASU: For these drywell venting cases.

MEMBER BLEY: Yes.

MEMBER CORRADINI: Is there -- if I

might just ask since a bunch of us are still unfortunately buried in the weeds. Is there a backup document from Sandia that we can look at so we don't have to keep on asking this stuff?

MR. BASU: We have a document that we're --

MEMBER CORRADINI: Putting together?

MR. BASU: -- putting together.

MEMBER CORRADINI: Okay.

MR. BASU: It's not Sandia.

MEMBER REMPE: And it'll identify the different scenarios and the assumptions?

MR. BASU: That's correct.

MEMBER REMPE: And present pressure histories for the reactor.

MR. BASU: And I see we're putting together a document which will form the attachment to the SECY paper.

MEMBER CORRADINI: Okay, that's fine.

MR. BASU: That's something that we can share with you.

MEMBER REMPE: We're having another meeting, I forgot now, is it in a month or something like that? And so can we have that document or a draft of it before that meeting so that we don't go through this again?

MEMBER BLEY: Just for scheduling, we're actually writing a letter on this in November?

CHAIR SCHULTZ: At the November meeting.

MEMBER BLEY: When are we going to see this document? The November meeting?

MR. BASU: Before -- well, there is a subcommittee meeting on October 31st I believe.

MEMBER BLEY: That's like a week before.

MEMBER STETKAR: That's like 2 days before.

MEMBER BLEY: Oh, that's right, that's that week.

MR. MONNINGER: The various -- there's of course the Commission paper with a bunch of different enclosures. The status of those various documents is in different percentages. So, you know, it's probably 80-90 percent or so. Some of them are less.

To facilitate recommendation from the ACRS letter-writing we would have all the intent to give you, you know, the draft paper enclosures to support the discussions --

MEMBER BLEY: A couple of days before you want a letter.

MR. MONNINGER: Well, the question is how far in advance. The question is how far in advance.

MEMBER BLEY: How about now.

MR. MONNINGER: Well, today it's not written. The steering committee hasn't even -- you know, realistically the steering committee will have the first version of this on October 16th. And we have to reflect the views of the steering committee prior to getting it to the ACRS. Then there will be a second version that's given to the steering committee. So hopefully the intent would be to give the subcommittee the second draft that we would present to the steering committee.

We have to make sure that the staff's recommendation is supported because we're interested not only in your views on the analysis but the staff's recommendation. So we have to make sure we have a pretty firm recommendation prior to giving you that. And that, you know, is in the process of being made now and will become more and more firm as the steering committee sees our documentation and analysis.

MEMBER ARMIJO: John, I think we're talking about the Sandia report. It is not likely to change as a result of a staff recommendation. A report's a report.

MR. BASU: This is not going to be a Sandia report. It's still an NRC report.

MEMBER BLEY: But isn't there a Sandia report behind this that reports this analysis?

MR. BASU: No, there is no Sandia report. Sandia has only done the calculations. We are putting together the report.

MEMBER BLEY: What's kind of troubling is if you look at the difference between old 48 that we got electronically and new 48 that we got today there's a substantial difference which means things -- people are tweaking things in models that are in a state of flux. And for us to write a letter in November doesn't seem reasonable.

MR. MONNINGER: We did mention up front that the analysis is ongoing and we're here to present preliminary results. We could give to the subcommittee documents, you know, enclosure 1 this day, enclosure 2 that day, et cetera. And some of them are much more ripe for the ACRS review steering committee than the rest.

MR. RULAND: The staff of course is under extreme schedule pressure to deliver this.

And first of all, we're doing our best.

Secondly is to remember when I opened my opening remarks I said that the cost-benefit cases were not made. And so the purpose of the MELCOR calculations is to feed into the cost-benefit analyses.

And what I would suggest is that regardless of what the analysis shows it doesn't demonstrate that the cost-benefit hurdle was reached. So we are providing this because the Commission in fact directed us to do this. And so we're providing it and of course we need your comments.

But ultimately we didn't demonstrate that filters were cost-beneficial, that reached that level. And in fact the qualitative arguments were one of the things that we're going to talk about today. And we're going to be particularly interested in what your opinion is about our qualitative argument.

MEMBER CORRADINI: Let me ask then -- let me reverse the question we're asking then. So if you can go to slide, I don't know what slide. It's the one with cesium release to environment. After your tables. Back up.

So what I take out of this with fuzz since all of this is fuzzy -- so any line I add or subtract a factor of 2 at least -- is that, is kind of what Dana said to me to explain it which is if I don't vent it's going to leak out the top which is un-good. If I do vent at an appropriate time scale I make things better. If I spray and vent it makes things better. And that purple thing out there still gets me crazy. But except for that purple line that succession of things makes sense to me.

So then to get to Bill's -- let me ask Bill a question then. So what would have been the person-rem averted have to be to make it cost-beneficial? If 1 percent is not good enough or three-tenths of a percent is not good enough to have person-rem averted what would it have to have been to make it cost-beneficial?

MR. MONNINGER: So and we'll go through that some in the afternoon.

MEMBER CORRADINI: Okay. So you're holding off.

MR. MONNINGER: A lot more would be the potential next slide which would be the venting through the drywell. And you can see, you know, it's a -- you know, it's a factor of 100 greater, the source term through the drywell. And that is one of the concerns with regard to the current procedures do preferentially have venting through the wetwell. There is always the option there to go venting through the drywell and you're directed to vent irregardless of consequences. So if operator access was not available or random failure in the wetwell valves, et cetera.

The other scenario is, you know, what is the particular time in the accident where the suppression pool will be flooded up such that the wetwell vent is no longer available and you'd have to use the drywell. And we're not quite sure that we can bound all these various scenarios in the timing, whether the core melt is early, the suppression pool is relatively cool, you have very good scrubbing and you have plenty of room within the suppression pool. You transfer the majority of your source term to the suppression pool and then you can ultimately go to the drywell. Whereas a more bounding -- or realistic or bounding case, whatever, a later scenario where the suppression pool is more heated up, there's less scrubbing and there's the potential that early in the transit you lose the wetwell path.

So, you know, there's a significant difference in the releases between wetwell and drywell. And our analysis, even though we ran 31 cases, you know, and some of this stuff, it sort of took some of the good work that EPRI did is the timing is about 10 or 12 hours for the flooding up of the suppression pool.

Unfortunately we did not do the integrated analysis. We assume one or the other. We didn't, you know, now Monday morning we said wow, if we had to do it again we would do some type of integrated analysis over time that a certain portion of the transient goes through the wetwell vent and the rest of it goes through the drywell vent. You know, we didn't do that.

You know, it's obvious to us that maybe that would have been better to do now, but when you do look at the numbers and all the uncertainty, you know, in the end we did the analysis, we did the regulatory analysis and we think what is very important to us will be the qualitative arguments that we will develop.

We're not hanging our hat on any one scenario. We think there are scenarios that could be a combination between wetwell and drywell, and if we came in and we said well definitively we think it's going to be 19 hours and it's all going out the drywell we would be challenged. And that's -- it won't be a success path to argue this accident sequence versus that accident sequence versus that accident sequence.

MEMBER ARMIJO: But -- I'm sorry, I guess I'm really confused now. Case 3 looks pretty good. That's just case 2 with a wetwell vent and you leave the vent open. And you're saying that's not a real case? I'm talking slide 48. That one. So case 3 is the green line, lower right-hand corner, and it's just the case 2 and leaving wetwell vent open. What's wrong with that procedure?

MR. MONNINGER: There's nothing necessarily wrong with it. The question is, you know, if we were to take that accident sequence do we believe that that would represent the majority of the potential challenges to the plant.

MEMBER ARMIJO: Fair enough, that's fair enough. You don't know enough yet to say one way or the other whether that's -- but that's what I'm looking for. What's the best we can do with what we've got?

MEMBER STETKAR: Well, let me ask you,

is it a problem that you just simply don't have a decent level 2 SPAR model for the Mark I containment?

MR. MONNINGER: Right. I mean our models are --

MEMBER STETKAR: Because we've heard a lot about how much the PRAs are available and used for SAMA analyses and how much they're used. If you had an actual level 2 model you wouldn't be worried about all of this integration or what fractions or which ones might be worse or which ones. You'd have the whole spectrum.

MR. MONNINGER: And even then, some of the thought process goes when we do our PRAs, the level 1, 2 or 3's, we're very much focused on the early releases, the doses to the public. You know, there's a general mentality that the earlier the core damage occurs, the earlier release, the more challenging it will be.

MEMBER STETKAR: -- release categories.

MR. MONNINGER: It's not necessarily obvious that that would be the case for looking at the filters and environmental releases because the population has already been evacuated then. So then you're looking at when is the most challenging time for the filter, the challenging time for the containment. Is it early on or is it later? Is it these protracted Unit 2, Unit 3 scenarios that happened at Fukushima? You know, is that --

MEMBER STETKAR: You'd still have release categories.

MR. MONNINGER: So Marty Stutzke, and he did do some modeling of containment event trees and CCFPs and we will discuss that this afternoon. But it is a limitation that we do have.

CHAIR SCHULTZ: Regardless of whether you move forward with detailed evaluation of the quantitative response it certainly appears that there's some very important information with regard to drywell vent, for example, that ought to be drawn from the analyses that have been performed. Is that going to be part of the documentation and when will that portion be ready for review?

MR. MONNINGER: So, the MELCOR portion of it is written. The MACCS portion is still being written. What the staff globally thinks about those two hasn't been pulled together yet. But we know we need to provide that to the subcommittee.

CHAIR SCHULTZ: And will it include the discussion, perhaps even more elaborate that you've just provided which is the Monday morning decision-making about how one would do a better analysis to get more informed results about the performance and perhaps severe accident management approaches?

MR. MONNINGER: Yes, we definitely could weave that in there.

MEMBER BLEY: A very simple question. Is there a slide 41 that has cases 2, 3, 6 and 7? I got two slide 42's and no 41 in my package.

MEMBER CORRADINI: There is -- electronically there is a 41.

MEMBER BLEY: In the electronic one? Okay. I didn't pull that up. Let me pull that up.

CHAIR SCHULTZ: Other comments then related to this portion of the presentation? Thank you very much. I appreciate it.

MR. BASU: Thank you.

MEMBER REMPE: I guess, can we ask again about how soon we can get the report that's just the MELCOR description? I mean, we talked about that it's going to go to some sort of staff committee review, senior whatever, but if it happens the 16th are we going to get it like the 20th of the month?

MR. BASU: Okay, John?

CHAIR SCHULTZ: On our agenda we're

ready to move forward. I'm sorry.

MEMBER REMPE: But I had a question again. I didn't get a firm answer of how soon we could just get the MELCOR description report which shouldn't change too much more I would think.

MR. BASU: Joy is asking how soon after the steering committee --

MEMBER CORRADINI: Blesses it.

MR. BASU: -- blesses.

MR. MONNINGER: I think the MELCOR report is, you know, it's factual. So there isn't as much sensitivity to that. We do want to though provide a high-quality document to the ACRS. And all our documents of course are always high-quality.

(Laughter)

MR. MONNINGER: But with that said we should be able to get back, you know, by end of today or tomorrow to give you an ETA. I think it would be more of a notion of release from the particular offices than a blessing from the steering committee for the MELCOR reports.

What's more sensitive to us is how we use it, how it plays in our recommendation. You know, the draft Commission paper is much more sensitive to us.

MEMBER BLEY: I think we understand that but --

MR. MONNINGER: But we should be able -- yes.

MEMBER BLEY: -- the analysis report so we can see what's going on here.

MEMBER REMPE: And the assumptions in the case.

MEMBER BLEY: Would really be helpful.

MEMBER REMPE: They could expedite that and we could see it very close to after the 16th.

MEMBER BLEY: And if we get that too close to the end we just won't have looked at it and we'll have to say something like, well, the qualitative stuff's all right if the analysis was okay.

MEMBER REMPE: There were a lot of questions that we couldn't figure out.

MR. MONNINGER: We should be able to get an answer on the MELCOR report, you know, by today, tomorrow.

MEMBER REMPE: That would be helpful.

MR. MONNINGER: Not providing it, just when we would provide it.

MEMBER REMPE: Right, and asking them to

let you expedite that.

MR. MONNINGER: Right.

CHAIR SCHULTZ: All right. The next presentation is going to begin. This is a presentation of the MACCS analysis with Tina Ghosh and Nathan Bixler.

With regard to this it has been scheduled on the agenda as an hour. We want to maintain the afternoon schedule approximately where we had originally intended. If we need to break this we'll make that -- the presentation before and after lunch we'll make that determination as we go through. We may have to do that. I'm hoping we don't but let's see how it goes. Thank you.

MS. GHOSH: Okay, thank you. I'm Tina Ghosh. We asked Nathan Bixler to join us from Sandia. Nate is the -- kind of the MACCS lead for the NRC. In fact, I think the overall lead for MACCS at Sandia. So any code -- work and applications Nate's kind of the lead on. And if we can go to the next slide.

MEMBER POWERS: Tina, let me interrupt you and just say that I do work for Sandia Laboratories. I actually know this guy. I shall refrain from comment on his work. Which is superb, by the way.

(Laughter)

MS. GHOSH: We wanted to start with a brief overview of what MACCS is and what it does. And the reason is that, you know, there's been a lot more attention on MACCS the code that we use for our reg analysis in more recent times. Since Fukushima people have become a lot more interested in level 3 consequence analysis-type information. So it's been more recently that a wider audience has gotten exposed to the tool and a lot of questions come up.

So we thought this might be a good opportunity just to provide a brief overview of what the code actually does. And Nate will do that and after that I will provide a presentation of what our preliminary MACCS analyses have shown. So if we go to the next slide I'll turn it over to Nate for the overview.

MR. BIXLER: Okay. So MACCS2 is also referred to as the MELCOR Accidents Consequence Code System and it's version 2 which is the -- where the "2" comes from at the end. It was developed for the NRC by Sandia as a PRA tool primarily with the idea of being able to use it for analyses like the one that we're doing now. It was used in SOARCA, in a whole variety of other recent studies.

It was first released in `97 and stems from a whole series of codes that were developed at Sandia starting with CRAC, then CRAC2, MACCS, then MACCS2. CRAC was originally developed for WASH-1400. CRAC2 was used in what's called the Sandia Siting Study that was published in 1982, also some other early PRAs. MACCS, the original MACCS code was used in NUREG-1150 and MACCS2 has been used since roughly 1997.

The purpose of the code is to estimate consequences generally in terms of health effects. Before you get to health effects you have to estimate doses. So it really does that as well. And it estimates economic impacts in terms of land areas and economic cost.

It is the code that's used by the industry as well as by the NRC. There's no alternative code currently available that's used in the U.S. at least to compete with it. So it's used both by the industry and the NRC for evaluations of consequences.

Around 2001 we began developing an interface code called WinMACCS that is intended to make it easier to use the MACCS2 code. It assists in creating inputs so it functions as a pre-processor to MACCS2. It also functions as a post-processor. And one of the main reasons for developing it in the first place was to allow for uncertainty, sampling of uncertain input variables to determine how much effect they have on the outcomes. And you may be familiar with the uncertainty analysis that's being done for SOARCA is being used in that mode there.

It was reviewed at the beginning of SOARCA by an expert panel who evaluated the way that we were intending to use it for SOARCA and also made suggestions for improvements to the code. And many of those improvements were actually implemented to support the SOARCA study.

CHAIR SCHULTZ: What does that make the timing of that peer review approximately?

MR. BIXLER: I'm going to guess 2005. Something. Two thousand six maybe. Yes, right in there.

MS. GHOSH: And the overall SOARCA study was peer reviewed as well.

MR. BIXLER: Right, yes. So there was a separate peer review at the beginning of the work to give us comments on the directions we were planning to take, and then a peer review that -- a group that met and gave us comments along the way as we were conducting the study.

Okay, slide 52, please. This is a cartoon that we often use. It really depicts a couple of things. It depicts the ways that MACCS2 models atmospheric transport, the mechanisms that are used there. For example, it models plume rise and dispersion and also dry and wet deposition. Wet deposition occurs when it's raining.

The figure, the cartoon also shows the dose pathways that are modeled. Those include inhalation. Inhalation is both directly from the cloud or the plume and from resuspension. It models cloudshine, groundshine, deposition under the skin for determining a dose to the skin and ingestion. All of those pathways are modeled. Okay, next slide, please..

MACCS2 is divided into three modules. Earlier if you go back to the old MACCS code these were actually three separate codes that were run sequentially. One thing that MACCS2 did was to integrate these three separate codes as three modules so it's easier for the user to use now. You just run one calculation instead of three separate ones.

The three parts though are ATMOS which does the atmospheric transport and deposition portion of the calculation. It's not associated with a particular phase as are the EARLY and CHRONC parts of the code. EARLY does the emergency phase which is allowed to last between 1 day and 1 week. Typically for NRC applications we would use the full week to define the emergency phase.

It calculates prompt and latent health effects, and those are associated with doses that are short-term and longer lifetime doses to calculate those types of health effects.

It treats the types of actions that you would expect to see during the emergency phase which are sheltering, evacuation and relocation. I'll talk more about each of these modules in the next few slides so we'll come back to some of these thoughts.

In the CHRONC module of the code we're treating the longer term. Both what's called the intermediate phase which can last up to a year and the long-term phase which can last up to 10 to the 10th seconds which translates into about 317 years. But typically we set the long-term phase to be on the order of 30 to 50 years. Fifty was used in SOARCA and it's being used in this, the work that we're presenting today.

MEMBER ARMIJO: In the SOARCA work, in calculating health effects you used both the LNT model and a threshold model.

MR. BIXLER: Yes.

MEMBER ARMIJO: Did you use both in this analysis?

MR. BIXLER: So far we have only looked at LNT in this analysis. And to support a cost-benefit analysis what you really need are not numbers of health effects or health effect risk although we present those results. What you need are population dose and the offsite economic costs that MACCS2 predicts.

So those two pieces would be used in the cost-benefit analysis and they're independent of any dose threshold that you might implement. So I think the thinking here was it wasn't so essential for the purpose of this study to look at the threshold kinds of calculations.

MEMBER SIEBER: Do you always assume that there's an inversion layer?

MR. BIXLER: Yes, we always assume that

there's an inversion layer.

MEMBER SIEBER: And so that makes it pretty conservative.

MR. BIXLER: Yes, it adds some conservatism, definitely.

MEMBER SIEBER: Do you happen to know the percentage of time roughly that there is an inversion versus no inversion?

MR. BIXLER: At Peach Bottom in particular? No, I don't know that. I haven't looked into that.

MEMBER SIEBER: I used to fly every day so I don't remember seeing that many inversions.

MR. BIXLER: Yes, okay. The CHRONC calculation reports the effects of decontamination. These are the types of actions that would be taken during the long-term phase, decontamination, introduction and condemnation. We'll talk about each of those in a little bit more detail later as well. Okay, next slide, please, 54.

So looking at the ATMOS model, the ATMOS model again does the atmospheric transport with dispersion, deposition. It's based on a Gaussian plume segment model which is different than a steady-state Gaussian plume model if you're familiar with that distinction.

It has provisions for meander which is an expansion of the plume in a horizontal cross-wind dimension and also for surface roughness which causes an expansion of the plume in the vertical dimension.

It doesn't specifically treat some things that would exist in reality like irregular terrain, spatial variations in the wind field and temporal variations in wind direction. Once a plume begins to be released it travels in a straight line. So it has that kind of quality to it, that after beginning of release the direction doesn't change. So in that regard it's a single weather tower sort of calculation. It doesn't depend on multiple weather towers. Yes.

MEMBER SIEBER: And so you don't consider at all trapping in valleys?

MR. BIXLER: No.

MEMBER SIEBER: Where people live.

MR. BIXLER: No, we don't. That's not part of the calculation.

MEMBER SIEBER: So this sort of underestimates the health effect.

MR. BIXLER: It could in that situation,

yes.

MEMBER SIEBER: Right.

MR. BIXLER: Okay. There was a study conducted I'm thinking about 5 years ago roughly reported in NUREG/CR-6853 where we compared with two Gaussian puff codes. Those are RASCAL and RATCHET. RASCAL is used in the emergency response center here. Both of those two codes are created by PNNL and they're both based on Gaussian puff models.

We also compared with a Lagrangian particle-tracking code from the NARAC group at Lawrence Livermore called LODI which is considered one of the state of the art codes in doing atmospheric transport.

The comparison showed that MACCS2 on the average, averaged over a year's worth of weather was within a factor of 2 if averaged around the compass, and within a factor of 3. Generally much better than a factor of 3 but at the extreme factor of 3 at a specific grid location.

And that study was done out to 100 miles. For the purposes of a lot of the studies that are done with MACCS2 the distance is only out to 50 miles. So that was a bit farther than perhaps we needed to look.

Multiple plume segments are allowed in the newest version of the code. We allow up to 200. So you can -- the thinking behind that is to allow the maximum use of the wind data that you have. Usually we have the wind data on an hourly time frame. We can carve up the overall release into hour time segments and the MACCS2 code allows each plume segment to travel in a different direction depending on what direction the wind happens to be blowing at the beginning of the release for that plume segment. So you can in a simple way account for the fact that not all of the plume goes off in one direction and not -- the same group of people don't receive the entire dose. It could travel.

MEMBER SHACK: The segment then continues in that straight line through the whole calc.

MR. BIXLER: Once it begins it continues but then at the next hour the next plume segment may travel in a different direction.

The ATMOS also accounts for plume rise from the initial release height due to buoyancy of the plume, the effects of the building wake in terms of the initial size of the plume and also the potential trapping of the plume in the building wake. It accounts for dry and wet deposition, dry deposition being a relatively slow process, wet deposition being intermittent but a very rapid process for depositing the plume.

And it accounts for radioactive decay and ingrowth for up to 150 radionuclides in up to 6 generations. Usually we use about 50 to 60 radionuclides to do nuclear reactor accidents. So that's more than enough. Next slide, 55, please.

Okay, continuing with the ATMOS module. These days what we usually do at Sandia and the NRC has done in the study that we're talking about now is to use MELCOR to generate a source term. We have an interface tool called MELMACCS that digests the plot file produced by MELCOR and extracts all the information you need to run MACCS2 to do a consequence analysis. So it really automates the treatment of the source term. It automates it and is relatively foolproof so that you don't end up with operator error from trying to hand-create the inputs that you need.

The met data that are required by ATMOS include wind speed and wind direction at least hourly. And we have now capability to look at half-hourly and every 15-minute time periods as well.

You also need Pasquill's stability category. That's a derived quantity that's usually derived from measuring temperature differences in the atmosphere.

You need precipitation rate. All those first three bullets are hourly information. The last one is a seasonal, it's four times per year. We use an a.m. and p.m. mixing height. Those are minima and maxima in the mixing heights averaged over a season of the year.

There are a number of sampling options that the user can select. Several of them deal with just single weather sequences to look at a specific case. But most of the time we use multiple weather sequences so that we can get statistics on what the plume might do over the course of a year's worth of data. The year's worth of data is intended to be representative of -- it's archive data but it's intended to be representative of the future as well. And that's what we would normally do. Typically these days we're doing about 1,000 weather samples, weather trials to estimate the effect of 8,760 data points that we have in our weather file which represents 1 year, 365 times 24.

The outputs from ATMOS include basic

things like the dispersion parameters that go into the Gaussian plume equation, chi over q which is a dilution factor and the fraction of material remaining in the plume accounting for radioactive decay and deposition under the ground.

We can also get time-integrated error concentrations and ground concentrations at various points along the path of the plume.

MEMBER STETKAR: Nathan, are all your meteorological data just sampled independently? The precipitation.

MR. BIXLER: They're usually from a single tower at the plant, at the site.

MEMBER STETKAR: No, I'm talking about you had 8,760 data points for each of these. Some of them would be correlated in the real world.

MR. BIXLER: Yes.

MEMBER STETKAR: The storms, for example.

MR. BIXLER: Right. Well, these are measuring the data points. So, if there's a real correlation that should be observed in the data that we're using.

MEMBER STETKAR: A single sample of all four of those sub-bullets under number 2 or are they four separate samples?

MR. BIXLER: Okay, I think I understand the question. What we do is we start -- when we do a weather trial we start at a particular time and then we look at hour by hour what are the data in the weather file. So we're not independently sampling one hour and assuming that it stays that way, we're looking at -- our sample really is selecting an initial time point when the release begins and then looking at the data in the weather file hour by hour.

MEMBER STETKAR: But again, under that second sub-bullet you have four different pieces of data. You're saying you sample all four of them at the time that they were reported.

MR. BIXLER: Yes.

MEMBER STETKAR: Thank you.

MR. BIXLER: Yes, exactly. Okay, next slide, 56, please. Okay, now we'll look into the EARLY module, the second module in MACCS2.

MEMBER CORRADINI: Just -- I'm sorry. This is a side question. So as you went through ATMOS the basic assumptions are very similar to RASCAL. To a first approximation they're essentially the same.

MR. BIXLER: I think that's right. The difference would be RASCAL allows you to have multiple weather towers instead of a single one.

MEMBER CORRADINI: I just wanted to make sure because you were comparing it to something much more sophisticated. Something that's in the open for emergency planning that comes to my mind is RASCAL but they're of a similar vintage and type.

MR. BIXLER: Yes.

MEMBER CORRADINI: Okay, that's fine.

MR. BIXLER: RASCAL is a Gaussian puff model which means that you have -- the puff is located by a single point at the center of the puff and it can travel three-dimensionally around the -- through the grid as opposed to a Gaussian plume model that is a straight line kind of model. So that's the major difference between the two. Okay.

Okay, so EARLY is looking at the emergency phase. And it calculates acute and lifetime doses for each of the pathways that are listed there. The only one that's missing is ingestion. We don't consider ingestion during the emergency phase. We only in fact consider it during the long-term phase.

EARLY also calculates the health effects that are associated with those doses which are early injuries, early fatalities and latent health effects both occurrences and fatalities from latent health effects induced by a type of cancer.

The doses are subject to several actions that can occur during this time, sheltering, evacuation and relocation. The difference between evacuation and relocation is really the way that those two things are triggered. Evacuation is generally implemented following the declaration of a general emergency at the plant. Relocation is based on exceeding a projected dose. So it would be usually implemented at a later point in time, that evacuation would have the higher priority and be implemented more rapidly, relocation a bit on the longer range of time.

MEMBER SKILLMAN: Nathan, how would EARLY, results from EARLY differ for instance if it were applied to Cooper Nuclear Station out in the Midwest in a vast, very low-population area versus Indian Point that is in close to a large urban population?

MR. BIXLER: Okay. I haven't talked about it up to this point, in fact, I don't think it's in any of the slides, but part of the input to

MACCS2 is what's called a site file. The site file contains the surrounding population on a grid-by-grid basis, so a fairly good detail on where the population are actually located. It also, the site file also contains economic values for the land surrounding the plant. So the value of property for example would be contained in the site file.

So those two things, those two categories of information would be very site-specific. In addition, the met file would typically be site-specific. So you'd look at a met file for each of those locations separately.

MEMBER SKILLMAN: Thank you, Nathan.

MR. BIXLER: Yes. Okay. Outputs from the EARLY module include doses, health effects, land contamination areas and things of that nature. Next slide, 57, please.

Now looking into the CHRONC module. The CHRONC module includes the intermediate phase. Typically for NRC applications up to this point in time we have not treated the intermediate phase. We've set the duration to zero and basically skipped over the intermediate phase.

But if you include the intermediate phase it's a fairly simple part of the calculation.

It's just looking at groundshine doses and resuspension inhalation. Again, not including any treatment of ingestion doses. And the only protective action that's considered is continuing relocation. The people may still be relocated away from their homes if doses would warrant that.

The next phase is the long-term phase, typically 50 years in most of the calculations we've done recently. I've seen some SAMA analyses that are based on 30 years so both of those are being used.

The dose pathways include everything that's still applicable at that point in time. Groundshine resuspension from things that have deposited and kicked back up into the air and ingestion. So at this point we would pick up the ingestion pathway.

The protective actions are based on two criteria, habitability and farmability, habitability being the more important of those two criteria. The actions that would be taken based on those two things are decontamination of land, interdiction of land which would extend beyond decontamination. Decontamination is considered a period of interdiction, so it's the beginning of interdiction but interdiction can follow and continue longer than the decontamination period would take. And then the final option if all else fails is condemnation. Next slide, please.

MEMBER CORRADINI: Which you have a payment associated with.

MR. BIXLER: Yes. Yes. The condemnation you're saying?

MEMBER CORRADINI: Yes.

MR. BIXLER: Yes. We would tally the value of the land, of the property that's being condemned in that case, yes.

Okay, this is a logic tree or a decision tree for the protective actions that would be taken during the CHRONC module.

The first question is is the habitability criterion met initially right after the emergency phase. And if the answer is yes then no actions are needed. People would return to their homes at that point if they're not already at home.

MEMBER ARMIJO: What is that criterion? Is it a single number or a number of different things?

MR. BIXLER: It's a number in terms of a dose. It's an organ which is usually effective, so it's an effective dose. And it's a time period. So for example, at Peach Bottom the state criterion for habitability is 500 millirem in 1 year, in the first year, and not more than that in subsequent years. But usually the doses tail off in subsequent years. So the way we enforce that is to check to see if anyone would receive more than 500 millirem in the first year after -- beginning at the beginning of the long-term phase. Okay. So, that's what happens if the habitability criterion is initially met.

If the answer to that first question is no then the next question is asked and that's can we decontaminate to a sufficient level to restore habitability. And MACCS2 considers three decontamination levels. So it would begin by asking for the lowest level of decontamination is that good enough. And if it is it would do that level of decontamination, population would return afterwards and that would be the end of it.

If the answer is no it would sequentially consider higher levels of decontamination up to the highest level that is in the input. And if that's still -- if that's sufficient then it would do that.

If not, it will ask the next question

which is can I restore habitability by decontaminating plus an initial period of interdiction. And if the answer to that is yes it would first start out by performing the highest level of decontamination and then it would interdict for an additional period of time up to -- the maximum that's allowed in the code is up to 30 years. So it would potentially go as far as 30 years, usually much less than that, but that's the max allowable. And then after those two things are performed the population would return home.

MEMBER CORRADINI: So is this -- are all of these based on the protection action guidelines? So that if I have a long-term dose of greater than -- I can't remember the number, they can't come back?

MR. BIXLER: Yes. EPA has the -- EPA PAG has 2 rem in the first year and one-half a rem per year thereafter. And that's what most states would adopt as their --

MEMBER CORRADINI: Some states are more restrictive though.

MR. BIXLER: Pennsylvania is more restrictive. I don't know if there are others but there may be.

MEMBER CORRADINI: So 2 rem in the first

year and one-half a rem thereon.

MR. BIXLER: Yes.

MEMBER CORRADINI: And all these kind of if/then/elses inside the computer thing just basically says what got deposited, where does it sit relative to those protection action guidelines.

MR. BIXLER: Yes. Okay, the last thing that's considered if everything up to this point has failed, and there are two ways that it can fail, is -- the first way that it can fail is the habitability can't be met by the highest level of decontamination plus up to 30 years of interdiction. You still can't meet the habitability criterion so we condemn the property.

The second way that you can condemn property is if it's not cost-effective. MACCS2 makes the decision purely based on economics. I don't know if that's the rule situation or not but that's the logic that's built in is the decision is purely based on economics.

MEMBER REMPE: So the user has to then input the worth of the property and then how much it cost for labor?

MR. BIXLER: To do the decontamination, yes.

MEMBER REMPE: And the user has to be savvy enough to know the hours for the decontamination and the cost of the labor.

MR. BIXLER: Yes. There's a period of time needed to conduct the decontamination, a decontamination factor and a cost associated with that. A few other parameters as well but those are probably the primary ones.

Okay, next slide, please.

MEMBER CORRADINI: But what about -- just out of curiosity because -- so if one wanted to look at a sensitivity on the protection action guidelines is there a flexibility to look at different guidelines?

MR. BIXLER: These are all user input values, so yes, they can.

MEMBER CORRADINI: Just curiosity. Thank you.

MR. BIXLER: Yes. Okay, continuing with the CHRONC module. The economic costs that are reported include six items. Yes, I think this is the right slide, 59. The six items are listed here. There's a per diem and lost income cost for people who are evacuated and relocated.

Over the longer term if people have to

be away from their homes for a longer term there's a one-time moving expense that can include lost income for some number of weeks or whatever it is that you want to include with that.

The next category is decontamination labor and materials. The next one is loss of use of property. That's based on kind of an expected rate of return on investment for property that you own. The next one is condemnation of property which is just the value of the property itself. And the last one is in case the accident were to occur during the farming season, the growing season, the value of the crops or dairy products that are lost as a result of the accident.

The outputs are doses -- was there a question?

MEMBER STETKAR: What's the use of property, for example, if property contained General Motors for example. Is it simply the value of that manufacturing facility and the real property that it sits on, or is it loss of the entire production of General Motors automobiles for some period of time?

MR. BIXLER: No, the current model just accounts for the value of the property itself. It doesn't account for any economic activity at that property.

MEMBER STETKAR: Okay, thank you.

MR. BIXLER: Okay. So the outputs are doses by pathway and organ, latent health effects, and those are usually calculated for a variety of organs and then summed up to get a total, and the economic cost. And as we mentioned earlier you can also get land contamination areas can be output as well which is sometimes considered a subcategory of economic cost.

MEMBER ARMIJO: In all of these economic costs is there inflation adjustment in your model?

MR. BIXLER: There is not really an inflation adjustment. There's an expected rate of return and there's a loss of value of property due to lack of maintenance. Both of those are a rate. For example, during interdiction you don't maintain property so there's a loss per year. Usually it's 20 percent is the assumed loss per year of the value of property.

MS. GHOSH: In terms of the input values if we have Census data -- the inflation is different.

MR. BIXLER: Okay, yes. Tina makes a good point. We usually would base the calculations on a specific year, a target year, and we would inflation-adjust if we have, for example, if we have 2002 economic data, that's what was used in SOARCA and also used in this study, we would inflation-adjust that to a target year when we assume that the accident is going to occur. We would also do the same thing with the population data. So in that sense, yes, they are adjusted.

MEMBER ARMIJO: That's what I was getting at.

MR. BIXLER: Okay.

MEMBER SHACK: But then you do -- everything is then expressed in terms of 2012 dollars.

MR. BIXLER: Yes, exactly. That's right. Okay, next slide, number 60.

CHAIR SCHULTZ: Nathan, at this time I think this is a good -- this slide's a good introduction to what is going to follow which is another section of the presentation. You've made a very comprehensive presentation on the descriptive features of the methodology so thank you for that.

With that I will call a recess for lunch. And I'm going to ask so that we can start the afternoon well for a sit-down time of 1:30. And

I'll bang the gavel at 1:35. Just so everyone knows we will therefore begin at 1:35.

(Whereupon, the foregoing matter went off the record at 12:34 p.m. and went back on the record at 1:34 p.m.)

CHAIR SCHULTZ: Break is completed for lunch and we're ready to resume the presentation. We are in the middle of the presentation associated with the MACCS code and the second piece associated with that as well. So with that I'll turn the presentation back over to you, Nathan, for this slide.

MR. BIXLER: Okay. This is my last slide before I turn it back over to Tina again. And this is just describing some of the standard uses for the MACCS2 code.

The first category there is for PRAs and things that are kind of like a PRA, for example, SOARCA we've used MACCS2 for. This type of study, a reg analysis, is something that MACCS2 is very useful for.

NEPA studies are used in licensing and license extensions in terms of SAMA and SAMDA analyses. Those are generally done with the MACCS2 code.

And the last category there is another -- is not an NRC-type activity, it's a DOE activity where MACCS2 is used pretty much throughout the community of DOE facilities to do safety analyses for authorization bases. These are often called documented safety analyses.

And then the last bullet there is just pointing out that there's an international usership for MACCS2. I think we're up to 12 countries now including the U.S., 11 international countries plus the U.S. And I've kind of lost track of the number of users but I think there are probably several hundred at this point.

One thing I'd like to inject before I turn it back over to Tina is that it was pointed out earlier that there are some situations where MACCS2 would give you a conservative result or a non-conservative result.

For example, the mixing layer height issue or valleys and a variety of things like that. There are situations where you may get a conservative answer or you may get a non-conservative answer.

For NRC applications we use MACCS2 in a role where we're looking primarily at mean results and those conservatisms or non-conservatisms tend to average out, not entirely and not always but they tend to do that. And so the means tend to lose most of the effect of some of those conservatisms and non-conservatisms.

Okay, I think with that, Tina?

MS. GHOSH: And we can skip this slide. We added some references, that's just for your own reference. We don't have to go through those. So I'll talk now about the analysis which is in progress but I'll talk about our preliminary analyses for the filtered vents.

So, in terms of supporting the regulatory analysis, the cost-benefit analysis portion, we used MACCS2 to calculate the offsite population doses which feeds directly into the reg analysis as well as the economic cost.

And just a quick note that MACCS for the offsite population doses, it's not only included the public doses, doses to members of the public, but also decontamination workers who are doing the offsite decontamination. Those all get lumped into the offsite population dose.

Then in addition to those two metrics that we are feeding into the reg analysis we also looked at a few additional metrics. One was the population-weighted latent cancer fatality risk which we've generally called individual latent cancer fatality risk and the individual prompt fatality risk, and land contamination. Which again the other metrics are dependent on land contamination but we looked at it as a separate metric.

And the way we defined land contamination for our purposes is to look at different thresholds of cesium-137 concentration in the soil. And when we get to the results you'll see what that is. That's one way of defining land contamination.

And we, for the purposes of reg analysis we do everything out to 50 miles. So for most of these metrics we looked out to a circle of 50 miles, a radius around the plant.

The only exception to that is for the land contamination numbers that we're reporting we actually went out as far as we still found some land contamination that exceeded the thresholds. In some cases that's beyond 50 miles that we found exceeding the threshold. So for land contamination the only metric where the results are not limited to 50 miles. All the other results are for the 50-mile circle.

MEMBER RYAN: What would drive that? I guess the meteorological conditions?

MS. GHOSH: Yes, that's right. How much the source term is and the meteorology.

MEMBER RYAN: That's fine. I just want to understand what role -- thanks.

CHAIR SCHULTZ: And Tina, those are done as Nathan indicated on a best estimate basis or not getting into non-conservatisms associated with the boundaries?

MS. GHOSH: Right, yes.

MR. BIXLER: For NRC applications we tend to use MACCS2 in a best estimate mode. We try to do the best job we can of matching what the real conditions might be. For DOE analyses, on the other hand, they tend to be very conservative. They're looking at 95th percentile weather and things like that. So those are two different ways of using MACCS. You can use it in either mode, but for NRC applications we tend to try to use it in a best estimate mode.

MEMBER RYAN: It's interesting too. Maybe you'll talk about this and if you will I'll wait, but cesium, I understand why it's a marker, it's fairly soluble, it's fairly prevalent and all that and it's a nice marker. Strontium on the other hand is insoluble but it's an important marker. On that side of it there's lots of other individual radionuclides that for one reason or another may rise to prominence in a calculation or in a real-world circumstance. Have you treated any other nuclides or you're really just looking at cesium?

MS. GHOSH: Well you know, the analysis itself certainly looked at all of the important radionuclides. I think Nate mentioned typically fifty-something.

The reason we focus on cesium is because iodine of course is important. When you look at prompt fatality risk you have to look at iodine. In this case, and I'm getting partly to the --

MEMBER RYAN: If I'm getting ahead of you, that's okay, I'll wait.

MS. GHOSH: Yes, for land contamination we concentrate on cesium because that turns out to be the most important.

MEMBER RYAN: I'm fine. All right, that's good. Thanks.

MS. GHOSH: Okay.

MEMBER POWERS: Typically there's about a factor of 10 difference in the release fractions typically between strontium and cesium.

MS. GHOSH: So, the inputs we used for the MACCS deck, we started with the SOARCA project deck as was mentioned, the same with the MELCOR folks. And there was a couple of key differences. Obviously the source term would be different. We took the source terms that were generated by the MELCOR analysis to feed into MACCS. And in addition, the ingestion pathway was actually turned off for SOARCA and we turned it back on for this analysis. So those are the two key differences.

The habitability criterion that we used, that's when you allow people to come back, because we're looking at Peach Bottom we based it on the Pennsylvania state guideline which I think we discussed this morning. It's a little bit more stringent than the EPA guideline, it's 500 millirem per year starting right at the first year.

And then --

MEMBER ARMIJO: Quick question. Do you remember or know what the Japanese habitability criterion is for return? Is it more conservative than this, or the same, or higher?

MEMBER CORRADINI: As I understood it the protection action guidelines are very similar to this. They moved them out basically on 1 rem. But the moving back in, there was a -- the staff probably has it somewhere. There was a July 17th date where they actually have regions where they're moving them back in but I don't know what the dose level is.

MEMBER ARMIJO: I have a number -- I have a suspicion it's more conservative than the 500 but I'm not positive.

MEMBER CORRADINI: I think it is.

MEMBER POWERS: Somehow 50 millirem is sticking in my mind.

MEMBER ARMIJO: Fifty?

MEMBER CORRADINI: Above background. A delta, a very small delta.

MEMBER POWERS: But you know, why that's sticking in my mind I don't know.

MR. NOSEK: Hi, my name is A.J. Nosek, I work at the Office of Research.

I believe what the Japanese are using, for habitability they're using a 2 rem threshold, for return and habitability. And they plan to in the future clean that down to 100 millirem past habitability. That would be their cleanup standard.

MEMBER ARMIJO: That's the same as us, same as EPA. That's what it sounds like.

MS. GHOSH: Okay, so the next point actually Nate already covered in his overview. We do do a statistical sampling of weather sequences and in this case we used about 1,000 weather trials because obviously we don't know when a hypothetical future accident might occur. So we're taking into account the uncertainty and the exact starting point that the accident might occur.

And we limited our analysis to the linear no-threshold dose-response model which is our regulatory model still at this point. So unlike SOARCA where we looked at the alternate dose threshold models, in this case we only looked at the LNT model. Next slide, please.

So just a quick overview. In the emergency phase, you know, MACCS essentially models people evacuating. And this is done by grouping the population into groups of people who behave similarly and we call those cohorts. So cohort 1 is the zero- to 10-mile public, just the general public that's in zero to 10 miles.

Cohort 2 is the 10- to 20-mile shadow

evacuation. So these are folks who haven't been directed to evacuate but they hear that zero to 10 has been directed to evacuate and they voluntarily choose to evacuate themselves.

Cohort 3 is a special category for the zero to 10 schools. Generally the schools are evacuated I believe in advance of the rest of the population. They generally get an early evacuation. And then similarly there may be others in the general population, a zero to 10 shadow who evacuate earlier than they're directed to do so.

Cohort 4 is the special facilities that are within the EPZ and that's hospitals, prisons, basically institutions that for example have good shielding and need special evacuation provisions in essence.

Cohort 5 is the zero to 10 tail. These are the slow pokes, so they kind of are much slower than the rest of the general population.

And then much like NUREG-1150 and other studies, we also assume that there's some portion of the population in the zero- to 10-mile region that simply won't evacuate even though they're told to do so. And in this case we assume that to be 0.5 percent of the population. Next slide, please.

So, I just wanted -- we wanted to make a few notes on the decontamination factor of the filters that we're assuming. So for the MACCS portion of the analysis we essentially took all of the MELCOR source terms --

MEMBER CORRADINI: Just one little clarification.

MS. GHOSH: Yes.

MEMBER CORRADINI: I know that in certain states you don't evacuate based on distance as much as you evacuate based on an emergency planning region that is approximately distance, like county. Is that how that's done in these little circles? You know what I'm saying?

MEMBER SIEBER: That's the way Pennsylvania does it.

MEMBER CORRADINI: There's a name for it. I can't remember the acronym.

MR. BIXLER: It's called a keyhole.

MEMBER CORRADINI: No. No, no, no.

MR. BIXLER: ERPA? You might be thinking about ERPA?

MEMBER CORRADINI: Yes.

MR. BIXLER: Here we're evacuating the entire 10-mile zone.

MEMBER CORRADINI: You're just going out and --

MR. BIXLER: Yes, right. MACCS2 currently doesn't have the capability of just evacuating a portion of the 10-mile EPZ. It does the whole thing.

MEMBER CORRADINI: Or a keyhole. Because one thing is just this, the other thing is with the keyhole approach. But then on top of that at least in Wisconsin they overlay that for any sort of emergency and then say okay, within this fraction of a county they have a siren. And it's not exactly what it is, but that grouping is alerted and they go out. Whether it's -- it's usually a little bit larger than whatever any of these are.

MR. BIXLER: Yes, yes.

MEMBER CORRADINI: And that's not here.

MR. BIXLER: No, it's not here. We're working on a keyhole evacuation model currently. In fact, it's basically complete but not available for use quite yet. It needs to be tested and so forth. But not used in this study.

MEMBER CORRADINI: Okay, thank you.

MS. GHOSH: So, the decontamination factor of the filters. So you'll see in the results that are coming up on the next slides we took the source terms from MELCOR and then we modeled both the cases with and without filters.

And we just want to note that neither MELCOR nor MACCS2 actually models mechanistically the decontamination effect of the external filter. So in essence we are just assigning a decontamination factor value. It's a prescribed value that we've assigned to the external filters. And we've used several example values to see what the differences might be.

And also the decontamination factor -- well, I guess this is an obvious point. But would only be applied to the portion of the release that's going through the pathway that's connected to the venting, the filtered venting.

MEMBER POWERS: One of the things the MACCS does is it calculates the deposition of radionuclides in this plume as it moves along. That deposition -- those deposition velocities are functions of particle size. This decontaminated material presumably has different particle sizes than the non-decontaminated material. Do you account for those in doing your deposition calculations?

MR. BIXLER: The short answer is no. We do account for what MELCOR tells us comes through the suppression pool accounting for that decontamination. But since we're just applying a decontamination factor to the MELCOR flow that comes out through what would be the filtered vent we're just applying that DF across the board to all aerosol sizes. We don't have a basis for selecting which aerosol sizes get decontaminated differently than others.

MEMBER POWERS: So you're just attenuating the entire distribution by a factor and not shifting the size distribution.

MR. BIXLER: That's right, yes.

MEMBER POWERS: So that has the effect of accelerating your -- of increasing your particle deposition relative to what it probably would be. I mean, there's no -- there's the other problem of course of agglomeration of those particles that may shift them back into the larger distribution.

MS. GHOSH: Yes, that's true. I guess based on discussions, and I wasn't part of all the discussions, but based on internal discussions we've had I guess there have been some vendor claims that the latest filter technology is able to filter particles down to lower sizes than one would previously have thought.

I don't think we've done -- we haven't done any independent studies on that but I guess that was one thought, that perhaps this isn't that -- if that were true then perhaps it's not that far from what would actually happen. It may be an open question.

And, right. So for the MACCS input then the MELCOR source term only from the relevant flow path, you know, where the filtered venting is reduced by the decontamination factor that's assigned to that filter. So if we can go to the next slide.

The next two slides, there's a lot of information here we've just summarized in two tables. So these are the same eight cases that you saw the MELCOR results were this morning and even earlier.

And I just want to point out a couple of things before I start. We're only presenting a couple of the decontamination factor cases that we've run. For the wetwell venting cases we also ran a decontamination factor of 2 and 100. And those results will be available in the draft SECY enclosure that we are developing now. But anyway, to give an idea of what difference the different results produce we just are showing the decontamination factor of 10 cases for the wetwell venting.

The contaminated area which is the third row in the tables, again we base this on a threshold level of the cesium concentration, the aerial concentration of cesium. And we picked -- we looked at three or four different values. And these were based on what IAEA were reporting following Chernobyl.

And just so you know, the 15 microcuries per meter squared in the case of Chernobyl corresponded roughly to about an external dose about 800 millirem per year the first year, 1986, and then dropped down to about 200 millirem per year for several years after that. Just so you have some idea at least for the Chernobyl case what that contamination level corresponded to in terms of external dose.

So we have here the population dose for that 15-mile circle around the plant as a first entry. The second is the individual latent cancer fatality risk. The third is the land contamination area and the fourth is the total economic cost.

MEMBER CORRADINI: And then if I might just, just to remind myself. The last row is all the things that you guys went through this morning.

MS. GHOSH: That's right.

MEMBER CORRADINI: So in theory this should account for everything. In theory.

MR. BIXLER: If you were doing a SAMA analysis you would add in the population dose times $2,000 per person rem. We're not doing that.

MEMBER CORRADINI: Okay, except for that.

MS. GHOSH: And not the onsite cost either.

MEMBER CORRADINI: Sure.

MS. GHOSH: So you'll see that later in the reg analysis. So this is just the offsite economic cost minus the population dose cost.

MEMBER CORRADINI: Got it. Right. So, just the reason I asked that because my next question is so, I benchmark this against what to get a sense of reality? Or is it just a relative thing? I should look at the base case divided into all the others from a relative reduction. In other words, should I believe the numbers or not believe the numbers?

MR. MONNINGER: For cost, for economic cost we have on slide 78 some benchmarks that Marty Stutzke will cover in detail.

MEMBER CORRADINI: Well, my next question would be did you apply this analysis to one of those base cases to see if you were within a factor of 10, 2, or 10 percent.

MS. GHOSH: So, I think you asked this question yesterday.

MEMBER CORRADINI: Yes, I did.

MS. GHOSH: I guess in a different forum.

MEMBER CORRADINI: It's not a different forum. It's highly connected.

MS. GHOSH: No, no, no, I know. The topic of that discussion was different but of course it's connected. In fact, this is one of the activities that has to do with that SECY.

We haven't modeled Fukushima yet. In fact, we think it's a little bit premature to do so just because a lot of the -- we're still gathering information. Even on just the source terms I've seen quite a few different numbers coming out. And certainly on the real economic cost. I mean, we've seen some projections but we're still gathering data. So we haven't done that type of benchmarking yet.

I think there are a number of us who think that it would be valuable to do at some point but it's premature at this point. But I think what you can see is so we're giving you a range of cases.

MEMBER CORRADINI: That's fine.

MS. GHOSH: And a range of numbers that we've computed at least for the calculations we've done. And you can kind of compare those against some of the real-world costs that you'll see in the slides later to kind of see where it falls, you know, with respect to other real events.

MEMBER CORRADINI: Okay. I just kind of anticipated you were going to tell me don't believe any of this, just take column 2 and divide row 4 into the next set just to look at a relative change. Because -- until you benchmark. While you benchmark.

MS. GHOSH: Yes. Certainly the relative numbers are maybe more valuable at this point than the absolute numbers.

Okay, and so on that point in terms of the relative numbers, you know, one of the things that we're really trying to look at is how much benefit do you get from applying a filter to venting. So venting and then applying the filter to the venting.

So, you'll see that there is inherently a non-linear relationship between the decontamination factor and what you get in terms of a population dose and individual health risk as well as the contaminated area and economic cost. And I guess intuitively it makes sense, right? Because the decontamination factor is only applied to one pathway. So where you have a release coming from multiple pathways you're not going to get the full benefit of that decontamination factor. So that's one intuitive point.

With the land contamination area you can often see a super-linear effect and that's because we're reporting contamination levels above a particular threshold. So, if you don't reach that threshold, if you're just under it you might lose a big chunk of, you know, area. So that also makes intuitive sense. So that explains some of the inherent non-linearities.

The other thing is with the latent cancer fatality risk for a lot of the numbers that we've calculated the habitability criterion kind of provides a backstop against how much risk you can incur. Because you don't allow people to come back and get long-term doses until you reach that habitability criterion. So that can account for some non-linearities as well.

MEMBER ARMIJO: But if you had used the same threshold value on health effects as you used in SOARCA for this calculation would there be any difference among any of these cases for the latent cancer fatality risk?

MS. GHOSH: Do you mean in terms of trends between --

MEMBER ARMIJO: Yes, just there's a threshold below which, you know, the number is -- latent cancer fatalities.

MS. GHOSH: Yes, I think much like the land contamination area you probably -- you would see a greater non-linear effect because in essence you don't start counting until you reach a certain threshold. So it would be a more pronounced effect if you looked at the threshold dose models.

MEMBER ARMIJO: But the benefit of the filter would be less.

MR. BIXLER: It would be less if you had

--

MEMBER STETKAR: But it might look like the land contamination in that sense.

MS. GHOSH: It may be more, actually. I think it may be more because with the LNT model you may see bigger differences if you apply the dose threshold.

MEMBER ARMIJO: Well, that's what has me confused. So maybe offline I'll talk to somebody else.

MEMBER CORRADINI: Just a follow-up to Sam's question. Maybe I misunderstood. The third row is the contaminated area -- maybe it isn't the same. Is the third row anywhere related to the protection action guidelines for rehabilitation? Is this like an intermediate number?

MS. GHOSH: Yes, so that's what I was mentioning before. In this case we're simply reporting a threshold value for cesium aerial contamination. So we can translate that to what it was for Chernobyl. So in IAEA's calculations for Chernobyl that translated to an 800 millirem per year dose in the first year and about 200 millirem per year for several years after that.

MEMBER CORRADINI: Okay, I missed that.

Okay, thank you. Thank you very much.

MS. GHOSH: Okay, so and the other thing is I almost I had reproduced the MELCOR results right before these tables because in order to understand why you see the differences that you do in the results you need to, you know, what I just said about the non-linear effects but also you need to see what's going on with the source term in the release pathways in order to get the full explanation.

So I guess -- well, we all have the hard copy handouts. The key results to look at in parallel are on pages 41 through 44 which basically tell you what's happening with the source term coming out that's feeding into the MACCS analysis.

MEMBER STETKAR: Tina?

MS. GHOSH: Yes?

MEMBER STETKAR: Can you go to the next slide? Unless there's something pertinent particularly on this one. Because we raised the question a few hours ago about 15 versus 14.

MS. GHOSH: Right.

MEMBER STETKAR: And the MELCOR results on slide 44 show higher releases in case 15 compared to case 14 by about a factor of 3 roughly. These results seem to indicate that with a filter case 15 is much better than case 14.

MEMBER BLEY: Which is where we came in thinking --

MEMBER STETKAR: Which is where we came in thinking it ought to be.

MR. MONNINGER: But the MELCOR doesn't have the filter applied.

MEMBER STETKAR: Oh.

MR. MONNINGER: The MELCOR would be the unfiltered red.

MEMBER STETKAR: Unfiltered versus 14. Okay, never mind.

MR. MONNINGER: Tina threw the 10 on hers.

MEMBER STETKAR: Never mind. You get about the factor of 3 here so, sorry. Thank you. It does hang together.

MS. GHOSH: Yes.

MEMBER STETKAR: MELCOR only had a vent. It didn't have a filter. It sort of had a filter --

MEMBER BLEY: Even though it had a wetwell vent you didn't take advantage of the wet.

MEMBER STETKAR: It sort of --

MR. MONNINGER: We took advantage of the

wetwell scrubbing but we didn't throw an extra --

MEMBER BLEY: An extra filter.

MEMBER CORRADINI: When they have "unfiltered" here that means nothing external to the --

MEMBER STETKAR: MELCOR model.

MEMBER BLEY: But it did go through the wetwell.

MR. MONNINGER: Yes.

MEMBER BLEY: And back on the old one, going through the wetwell didn't do what --

MEMBER STETKAR: And it had a de facto reactor building filter on it, you know, factor of 2 or so.

CHAIR SCHULTZ: It appears it had a benefit there, the wetwell did, and then as a result it appears that the DF associated with the filter for the wetwell vent is much lower than what it's been proposed for the drywell.

MEMBER BLEY: Actually that's not so. Back on 44, 43-44, the wetwell, going through the wetwell made it worse.

CHAIR SCHULTZ: I'm talking about the assumptions here though with regard to the DF for the filter associated with drywell and wetwell.

MEMBER CORRADINI: Just the other thing that -- because we had discussions at break about this. Just to take case 14. Case 14 is what got out by 48 hours, not what got out up to 30 days. This is just the release up to 48 hours.

MS. GHOSH: Right, it's truncated at 48 hours.

MEMBER CORRADINI: That's probably a big effect as to why -- I'm still looking at case 14. It looks just strange and I think it's just got to be because it was cut off.

MR. DENNIG: This is Bob Dennig. I'm not sure that I need to say anything, but --

(Laughter)

MR. DENNIG: -- the 10 is not in any way mechanistically or algorithmically or in any way connected to what kind of a scrub you calculate in MELCOR for the pool. The 10 is a 10. It was arbitrarily assigned that value. It was a low value as the minimum value which is what 90 percent for all -- for small particles it would be 90 percent removal for a factor of 10. And that's just in there, that's just an input.

CHAIR SCHULTZ: Tina, each of the categories that are selected there for a population dose down to the economic cost over the 50-mile radius. Each of those four have different stories that they tell associated with the comparative evaluation of each case. Are you telling that today as to what findings or are we going to hear that later? How is this going to be captured in the quantitative and qualitative assessment features?

MS. GHOSH: Yes, we -- I mean today we have just a very high-level summary of what came out of the MACCS analysis. I think you'll hear a lot more in the reg analysis and also Marty's uncertainty analysis talks about it because they've done additional sensitivity analyses and kind of put together the story of what it all means.

I was going to offer just a couple of very high-level thoughts. Certainly when you have cases 12 and 13 where you have main steam line rupture you can see that the overall consequences are quite a bit greater because everything is going to the drywell.

When you do put a filter, if you vent and you put a filter on the vent you can see that you attain a substantial reduction in all of the consequences across the board. And certainly if you're starting out with a decontamination factor of

1,000 and then looking at the comparison with 5,000, the incremental benefit there is not very large. You're getting a very large benefit from the DF of 1,000.

For cases 14 and 15 the drywell sprays are effective and you don't get any containment failure in case 15. That's just a note.

And if we can go back to the previous slide, slide 66, we can see that essentially any kind of wetwell venting is better than nothing at all. So for these cases even when you have unfiltered venting you're still better off than if you don't vent at all. And you do get of course an additional benefit when you put the filter on.

MEMBER POWERS: I guess I always have trouble drawing that kind of conclusion from this portrayal of the results. Because there are in fact no descriptions of the distribution of the output here. That if I look for instance at the difference between 400,000 rem and 180,000 rem in me, but if I found that looking at 1 sigma on either side of it, the two numbers were in fact indistinguishable I might draw a different conclusion than if in fact I found that there was some differences in the 2 sigma distribution there.

I'm wondering why you present things as just the mean and don't provide -- since you calculated I presume in MACCS some indication of what the distribution of the results are.

MS. GHOSH: Yes, and you know, I guess maybe we should clarify here. The distributions that we're getting are based just on weather uncertainty. So it's only on --

MEMBER POWERS: I think I understand that.

MS. GHOSH: Yes. But there's also epistemic uncertainty which we have not --

MEMBER POWERS: Well, I'm certain there are, but even given the limitations in your code of just having the weather which I think is unremovable uncertainty, that no amount of research is going to change the fact that the weather changes, it seems to me that that's integral for drawing conclusions from these results. Or am I missing something?

MS. GHOSH: I think that's certainly one way to look at it. You know, I think the reason we focused on the mean is just because it's kind of been NRC policy to use the mean results and cost-benefit analysis. But essentially we do have the information on the distribution of results.

And as I mentioned, you know, I think Aaron and Marty's going to go through the sensitivity studies and uncertainty analyses that they've done so we are going beyond just these mean kind of point estimates almost in the overall analysis. But we could also look at the range of results from the weather uncertainty.

MEMBER POWERS: Just because you're comparing two things. And especially where you have a distribution in the result there's a pretty fair probability that you get numbers that within the range of variability of the weather you really can't tell the difference between the two numbers in actuality.

MEMBER STETKAR: You said you only run 1,000 samples out of your 8,760. Do you test -- is it Monte Carlo sampling? Do you test for convergence on the mean? I mean, if they test for convergence --

MEMBER POWERS: Oh, well, convergence on the mean is probably instantaneous. It's probably 10 that got convergence on the mean. Even for the 1 sigma level I would assume that 1,000 gets you more than adequate convergence there.

MEMBER STETKAR: Yes, I would believe

so.

MEMBER POWERS: If you were asking about the 99th percentile then it would be more dubious, but --

MS. GHOSH: I suppose one thing I would wonder is, you know, if the effects of the weather uncertainty are about the same on the two cases, while you may have some overlap if you look at the total spread one would expect that you're going to get the ranges to be different. And so maybe what you're interested in is what percentage of the total spreads are overlapping in some area. I think that's an interesting question.

But I don't think we have any intuitive reason to believe that the spreads would be that different for one case versus another. So we could look at the total range of the two but I think comparing the means is still a meaningful metric because the spreads would be around, you know, the mean.

MEMBER CORRADINI: But just to get to Dana's point though, it's fair to say that you've got the data and you could look at it.

MS. GHOSH: Yes, that's fair.

CHAIR SCHULTZ: And I think that would

help in what I'm sure we could spend weeks on if not the afternoon associated with comparing and asking why are the differences here where we see between case 3 and case 7, or the results from different elements that are part of the output. How are they connected or disconnected and how might we use the results then in a regulatory analysis. What's the appropriate way both quantitative and qualitatively.

MEMBER RYAN: Tina, have you done a lot of either sensitivity studies or inter-case comparison studies to see how they react to various parameter values or changes in parameter value?

MS. GHOSH: Well, Marty is going to --

MEMBER RYAN: I guess I'm asking the basic question what do you know and what don't you know in these four cases.

MS. GHOSH: In terms of individual inputs to the analysis for instance?

MEMBER RYAN: That's one aspect but the other is how they behave once you start running the calculation one to the other. We're making a lot of comparisons and discussing a lot of parameters and how they behave, but I'm not real sure -- I don't have a hook in reality yet which one of these I actually believe is fact and what's a calculated estimate.

MS. GHOSH: Yes. I think, yes, I guess this discussion today is not going to be completely satisfying. I think our writeup is going to be hopefully more satisfying because we go into more detail about explaining why the different results are what they are. I mean, I think we have explanations for the differences, and again, it has partly -- for these results has partly to do with what's coming out of the MELCOR analysis and the source term signature.

So it's which pathways, you know, how long stuff is leaking out of the drywell head flange, for instance, whether or not you have drywell liner failure, whether you even have containment failure, how effective the sprays are, either core spray or containment spray when you do have them.

It's a very -- it's a long story and we don't have a satisfyingly succinct summary today but I think when you do see the SECY enclosure hopefully it'll get to more of that.

MEMBER RYAN: Okay. I guess when you get to that point you'll be dealing with a little bit more complex kind of human exposure circumstance. I guess right now we're kind of dealing with contamination and external doses. Have you looked at intake pathways other than just external exposure?

MS. GHOSH: Yes. Actually --

MEMBER RYAN: Direct gamma and crude and all that other stuff sometimes can be much more important than external gamma radiation.

MS. GHOSH: Yes and -- well, actually, we can get to that in the -- we can go to slide 68.

MEMBER RYAN: Well, I don't want to rush you out of order. If you're going to get to it that's fine.

MS. GHOSH: Well, that's okay. I think we could continue to have a very lengthy discussion on this but I still don't know if it will be completely satisfying.

MEMBER RYAN: That's fine.

MS. GHOSH: We should get to some to the punch lines for at least the MACCS portion of the analysis. And I don't think these will be surprising but we did model all the pathways. This kind of confirms what we've seen in other applications.

In terms of the long-term radiation the

most important isotope is still cesium-137. And this is accounting for everything. And the doses are mostly coming from groundshine versus other things. I believe that's because the residence time in the body is pretty low for cesium-137. So groundshine is the overwhelmingly dominant exposure pathway. That's kind of why we have spent so much time concentrating on the cesium-137.

In terms of the prompt fatality risk we see essentially no prompt fatality risk. Even in the cases 12 and 13 where we had much higher release fractions, particularly of iodine if you go back to the MELCOR tables we still don't see a prompt fatality risk.

I think in one case there was a conditional 1 in 1 billion chance, so conditional. So then if you weight that by the frequency of how likely that accident is to happen we are way down in the weeds. And we're comfortable saying essentially no prompt fatality risk. And the other ones, there wasn't even a number that we could compute. So we continue to focus on the latent cancer fatality risk.

There are a couple of cases that were very, very low absolute risk where the emergency phase had a higher contribution. But for the most part we're really talking about risk coming from people coming back to their homes after the habitability criterion has been met. So it's the long-term phase of accumulating a lot of small doses after you've come back to your property.

And then, the other thing as I mentioned before, just inherently there is a non-linear relationship between the decontamination factor that you apply and both the land contamination area and the health effects for the reasons I mentioned before. So anyway, that's our very high-level summary of what we're seeing new out of the MACCS analysis.

But yes, I recognize for the discussion of the tables we have to put together the story all the way from the beginning of what's happening in the reactor all the way through the offsite consequences portion. So if there are any more specific questions on the table entries, I mean we can try to address those here but I don't know if that would be valuable or not.

CHAIR SCHULTZ: Other questions from the committee at this time?

MEMBER SHACK: The sensitivity studies

between say the 4-hour battery life and the 16-hour battery life are going to be covered by somebody else?

MS. GHOSH: Did anybody do that sensitivity?

MEMBER CORRADINI: This morning we were told that there was some sensitivity.

MR. MONNINGER: Yes, and that would -- the results would be in the MELCOR report. The difference -- yes.

MR. BASU: In the MELCOR portion of the report, MELCOR analysis?

MEMBER SHACK: Somewhere.

MR. BASU: Now, we haven't done the MACCS analysis with all the sensitivities that we did in the MELCOR area. So I don't think you're going to --

MEMBER SHACK: Well, I'm just sort of wondering how much of what we're seeing here is due to the fact that you have a 16-hour battery life and this is a very, very protracted extended accident versus shorter battery life. That just seems to me as sort of a basic case to look at. I could go back and look at SOARCA except SOARCA didn't calculate all these things.

MEMBER STETKAR: Or RCIC failing to start.

MR. BASU: For MELCOR we're still going to give you the release fractions of cesium and iodine for 4-hour and then 12 hours. So that, you can look at the proportion and see what sort of effect MACCS will --

MEMBER SHACK: When it's non-linear I, you know.

MR. BASU: Yes.

MS. GHOSH: I think, well we talked about some of the preliminary SOARCA uncertainties when we came in April, back in April. And the one small --

MEMBER CORRADINI: You're assuming old people can remember.

MS. GHOSH: You guys are not that old. I don't take that -- not a good excuse. I think that from there we went up to an 8-hour battery life. So we didn't go all the way up to a 16-hour battery life but what we found is it doesn't make much difference for the 48-hour release. It doesn't make that much of a difference.

But anyway, I'm sure the MELCOR writeup will have the 16 versus 4. So it makes of course a difference in the early hours but almost no difference for the 48 hours which is -- actually, we were surprised, frankly. We thought that it would make more difference.

CHAIR SCHULTZ: Hearing no more questions, thank you very much for your presentations. We'd like to go right into the next presentation on the agenda which is risk evaluation by Marty Stutzke.

MR. STUTZKE: Being aware of the schedule I thought I'd tell you a little anecdote. I was preparing my presentation last night and my 10-year-old daughter came and asked me for help with her homework problems. And she laid down about a dozen 3-digit subtraction problems. I said this is going to take a long time, and she goes well, it will be a lot faster if you just watch and don't ask any questions.

(Laughter)

MEMBER STETKAR: Are you trying to tell us something?

MR. STUTZKE: I didn't think I could get away with it.

MEMBER STETKAR: But it's a very good story, thank you.

MR. STUTZKE: So, I'll reintroduce myself. I'm the senior-level advisor for PRA technologies in the Office of Research. We'll be talking about the risk evaluation here with some background.

First of all, the purpose of why we did it, some background on CCFPs and some insights from SAMA analyses. I'll summarize the tech report or approach that I used, and the results and some crude uncertainty work that I've done to try to give you some insight. Next slide, please.

So, the purpose is to estimate the risk reduction, the delta risk from installing severe accident containment vent in the reg analysis. And the metrics of importance are the change in the 50-mile population dose, the change in the 50-mile offsite cost, the change in the onsite worker dose risk and the change in the onsite cost risk.

In addition, because the MACCS people had calculated all these measures of land contamination I decided it would be helpful to look at the change in land contamination risk. Land contamination as Tina told you, it's the area, square kilometers, of land that's contaminated above 15 microcuries per square meter.

So if I do a normal risk calculation I would take that metrics, square kilometers times the accident sequence frequency and at least made a unit of measure of square kilometers per reactor year which I have no idea on Earth what that means.

MEMBER CORRADINI: Why not take the ratio of the square kilometers to essentially what the utility owns? So I would have essentially a ratio of what is offsite to onsite.

MR. STUTZKE: That could work. What I did was then take the risk and I divided it by the sum of the release sequences. So what you get is a frequency-weighted average area that's contaminated above a certain level conditioned on the occurrence of the accident. So it shows you units of -- changes of square kilometers and things like that. It seemed to be a little bit more helpful to me. But realize there's no regulatory guidance on something that's acceptable like this. Okay. Next slide, please.

Conditional containment failure probabilities. These are -- for BWRs it's taken out of the IPE results like this for Mark I's, II's and III's containments. In general IPEs found that the early containment failures were all due to liner melt-throughs, large majority of them. And the late containment failures are overpressurization failures as well as basemat melt-throughs.

So you see similar results between the Mark I's and Mark II's, and the Mark III's there's a different distribution. If you flip over to the next slide -- yes.

MEMBER CORRADINI: When you said early and late you only were talking about Mark I, about liner melt-through. There ain't no such animal under Mark III.

MR. STUTZKE: Yes.

MEMBER CORRADINI: Okay. So what is the early in the Mark III?

MR. STUTZKE: I'd have to look that up.

MEMBER CORRADINI: I don't remember myself but I --

MR. STUTZKE: Yes, I'd have to look it up. Since the focus here has been on Mark I's and Mark II's.

MEMBER CORRADINI: Okay, that's fine, that's fine.

MR. STUTZKE: The next slide shows the results for the PWRs as well but I won't discuss them.

MEMBER STETKAR: Marty, you didn't mention containment isolation failure. Are those -- is that part of late?

MR. STUTZKE: That's part of the bypass.

MEMBER STETKAR: Part of bypass.

MR. STUTZKE: That's part of bypass.

MEMBER STETKAR: So that's not -- okay. Thank you.

MR. STUTZKE: And there are issues with reportability of segregating those out.

MEMBER STETKAR: Surprising where that is then. Thank you.

MR. STUTZKE: Yes.

MEMBER SKILLMAN: Marty, what are the early failures for the large dry and for the ice condensers, please?

MR. STUTZKE: In terms of what --

MEMBER SKILLMAN: I presume bypass is failure, late failures are overpressurization. What is early failures for those two classes?

MR. STUTZKE: I'm going to have to look those up.

MEMBER SKILLMAN: Just curiosity. Thank you.

MR. MONNINGER: So we tried to put it in

here for our perspective but for the other containment designs --

MEMBER SKILLMAN: You're doing peas versus peas is what you're doing.

MR. MONNINGER: Yes.

MEMBER SKILLMAN: Okay, thank you.

MR. STUTZKE: The next source of information comes from extending the intervals between integrated leak rate tests that are required by Appendix J in Part 50. And a number of licensees have submitted and the staff has approved various license amendments.

This is not a complete set. This is a sampling of the information. But the methodology provides information that lets one derive conditional containment failure probability. In fact, in some of these submittals they actually report the numbers like this.

MEMBER CORRADINI: This is after they've done all the tightening and all they've tried to do? I don't understand what the final number means. Because with an ILRT I thought they go through a lot of -- to pass the test.

MR. STUTZKE: Right, but the idea here is originally plants did ILRTs three times in 10 years. And now the idea is to extend the interval to once in 10 years or once in every 15 years like that -- like this. And what you find is the following breakdown by the causes of conditional containment failure probability.

You know, the ILRT is fixated on the isolation failures, the liner leak-throughs and things, things that would be detected by the test and as a result because the contribution is small you don't set much influence or sensitivity to the interval between tests.

What I was interested in was the contribution from accident phenomena that would include things like liner melt-through, overpressure failures, and I was trying to make a comparison between this and the previous graphs I showed you to see what have we learned since we did IPEs about the likelihood of containment failure.

This accident phenomena column is the ground on which we play here for filtered venting if you want to look at it that way.

Okay. Then we went through a process -- next slide, please.

MEMBER CORRADINI: Marty, I'm sorry that I'm slow. Since none of the numbers change do I interpret that to mean I learn nothing or the test -- I really don't understand what we're trying to get out of this. I'm sorry.

MR. STUTZKE: Okay. The numbers that change because of ILRT are the frequency of the percent contributions of the isolation failures.

MEMBER CORRADINI: They kept going up but don't really amount to anything.

MR. STUTZKE: Well, actually, they go --

MEMBER SIEBER: Well, look at the conditional containment failure probability.

MEMBER REMPE: You're testing less frequently.

MR. STUTZKE: Yes, you're testing less frequently and you expect the contribution to go up proportionally like this.

MEMBER SIEBER: What was the last column? There's a pretty wide variation there.

MEMBER CORRADINI: But what I guess I was -- now I see, I think I understand what Marty was saying. The only column that really is changing is the isolation failure.

MEMBER SIEBER: Yes, that's right.

MR. MONNINGER: For our purposes one of the questions out there are what are the potential accident sequences or scenarios in which a filter may or may not be beneficial. And what we're trying to say is that for some of this accident phenomena, liner melt-through, overpressure, et cetera, the boilers, the Mark I's and Mark II's have a high probability of failure and could the filtered vents play a beneficial role in there.

Could the filtered vents play a beneficial role in this accident phenomena column? They're not going to help isolation failures. So licensees are reporting a high failure probability for their own plants and this is where we believe the filtered vent has value in potentially driving these numbers down.

MEMBER STETKAR: John, is this -- or Marty, is this different than the message that I -- kind of subtle message in the EPRI report which says well, there are a whole bunch of other ways that the containments fail so we're only going to focus on this -- the message I got -- small fraction of the events that a filter might help you? This says a large fraction of the events a filter might help you.

MR. STUTZKE: Potentially. The problem here is it just says -- for the ILRT methodology it just says accident phenomena. And you can't really break out is it overpressure failure versus liner melt-through. Some of the analyses, the submittals actually give you that level of detail.

MR. MONNINGER: I think the other thing they potentially say is a filter by itself is not necessarily a solution. You need a package deal.

MEMBER STETKAR: Oh, I understand that. There's a lot of introductory material in that EPRI report where they go through winnowing down all of the scenarios into the subset that they're really going to look at. Okay, I guess I understand. Thanks.

MR. STUTZKE: Okay, slide 75. We went through every license renewal submittal up to February of this year and looked at all of the SAMAs.

And this is a breakdown by plant type of which SAMAs had considered filtered containment venting before, and if they had to what type of analysis was done, so forth and so on.

So, if you look at the 23 BWR Mark I's in 5 of the submittals the filtered vent doesn't show up. It's simply not one of the SAMA options that was evaluated. But it was evaluated in 16 of the other ones, 11 through a screening analysis and 5 through a more detailed analysis.

When we say "screening analysis," the way that that's done in SAMA is they take the baseline risk of the plant and they monetize it. And then one assumes that the fix, the plant modification being considered completely eliminates the risk. So the risk is now zero. If the cost of the implementation is bigger than that maximum possible monetized risk they screen it out. Something like that. And so that's where the --

MEMBER STETKAR: Monetized risk at $1,000 per person-rem?

MR. STUTZKE: Two thousand.

MEMBER STETKAR: Two thousand.

MR. STUTZKE: Two thousand. Yes, and there's an agreed-upon NEI methodology on how these SAMAs are conducted like this.

MEMBER CORRADINI: So could you just repeat that again please for the screening?

MR. STUTZKE: Okay, you take the total risk. So in this case we're talking about offsite risk, population dose risk, the offsite consequences that are computed from MACCS by the licensees through a level 2 type of PRA-type process, plus the onsite risk which would include doses to the workers, the onsite cleanup cost. In this case, in SAMAs they include replacement power cost, et cetera. And all of those risks are then monetized. So they come out with some sort of a dollar amount.

MEMBER CORRADINI: And they compare it to?

MR. STUTZKE: They compare it the cost of implementing a proposed --

MEMBER SHACK: The maximum possible benefit you could get from anything.

MR. STUTZKE: And so the point here is when you get this sort of screening analysis you don't get any detail about filtered venting and what they assumed in the analysis like this. So I had a look --

MEMBER CORRADINI: Just out of curiosity since they did a comparison of dollars to dollars, what were they using for the cost of the filtered venting?

MR. STUTZKE: Well, it varies. Some of them are at $1 million. There's a lot of them at $6 and then there's some at $10.

MEMBER CORRADINI: So all lower than what staff has been suggesting is the delivered --

MR. STUTZKE: You know, as you would suspect. You know, there's basically one quote that one utility made and everybody else copied it.

(Laughter)

MR. STUTZKE: Well, you know, in fairness they do 100 SAMAs. There's 200 different mods and they're looking for some efficient way to zap through the analysis like that. But I drilled down into some of the Mark I containments that actually provided.

This is the sum total of information on how those detailed analyses were actually done. Those benefits are not times 1 million or anything, that's just the actual benefit. Like this -- and you can see what they're doing is to adjust the accident progression source terms just by a factor of 2.

And it raises all sorts of questions because it's not clear that the venting to prevent overpressurization failure is part of the analysis here. It's not what we're really talking about here. So, I'm left with somewhat of a suspicious mind here that these things aren't maybe as illuminative as I thought they would be -- illuminating, illustrative as I thought they would be.

Okay, so while I was compiling tables -- don't worry, I'll start doing some analysis in a few minutes. There's been this debate or discussion within the staff on what the appropriate core damage frequency is to use in this type of an analysis because the severe accident event starts with the occurrence, the assumption that core damage exists. And so if one wants to calculate delta risk, those delta risks are directly proportional to the CDF. It's pretty simple. So, from NUREG-1150 a cdf --

MEMBER CORRADINI: Not in the real world though, right?

MR. STUTZKE: No.

MEMBER CORRADINI: Okay, yes.

MR. STUTZKE: From 1150 the Peach Bottom results using the Livermore seismic hazard curves sums up about 10 to the -4. The staff has three Mark I SPAR internal and external event models combined. Those are patterned after licensees' IPEs, we just adapted them over.

And you can see they're in the low 10 to the -5 ranges like this. The range of core damage frequencies from SAMA analyses from 2 to 6 times 10 to the -5. I should point out most SAMA analyses only do internal events.

MEMBER BLEY: How about this SPAR -- oh, the SPAR has the external vents in it.

MR. STUTZKE: There's a few. These are the ones that I have that are relevant.

MEMBER BLEY: The external?

MR. STUTZKE: Yes, these are the real external event, full set of fault trees, event trees.

MEMBER STETKAR: Without seismic?

MR. STUTZKE: No, these are with seismic.

MEMBER STETKAR: Those have seismic.

MR. STUTZKE: Yes.

MEMBER STETKAR: Oh, good.

MR. STUTZKE: But what I was saying was most of the SAMA analyses don't even do external events. What they do is put on an external event multiplier onto the benefit and to scale it up by a factor of 2 or 3 or 2.7 I've seen like this and it's not helpful because I don't really know what the CDF is coming out of it.

Then last and not least is what we've termed the global statistical value. That's five events, TMI, Chernobyl, three units at Fukushima divided by 15,000 reactor years. Gives you a number of 3 to the -4.

MEMBER CORRADINI: And that's close to the upper bound, the report upper bound in WASH-1400.

MR. STUTZKE: Right. Now, there is a staff working group looking at this separately so I'll set that aside.

Onto slide 78. I started to compile some offsite economic consequences. And I may get to your question of how do you know these numbers are any good, but MACCS is computing out of here.

The first place is in the reg analysis handbook. It says if you don't have information or opportunity to do a consequence study assume $3 billion for core damage and offsite consequences.

MEMBER CORRADINI: In 1990.

MR. STUTZKE: In 1990 dollars.

MEMBER CORRADINI: Wow.

MR. STUTZKE: Those actually came from NUREG-1150. Those are actually out of NUREG-1150. It's a little follow-on study that was done.

For the SAMA analyses, you know, they rangte between six-tenths of $1 billion up to $30 billion like that. Peach Bottom is up at $10 billion.

MEMBER BLEY: And those are whatever dollars were used when they were calculated.

MR. STUTZKE: At the time of the SAMA. So those are like 2005 up to the present time, stuff like this -- like that.

Looking on the internet I discovered a report that was issued by the Japan Center for Economic Research that was issued last year. And they estimated the total cost of the accident of $250 billion.

When you look at what they did they had $190 billion to clean up and replace the unit in that. In our regulatory analysis that's a separate thing, that's not part of the offsite cost. So I subtracted it out. So you get this $62 billion for the three units.

And I tried to look into the assumptions that were driving that and they said well, we'll just assume all land within 20 kilometers is condemned and we'll buy it. No cleanup, no interdiction, it's gone. And we'll pay people for 10 years that lived in that region. So it gives you a value.

Last and not least is the current cost

of the oil spill from the Deepwater Horizon accident. It's roughly $23 billion they paid out so far in compensation. And I realize I threw that one on there because it's an available number. I actually learned it watching football the other weekend. And the analogies are slippery -- pardon the pun -- with the oil spill because, you know, an oil spill is not like a reactor accident. But it's some large industrial accident so it gives you some ideas.

MR. MONNINGER: And maybe a marker for what we've done for this would be base case 2 where in today's dollars we calculated $1.9 billion.

MR. STUTZKE: That's correct.

MR. MONNINGER: Is our base case. And then we will then look at options.

MEMBER CORRADINI: Is there anything in the chemical industry? I'm thinking of the explosion in the plant in northern Italy that essentially the land had to be -- I don't think anybody's still living on it. I'm trying to think of the name of the accident. It was in the Dolomites. Do you know what I'm thinking of? It was an explosion of a reactor essentially going out of control and exploding. Loss of about 100 people.

MEMBER SIEBER: That was in India?

MEMBER CORRADINI: No, I'm not talking Bhopal. I want to get to a country that worries like we worry about it. So northern Italy. It was about in the late nineteen seventies, `77, `78. I'm pretty sure it was release of PCBs for dioxins.

MR. STUTZKE: I haven't looked at it in detail. The thing about Bhopal with the cyanide release is it all chemically combined and it went away. Cleaned itself up. So you raise a good point, I might be interested to collect some sort of comparable industrial accidents that leave the same lingering, long-term problem. Give us a benchmark.

Okay, slide 79. So, the decision was made we're going to focus on BWR Mark I plants. That's --

MEMBER CORRADINI: Seveso. S-E-V-E-S-O.

MEMBER BLEY: Thanks. That's been a few years back.

MEMBER CORRADINI: But lost a number of people in the general public and the land was contaminated for a wide region.

MEMBER STETKAR: Marty, on the previous slide, just a quick one. They're really interesting dollar comparisons. Does it give you much pause with the guidance that's in NUREG whatever the heck it is, BR-0184 regarding valuations that are placed on these things?

MR. STUTZKE: I'm not going to bite on that question.

(Laughter)

MEMBER STETKAR: It was worth a shot.

MR. STUTZKE: No, I mean it's true. First of all, these analyses that's in the handbook are older. I mean they were done right after 1150 was done. And you know the plants are different that way and of course the population, the demographics have changed, et cetera, et cetera.

MEMBER STETKAR: Okay. Sorry. It was worth a shot.

MR. STUTZKE: Okay, so as far as coming up with a technical approach obviously if I were king we would have banks of level 3 PRAs sitting up in the Office of Research that I could go diddle with and things like that. That's not going to happen like that. We do have some simplified level 2 SPAR models but those are more proof of concept that the Sapphire Software platform actually will link things together like that.

MEMBER SIEBER: And they're just

internal events too, right?

MR. STUTZKE: Those are internal events. And so there is some effort to expand the level 2's into level 3's and into this -- to throw in the external events as well. It's the ICM model, integrated capabilities model. But those are still in the future so I don't have, you know, fully operational quantum loaded PRA so to speak to play with here. So bear that in mind.

The other thing was that as the analyses were progressing I kept getting different sensitivity runs from the MACCS people and the MELCOR people. We did this run, you know, no, we did this one.

Okay, so what I did was I tried to organize them into what I'll call candidate modifications classified according to how does the vent get open. Is it manual or is it passive through some sort of a rupture disk because that drives the frequency of the sequences.

The other two, where it's located. Is it installed on the wetwell or on the drywell and is it filtered or is it unfiltered. That affects the consequence estimates. So I ended up with eight modifications to the third power and ran those into the PRA. And so what you'll actually see are the delta risks with respect to what I call mod zero which is the base case for each one of those. So you can see, you know, the change in risk if I have a passive drywell event without a filter. It's in the pages.

The other thing that's necessary within the event tree structure is to consider the fact liner melt-through may be prevented by installation of portable pumps or something like this. And we wanted to credit that.

I think one of the things that bears repeating is when we started the analysis it was believed, and if you look at some of the old PRA results we break down containment failure modes. Oh, it's overpressure or it's a liner failure. And we don't really talk about the fact you can have both. It's an overpressure, oh, and then the liner failed some hours later. We tend as PRA analysts to group them and of course we all think mutually exclusive and it ain't so in some cases. You can have multiple things like this. And so you'll see when I get into the structure I've tried to be very clear about what I thought was going on here.

Some of the assumptions and the ground

rules here is we're using the existing guidance so we're looking at a per-reactor basis. We're not looking at multi-unit accidents yet.

We're not looking at spent fuel pool accidents although my office director really wanted me to go after that. The idea is well, without the vent then you get Fukushima and maybe the spent fuel pool gets damaged and there's this release. And I'm going I don't know how to estimate the risk. There are projects going on to be able to do that. So it's set aside.

The other thing is that if you look at the suite of MELCOR and MACCS runs -- and on a personal note, I mean this has been a very collaborative agreement between the Division of Risk Analysis and DSA over in Research. We've worked very closely. But unfortunately they can't run all the sequences I can dream up.

It's like, well, what about LOCA sequences or ATWS sequences, you know. Let's get to some of the really sexy ones because all you guys are doing are blowing the plant down and watching, you know. Kind of boring. So everything I have is station blackout sequences and from that I have to infer well, does it apply to all types of sequences that I'm interested in.

MEMBER STETKAR: Marty, do you have a sense of other high-pressure sequences, how well station blackout does as a kind of/sort of surrogate for those?

MR. STUTZKE: I really don't.

MEMBER STETKAR: You don't? Okay. I was trying to think about that and I'm not sure either.

MR. STUTZKE: I mean, one could argue, you know, if I had a LOCA that voids the vessel then maybe the sequence progression is roughly the same as when I voided it with station blackout. That may be true with respect to the core but probably not with the containment conditions.

MEMBER STETKAR: Yes, that's what I'm starting to think.

MEMBER CORRADINI: Is a loss of heat sink considered a subset of a station blackout?

MR. STUTZKE: I think it would be, yes, a subset of that. It's more benign. It's like I say, this starts with the teapot full and it just boils it down.

MEMBER RAY: Well, wait a minute, Mike. Suppose you lost the heat sink due to a dam failure?

MEMBER CORRADINI: I simply asked --

MEMBER RAY: I understand. I understand why you asked the question but I'm just trying to say it doesn't seem to me like it's a subset of SBO.

MEMBER CORRADINI: But wouldn't it progress in terms of the accident similar to it? It's essentially an outside, it's an outside-in event but you still would progress that you're all bottled up.

MEMBER RAY: Very possibly but if the dam failure was very likely and the SBO was very unlikely it seems like the two things are unrelated.

MR. STUTZKE: Okay, we had the most MELCOR and MACCS cases for the 16-hour RCIC time. Yes. And so you know, the presumption is well, the thing's going to run 16 hours. I used the smallest decontamination factors when filtering was considered, generally 10. Standard PRA assumption about no credit for recovering offsite power if it's an external event.

The last bullet turned out to be rather important in the analysis, and it's the notion that as John had said before, venting a containment is only part of the fix. You need to cool the debris bed.

And the assumption that I made in here was, well, if you failed open a vent so now you -- we always talked about it as you're going to lift the drywell head. Well, you might fail other parts of the containment. And the point is that the reactor building or the aux building would be contaminated and it's certainly going to be full of steam and things like that. And so the assumption I made was once that happens if they don't have the portable pump and running it's not going to happen.

And if you look at the timing of the MELCOR sequences for all of these you're seeing core damage, the onset of core damage is about 24 hours. And the challenge to the containment is roughly at 25 hours. So with 1 hour after core damage you begin to get this 80 pounds inside the drywell. So it basically says then if the portable pump doesn't get up and running in that 1 hour after core damage it's not going to happen. And you'll see how that's reflected in the tree logic.

So without further ado we came up with a simple release tree. Let me walk you through it for those that are not PRA analysts. Generally the up-branches mean yes or success, the down-branches mean no or failure. The tree progresses through a partitioning process. So we take the total core damage frequency and we divide it up. Some fraction of it's due to internal events, loss of offsite power, loss of grid, the LOCAs, things like this. Some portion is due to external events, seismic, tornados. Floods.

From that then we partition them into sequence types. And the characteristic, the defining characteristic here is one is what's going on with offsite power because offsite power could be recovered at some time. And the other thing is what -- how much available time does the operator have to respond. Some of these sequences like ATWS, the operator would have very little time to get a manual vent open. In other cases he's got time to do it. So I tried to partition the sequences that way.

Then funny enough the "other" category means it's not station blackout, it's not an interfacing systems LOCA and it's not one of these faster transients. It's all other. Same sort of partition exists for the external events except we've already assumed that offsite power is gone so it collapses down to simply bypass or not bypass.

Then you see the venting, you vent in there. The key assumption here is venting is always required, every sequence. The only time it's not required is if we're talking about bypass sequences, interfacing LOCAs or the containment. External event bypass means the containment is actually opened up like some seismic event has ripped the penetration loose from the steam line.

MEMBER STETKAR: How do you handle the fraction of containment isolation failures?

MR. STUTZKE: Those would be in the bypass. But you'll see it's --

MEMBER STETKAR: Okay. I just wanted to make -- okay.

MR. STUTZKE: They're intended to be in there and I understand.

MEMBER STETKAR: I mean, you know, a reasonable fraction of scenarios are containment isolation failure.

MR. STUTZKE: Right. Okay, then finally given that venting succeeds we can consider the use of the portable pump to provide either injection to core spray or into drywell spray. If venting has failed you see it goes directly to the end state.

The only subtlety here is if it is station blackout and venting has failed there's still a possibility to get water into the drywell.

If offsite power is recovered one could use condensate, high-pressure servicewater, things like this. So I included that in there.

Okay, so the 16 sequences then get classified as to what I'll call the status of the containment or the end state. And they're grouped into four bins, either the containment is vented, or it's suffered a liner melt-through, or it's suffered an overpressure failure, or it's suffered an overpressure failure and then a liner melt-through.

Now, quantification. Right now we accept the values as shown in this table, and there's some rationale behind them. The current core damage frequency is at 2E-5 which is out of the SPAR external event models. As I said the staff is debating this now. We did a sensitivity study at 3 times 10 to the -4 and I think Karen will show you some of those results.

The breakdowns, split fractions are coming out of the SPAR models, whatever they are. The one that I don't really have a good feel for is this breakdown of external events that you bypass the containment. NUREG-1150, that was one of the major failure mechanisms where the assumption was that the transient knocked the reactor vessel off its pedestal and it pulled all the steam pipings through and made this horrendous hole. And we no longer that's as likely as it was.

Okay. As far as the treatment of this I should -- the probability that the vent actually fails. One of the things that I did rather cleverly as a parenthetical comment is that I drew a single event tree and designed it so that I could get all of the cases by changing one number in the tree. And that number is the probability the venting fails. Everything else works.

So, for this mod zero, mod zero is the current base case. You just set the probability a venting fails to 1 and it's no credit for all it and the tree works out. For these others who are slower scenarios, station blackouts, 10 to the -3 comes out of the SPAR-H manual. I bumped it up a little bit for the faster transients to half. For the ones where venting is done through the rupture disk, the passive failure, I set it at 1 in 1,000. It seems a good mechanical reliability number. We have good offsite power recovery data for internal events from NUREG/CR-6890.

And the probability that the portable pump as installed is driven by SPAR-H. That one actually is very consistent. We had Idaho Labs a number of years ago do a study of the B.5.b mitigative measures and these are numbers that they derived.

MEMBER STETKAR: That includes the human --

MR. STUTZKE: It's all human. The hardware's not in there.

MEMBER STETKAR: A little better than that.

MR. STUTZKE: Yes. And it's almost implementation error but I won't even try to break it into diagnostic versus something like that. But yes, this is to account for the guys running around the plant schlepping the pump where it needs to go, running the hose where it needs to be installed, these sorts of things. Okay.

Now, for the mystery table which makes sense to me, but --

(Laughter)

MEMBER CORRADINI: So did you just skip it or what?

MR. STUTZKE: It would be faster if you just don't ask any questions.

(Laughter)

MR. STUTZKE: Okay, going across the top up here it says "Release Sequence End States" and hopefully you will recognize vented liner melt-through, overpressure or overpressure and then liner melt-through is that identifier. Those match up to the end states on the event tree, okay?

And because you are having as much problem as I do, you know, the MACCS people, the MELCOR people, they know that case 7B non-filtered means this and I don't know what that means. So I had to write my little pneumonics. Oh, that means it's vented. That means it was stuck on the wetwell. Okay? And that's what these designators are for.

So up here at the top when I say vented it means the containment is vented and the drywell is wet meaning there's no chance of liner melt-through. Or it's vented but the drywell is dry so there's no overpressure failure but liner melt-through could occur. And so forth. And the sequence numbers here that match each one of those end states are summarized so you can sort that out.

The more difficult problem now is coming down on it I have the description of the plant modifications in terms of the vent location and the filter. Remember what distinguishes a modification is the location, filtering or non-filtering, and actuation method, passive or manual.

As far as the consequences go I can lump manual and passive together because that only affects the frequency. So the way to read this table is if I want to consider modification 1, well, what is that modification? That is a wetwell vent that has no filter but is manually actuated. That's the definition of mod 1. And I wanted to know what MELCOR case, MACCS case I should use to worry about overpressure failure. And I would read over and say oh, that's case 6.

So, the consequences then change depending on which modification I have in the tree which accomplishes the other thing. And so I do this through a lookup function.

Another example is if I wanted to have mod number 6. So that's a wetwell location, it's filtered and it's passively actuated. And I wanted to know what is the consequence of the vented sequence I would use either case 7 or case 15. Seven is the case of course spray, 15 is the case of drywell spray. And in both cases it's the filtered case. So that's the magic link between all of the

MELCOR and MACCS runs that you've heard about and the end states of the event tree.

Okay, results. First is contributions to different types of containment failure modes. Again, these are only affected by the probability of actuation. So whether it's manually vented or passively vented, doesn't matter what the consequence is because we're dealing with frequency contributions. And so you'll see the various contributions lined up like that.

That total number is -- I'll call it, it's analogous to conditional containment failure probability. And the reason why I'll say that it's analogous is, you know, is containment venting actually a containment failure? Well, no. You've tried to preserve the containment's function but in fact the containment is not tight.

And so to avoid this word play with you, if I said it was CCFP you'd go oh, it's a failure, and I knew I couldn't win that argument. So I'll call it analogous with that understanding. Obviously if you had it in the containment venting it goes to 100 percent because it has to go to one of those categories. So that's the information. But it's a notable reduction.

What actually happens is that as you add the severe accident vent on here you move from one end state to another. So you begin to avoid the overpressure failures followed by liner melt-throughs. They just become pure liner melt-throughs. There's no overpressure failure so they shut.

MEMBER CORRADINI: You talked about this and I guess I now don't remember. How do I have the overpressurization liner melt-through? Because later on I dry out the drywell and then it proceeds onto liner melt-through?

MR. STUTZKE: Right, right.

MEMBER CORRADINI: Okay. And then the reason that that's so dramatically less in a passive is because there's some sort of failure to manually open it when you wanted to?

MR. STUTZKE: Right, and the passive is very reliable.

MEMBER CORRADINI: Okay.

MR. STUTZKE: Rupture disk. Okay. Slide 86 starts the baseline risk results. These are the point estimate values. We'll talk about the uncertainty in a little bit. And I've tried to put this header on the top so you can easily distinguish on the lefthand side are all the unfiltered cases and the right-hand side are the filtered cases, this location of a vent, wetwell versus drywell, and then where it's manual or passive.

And these are the changes, the reductions in risk with respect to mod 1. So green means it's a reduction, red means it was actually a risk increase. So the way to read this table would say if I'm interested in a filtered wetwell vent that has a rupture disk, it's passively actuated, that's mod 6 and the point estimate, delta person-rem per reactor year is 8.2. That number then gets input to the reg analysis, monetized by $2,000 a person-rem, discounted over time, et cetera, and Aaron Szabo will explain that.

MR. MONNINGER: So what's important is, for example, he talked about mod 6 there. We're comparing that back to mod zero or the base case. And for our base case the failure was liner melt-through and overpressurization. It didn't consider what we talked about before, the potential for drywell venting or wetwell venting.

So we're comparing all eight of these cases to no venting capability at the site. Because our first potential option would be to beef it up to the severe accident capable and the next one would be up to the filter. But we're not comparing these cases against the potential for drywell venting.

MEMBER ARMIJO: So this overstates the benefit because the base case has been defined very conservatively.

MR. MONNINGER: The base case is actually very minimal releases. The base case was --

MEMBER CORRADINI: Oh, the base case is really containment failure.

MR. STUTZKE: It'll be a combination of overpressure failure and overpressure followed by liner melt-through failures. The base case says, as John said, simply no venting is considered post accident. So the phenomena evolves the way that it's going to evolve and there's consequences to that.

MR. MONNINGER: So it's way back there. It's case 2 on page 41 and 43.

MR. STUTZKE: Like the MELCOR and MACCS folks I actually have a writeup and you can see the raw numbers for each modification. What I've shown you here are the deltas relative to the mod zero.

The red bars for mod 3 and mod 4 should

not surprise you. That says I have an unfiltered hole in the drywell. We all know that's bad.

(Laughter)

MR. STUTZKE: That's the reason why we have containment.

MEMBER SIEBER: And why you have them in red.

MR. STUTZKE: The next slide on 87 is the change or the reduction in offsite cost risk. And you see similar sorts of trends like this. You can see that installing a severe accident vent on the wetwell is better than on the drywell because of the scrubbing effect a little bit like this. Obviously filtering is beneficial and passive actuation is better than manual as far as the reliability goes.

MEMBER ARMIJO: Not a whole heck of a lot.

MR. STUTZKE: Surprisingly not a whole heck of a lot. And considering the uncertainties.

MEMBER POWERS: Those numbers are almost identical.

MR. MONNINGER: But then it's -- we only gave it a decontamination factor of 10 though for the filter.

MEMBER POWERS: Probably all it deserves.

MEMBER STETKAR: And this is only $2,000 per person-rem.

MR. STUTZKE: Actually these numbers don't defend on that monetization constant. These are directly out of the MACCS output and so they know the dollars --

MEMBER CORRADINI: So this is what MACCS is computing with all its --

MR. STUTZKE: All of its horsepower and assumptions, yes. The $2,000 would be on the previous slide on 86, a rough monetization.

Okay, we also have reductions in worker dose risk and onsite cost risk. And the assumption there on the consequences, those are not coming from MACCS because MACCS can't calculate onsite consequences. So in the regulatory analysis we used a value that said well, if it is vented and it's unfiltered the dose rate will be this. If it's vented but it is filtered the dose rate will be somewhat lower. And if it's a containment failure the dose rate to the workers is some really big number.

Same thing with the cost, cleanup cost.

You see on slide 89. That's why you don't see a distinction between wetwell versus drywell in these slides. The cost is the same.

What is interesting here is that some of the earlier mods, mods 1 through 4, it's unfiltered and yet there is a benefit to the worker. That's because you've discharged it to the environment and gotten it away from the worker. So it makes sense.

Last and not least on slide 90, remember I talked to you before about the reduction in conditional contaminated land area. And these are the results.

So one way -- the way to interpret this is let's consider -- let's pick a different mod now, being mod number 2. So it's an unfiltered severe accident vent attached to the wetwell passively actuated. 224.8 fewer square kilometers that would be contaminated above 15 microcuries. That's the reduction in the land area that's contaminated above 15 microcuries per square meter.

And as you would expect these pattern-wise match the population dose risk and they match the offsite consequence risk. You see the red bars are in the same place. I won't argue that they're the same heights, but you see the same general trend.

Okay. As part of the regulatory analysis in addition to the point estimates you see one needs some estimate of the high and the low values. And thinking about it a little more and thinking about the complexity of the event tree structure it wasn't clear to me how to generate the high value. Because if I say well, I increased the probability that the vent fails to actuate, the risk goes down a certain pathway. So it just seemed easier to do some sort of an approximate Monte Carlo approach to get a real feel for how this thing was behaving like that.

This is under the type of analysis that says the purpose of computing is insight, not numbers. And so I realize it's not a real formal analysis like that but it's trying to get a feel for where the uncertainty slides. So I put distributions not only on the numbers that affect the sequence frequencies but also the consequences.

And we'll talk a little bit about how that was done before I show you the results. CDF, that was actually the easy one. It's log normal, error factor of 10. People would debate whether it's log normal or it's gamma but it's not unreasonable.

For all of the various split fractions they're beta. The actual method is called constrained non-informative power distributions. That's why all of the parameters are set to one-half and the other ones come out. I preserve the mean value.

The technical insight is that when you get to split fractions that have more than 2 and the breakdown would be the sequence types for internal hazards have four different categories. How do you model that? Distribution. Generalized beta distribution. So technically that was fun for me, how to generate dose in Monte Carlo trial. Turns out to be trivial, something like that.

Flipping over to the next slide, mod zero were the event assumed to fail with probability 1's, not uncertain at all. The others follow on these distributions.

Consequences. How do you put uncertainty on the consequences in this type of a form? Obviously you would want to know the aleatory uncertainty because of the weather variations like this, but there's also epistemic uncertainty floating around like this.

Well, the SOARCA team has been working on this and I can tell you, I've read the draft uncertainty report and it is a tour de force of modern uncertainty analysis. If you have insomnia --

(Laughter)

MR. STUTZKE: -- it will fix that. It's actually, it's quite good. I shouldn't joke. I mean, how to break out what's driving the uncertainty in that type of an analysis is very, very impressive and I learned a lot out of it.

But, being that way, the easy way to generate the consequences is to assume that they are totally correlated, they're totally dependent. That means if the consequence in case 2 should be higher so should it for all the other consequences, so they're proportional. So I moved them up in lock-step, just scaled them up.

And I said well, okay, so that simplifies my computational issue too because it means I only need to generate one random number and I can calculate all the consequences because I'm just scaling everything. And I said well, not knowing any better, must be log normal with error factor of 10. I had read once in IEEE transactions on reliability about 25 years ago it says everything looks log normal until you look.

MEMBER POWERS: That's exactly right.

MR. STUTZKE: You know?

MEMBER POWERS: Log normal fits everything unless you look at it closely.

MR. STUTZKE: So I threw it on here and then lo and behold I got the draft on SOARCA uncertainty results. They gave me the 5th and the 95th and the median and so I got three points. And I dutifully plotted them up on log normal probability paper and it's almost a straight line.

(Laughter)

MR. STUTZKE: Like you said, don't look very hard.

MEMBER STETKAR: And you were shocked to learn that.

MR. STUTZKE: Yes, it turns out the error factor is about 4 for latent cancer fatality. And I'm going well, okay, so my 10 wasn't too far off, and given the crudeness of this analysis. So anyway, that's the spirit in which this is done, to try to get some insight as to how bad -- how much the numbers could be moving around.

So the next sets of viewgraphs show you

this. In all cases if you look at the ratio of the 95th to the mean values it's about three and a half to four, four and a half. It doesn't seem to change from mod to mod, it doesn't change from consequence to consequence. And it doesn't surprise me because what drives the uncertainty here is the uncertainty on the core damage frequency and the uncertainty on the consequence. All of the uncertainty on operator reaction and whether the pump's going to be installed seems to be irrelevant and that's not surprising.

MEMBER CORRADINI: It seems to be what? I'm sorry.

MR. STUTZKE: It's irrelevant. It's not driving, it's not affecting these numbers.

MEMBER CORRADINI: Not dominant.

MR. STUTZKE: But you would expect that, so. So we can flip through the last sets of slides. I don't know that there's anything to point out other than you don't see mods 3 and 4 in the uncertainty analysis. After realizing they were not beneficial I just kind of dropped them out of the analysis. There's no reason they couldn't be done.

I think maybe to wrap up here, these uncertainty results again, you know, the high and low values needed in the reg analysis will be taken as the 5th and the 95th values out of these types of computations. It's probably a wide enough range to demonstrate what the reg analysis needs to do.

If you all would care to comment on this conditional contaminated land area risk metric I would be very interested in that. Whether it's useful. I think it's misleading. I thought about it a great deal before I came up with this thing and it's still not totally satisfying in some aspects.

Or not comment formally, drag me out in the hallway.

CHAIR SCHULTZ: Comments for Marty on this particular issue or other questions?

MEMBER ARMIJO: I have a question. On your slide 90 I'm still trying to make sure I understand. The case in which you have drywell venting either manual or passive but no filtering, there's an increase in the contaminated land area.

MR. STUTZKE: Yes.

MEMBER ARMIJO: But the base case has no venting at all, no filtering and it fails at containment somehow, somewhere along the line.

MR. STUTZKE: Right.

MEMBER ARMIJO: How can this be worse?

MR. STUTZKE: This way you gave it a direct path outside the reactor building. There's no holdup. There's nothing slowing it down in mods 3 or 4.

MEMBER POWERS: Plus you release when you open up the vent and you do not get the benefit of any agglomeration and deposition in the containment.

MEMBER STETKAR: Okay, so you don't have any holdup volumes.

MEMBER CORRADINI: And just so I -- I've got to look back. In mods 3 and 4 -- I can't remember what slide it is. Mod 3 and 4, there are cases in there where the drywell has core sprays on it? Sorry, but I don't remember now.

MR. STUTZKE: You're on slide 84?

MEMBER CORRADINI: Right. I'm trying to understand mod 3 and 4 is manual passive in terms of that, but within that cases there's case 214, 12 and 13 which means you have a wet -- I do have a wet drywell.

MR. STUTZKE: Yes. That's what the upper rows are for because I couldn't remember them either.

MEMBER CORRADINI: Okay. I do have a

wet drywell but none of those are core sprays.

MR. STUTZKE: Well, if it says wet drywell that means in your core spray or drywell spray is on.

MEMBER CORRADINI: Okay. I'm sorry, I'm sorry. I'm sorry.

MEMBER BLEY: And we always have RCIC working?

MR. STUTZKE: Up to 16 hours until it turns itself off.

MEMBER BLEY: Always works. It never fails.

MR. STUTZKE: No, there's no RCIC fails on demand.

MEMBER BLEY: Or over time.

MR. STUTZKE: I hear you. That may be, you know, it goes back to that assumption. Everything looks like an SBO until you look.

MEMBER STETKAR: Well, but if you looked at one of your earliest slides 83 percent of the internal event scenarios don't look like an SBO.

MEMBER CORRADINI: But that's not what he's modeling. He's modeling the 12 percent.

MEMBER STETKAR: I understand that. That's what we're saying.

MR. STUTZKE: Well, the 83 percent that are not SBOs, the frequency is like it's what it is, but the consequence is assumed to be just like an SBO. Because we don't have MELCOR MACCS runs for those non-SBO types of scenarios.

MEMBER STETKAR: But I mean, part of that 83 percent is things like loss to feedwater and RCIC fails to start.

MR. STUTZKE: All of these things.

MEMBER STETKAR: Which are high-pressure melts.

CHAIR SCHULTZ: Other questions?

MEMBER BLEY: I have to study this stuff.

MEMBER SKILLMAN: You asked about our reaction to your contaminated land area.

MR. STUTZKE: Yes.

MEMBER SKILLMAN: I think it starts the conversation. I'm not sure that the metric gives exactly what it needs to be but I think it gets the conversation going. So I think it's constructive, it's useful.

MR. STUTZKE: I appreciate that because there's so many different metrics MACCS2 could actually produce. You know, they can talk about the number of people that are evacuated, they can talk about the amount of land that is interdicted, the amount of land that is condemned. And the distinction being that MACCS2 is using a return criteria which is expressed in terms of dose. This is contamination per unit area which in my mind is a different beast, it's a different animal.

MEMBER BLEY: I'm having a little trouble with one thing. I'm trying to align your mods with the cases. Mods 3 and 4 with the vented drywell always look bad. But in some of those cases you'd have drywell spray, right? Why don't we see something that lets us -- between 3 and 4 when do we have drywell spray? When we look at your results with the red bars on them we just see 3 and 4 bad and there's no distinguishing between those.

MR. STUTZKE: Yes. The question is which sequences does it go to.

MEMBER BLEY: Yes.

MR. STUTZKE: And --

MEMBER CORRADINI: Because you have -- just so I say it, this is what I was confused about. You have four sequences folded in, into any one of the mods.

MEMBER BLEY: Yes. And they're not

equally --

MEMBER CORRADINI: Or not necessarily four. You could have four or five.

MR. STUTZKE: Yes, the event tree sequences apply to all mods, all 16 sequences applies to every mod. And what you're changing is the frequency, the proportion that goes there and then the consequence that you multiply it towards.

MEMBER BLEY: So I can't see what I'm looking for because they're --

MR. STUTZKE: I haven't given you the level of detail --

MEMBER BLEY: -- probability weighted.

MR. STUTZKE: Yes.

MEMBER BLEY: Frequency weighted.

MR. STUTZKE: Right.

MEMBER BLEY: Yes.

MR. STUTZKE: In other words --

MEMBER BLEY: But some of those things would make a big difference. I would think they would make a big difference.

MR. STUTZKE: See, in other words if I go to wetwell venting -- or excuse me, drywell venting, that's the issue. Mods 3 and 4. Can we flip back to slide 81 to look at the actual tree structure?

MEMBER CORRADINI: But the way I interpret your table is there are four sequences that are within those two mods. Or is that an incorrect interpretation?

MR. STUTZKE: I think that's an incorrect interpretation. The way to interpret it is there are five sequences that comprise this vented status. Sequences number 1 and 4, 5, 10 and 13. Right? All of those are binned into this vented scenario which then if I'm going to evaluate modification number 3 I will apply MACCS case 13 to get its consequences.

MEMBER BLEY: Now, just this particular point I was hanging on. There will be differences in the results of each of those sequences that sit in there. We can't see that.

MR. STUTZKE: Not at this level of detail.

MEMBER CORRADINI: Nor do we know which one of those might dominate, of the five which one might be a dominant one or they just all are --

MEMBER BLEY: We might be able to dope that out if we look at them and think about it.

MEMBER STETKAR: Marty knows that.

MR. STUTZKE: It's in there but at the same time --

MEMBER BLEY: But I mean, the problem we were having, we were even talking about this. This says venting the drywell looks terrible. But if simultaneously you're spraying the drywell it probably doesn't look as terrible. You just can't see that in the way the results are summarized.

MR. STUTZKE: Right. Yes, I need to give you the further breakdown.

MEMBER BLEY: There must be more things like that that are kind of hidden because of the categorization we did. Which means we might draw some conclusions at this level that you might not hold. Except they should be probabilistically weighted such that they're probably okay.

MR. STUTZKE: Yes. I mean and that's the intent.

MEMBER BLEY: I have to think about that a bit more.

MEMBER CORRADINI: But can I -- I'm sorry that I -- now that Dennis asked a question now I'm -- so case 12 in terms of the MELCOR calculation linking to the MACCS calculation drives all five of these branch points, of these event tree branch points.

MR. STUTZKE: End states.

MEMBER CORRADINI: Case 12 is drywell vent at 24 hours.

MR. STUTZKE: Right.

MEMBER CORRADINI: Essentially modifying case 2 which is the base case. And that has the highest release fraction that MACCS then went and sends out.

MR. STUTZKE: That's correct.

MEMBER CORRADINI: And it's higher than everything. So unless one's looking at the MELCOR calculation and says there's something inherently conservative with that, that drives all five of the cases.

CHAIR SCHULTZ: And so the integrated response is fairly similar between each of these presentations. For each of the metrics that were chosen.

MEMBER CORRADINI: Yes. Because that's the highest release fraction that would affect all these key contributors, at least from what we heard from the previous presenters.

CHAIR SCHULTZ: Where those previous presenters were focusing in on particular event sequences and the differences in results. Core vent and no vent.

MR. STUTZKE: Yes, and what you see there is probabilistically weighted. It's the sum times the sequence frequency times the consequence summed up. Classic risk definition.

MEMBER BLEY: When we get to the point of figuring out whether your qualitative arguments eventually make sense some of it's going to hinge on the stuff that's tied up in this analysis in ways that we've got to figure out a little bit to see if those arguments really carry through. Maybe there is a particular set of things within one of these cases that would look very well if we pushed it in that direction. This might not all be clear to anybody, I'm just babbling a bit.

MEMBER CORRADINI: My reaction is if we stopped at just what MELCOR says is released out of containment it totally is dominated by that cesium fraction. I mean, all the subsequent things are totally dominated by what you released.

MEMBER SIEBER: That's right.

MEMBER BLEY: Which if we go back to this case says -- that's case 12, right, that gets us that one?

MEMBER CORRADINI: That's what I read it to be, yes.

MEMBER BLEY: If that's right then within mod 3 and 4 which look bad on the charts we were looking at, actually it's just the LNT case that's so bad. This stuff's heavily interrelated. I don't know if you guys have had a chance to distill it at this deeper level to really be sure about what you've got. I'm sorry, Marty.

MR. STUTZKE: No, maybe another way to do it is to flip back to slide 85 that showed you the frequency contributions.

MEMBER BLEY: Back with the top cases.

MR. STUTZKE: Each one of those -- so these are the contributions for overpressure, liner melt-through or both. And by implication, for example, if I look at the manual vent column what it says is 46.8 percent are vented, right? It's 100 minus the 53.2 percent, right? And so ask yourself then -- so I'm going to take 0.4 percent times the consequences of the overpressure MELCOR case and 19.6 percent times the liner melt-through case, et cetera.

And so the bottom one here when you look at mods 3 and 4 that says I'm taking 46.8 percent times the vented case for mods 3 and 4 which says it's through the drywell, it's not filtered and the consequences are big as you pointed out. And that's why you get the big red bars.

MEMBER CORRADINI: That's why the red bar for the passive is larger than the red bar for the manual.

MR. STUTZKE: Yes, because you've made that hole even more reliable.

(Laughter)

MEMBER STETKAR: Some of the earlier stuff we said is you don't put a rupture disk on there, it's actually worse.

MR. STUTZKE: The other way to interpret it is if you were to look at slide 87 for this monetization and you see the big red bars, that means you should be willing to spend $592,000 to remove the system. It's that bad.

CHAIR SCHULTZ: And I think that was coming out in some of the results that were shown earlier from the MACCS study.

MR. STUTZKE: These are the reflections of the MELCOR MACCS results, just frequency averaged together.

MEMBER BLEY: Unless you can make sure

you don't get into that problem over here.

CHAIR SCHULTZ: That's correct.

MEMBER BLEY: You've got to do it in a couple of pieces to get the argument. Interesting stuff.

CHAIR SCHULTZ: Other questions?

MEMBER SKILLMAN: Yes, Marty, your global statistical value on slide 77.

MR. STUTZKE: Yes.

MEMBER SKILLMAN: I've never seen that before. Just how did you get the denominator, please?

MR. STUTZKE: It's roughly 15,000 reactor years of worldwide operation.

MEMBER SKILLMAN: That's the calculated value approximately today?

MR. STUTZKE: I saw that number reported on the WANO website, World Association of Nuclear Operators.

MEMBER SKILLMAN: Because I get a number about half that. I was just curious. Thank you.

CHAIR SCHULTZ: We are ready for the next topic before we have a break and the next topic is regulatory analysis. Aaron Szabo is going to be making that presentation. Bio break for 5 minutes.

(Whereupon, the foregoing matter went off the record at 3:35 p.m. and went back on the record at 3:44 p.m.)

CHAIR SCHULTZ: The next presentation is associated with the regulatory analysis and backfitting evaluation approach. Aaron Szabo is going to make the presentation from the staff.

Aaron, please proceed. Thank you.

MR. SZABO: I'm Aaron Szabo, cost analyst at NRR in the Rulemaking Branch. I work on the regulatory analyses. Next slide.

This is just generally an outline I'm going to go through. I'm just going to apologize now for anyone who was here yesterday afternoon. A lot of it might be similar. Hopefully maybe we've got something new. But I'm going to go through just the regulatory decision-making process, the methodology for the regulatory analysis, kind of the methodology for backfitting and then just go specifically into the filtered vents regulatory analysis. Next slide, please.

So, the first point I want to make about regulatory analysis is it looks at all the costs and all the benefits for any regulatory action. The important thing to note is we've been talking in all these past presentations of quantified analyses to lead up to what eventually will go into the regulatory analysis.

But really the quantification is only one input to the regulatory analysis. For all those costs and all the benefits we can't quantify we do qualify them which the next presentation is going to go into in more detail.

And also with the regulatory analysis it's important for us to just outline all the uncertainties with the analysis which you guys have seen throughout today. In relation to just backfitting for this situation it's based under 10 C.F.R. 50.109 which is the backfitting provision. Next slide.

As you guys have heard before there's four options in relation to when you see the regulatory analysis. There's just a little bit of a terminology difference. We call them alternatives but it's essentially the same thing. We review all four of these options through this.

And we are doing that using the current framework which is NUREG/BR-0058 which is called the Reg Analysis Guidelines, NUREG/BR-0184 which is the Reg Analysis Technical Handbook and NUREG-1409 which is the backfitting guidelines. If there are any deviations that we make from the guidelines we just provide them as a sensitivity analysis.

I also wanted to just reemphasize a point about the technical handbook that Marty brought up. Really a lot of the numbers were used for examples. It was produced in 1997 based on earlier reports. And the idea is you try and use your MACCS code, your MELCOR and your MACCS when you can. You really just fall back on these when you don't have either the opportunity or the ability to use those codes. Next slide, please.

Just when we perform a regulatory analysis what we just do first is we identify the problem and just look at what the alternatives are. We determine if the action is a backfit which it would clearly be in this situation. And then we go through everything that we call attributes. Listed there is everything what -- the attributes we looked at for this regulatory action which include public health and occupational health in case of an accident, the offsite and onsite property as well as the industry and NRC implementation operation costs. As well as there's some other attributes like regulatory efficiency as well as some other situations like defense-in-depth that once again will be talked about more later.

We then combine all those attributes together, do a cost-benefit analysis and we develop some recommendations for the Commission. Next slide, please.

These recommendations are provided using what we call the best estimate calculations per the guidelines. As Marty pointed out their point estimates for -- in this case. And this is just kind of explaining what Marty's already done.

It's just -- we multiply all the benefits and the costs times the probability. We don't look at them without probability as clearly it would just obscure things to the high end and might give false impressions. And as stated before we provide sensitivity analyses for the decision-makers. Next slide, please.

On the backfitting, the first step in backfit after you determine it is a backfit and falls within the backfit rule is you look into whether it falls under one of the exceptions. Usually this would be adequate protection for these cases. So the first review the staff would do would be to look at whether any of these options would fall under the adequate protection determination.

If it doesn't fall under the adequate protection justification we then go into what's commonly called the backfit analysis. It's also called cost-justified substantial safety enhancement.

This is a two-part analysis. The first part is the substantial safety enhancement. The second part is the cost justified.

And I just wanted to lay out here something that the Commission stated back in 1993 in an SRM. It really states that for the substantial safety enhancement section they really want to keep it as a flexible option with what they originally intended. After the backfit rule the staff went back to the Commission with some lookbacks kind of on the backfit rule and this is what the Commission came back with.

It states that for the substantial -- that includes both quantitative and qualitative arguments. And the Commission would really like to see things that -- even if it's not necessarily considered what the staff might be substantial then if it's still cost-justified they would like to see it in front of them. And moving onto the next slide.

So for the substantial safety enhancement section the attributes that we would look at within the backfit rule would be just the public health and occupational health. So really the substantial safety enhancement section only looks at the averted person-rem and not at any of the onsite or offsite property or any implementation or operation costs. Next slide, please.

And then just moving onto the cost-justified section. This is where we would add in everything. And this is really, when you're looking at the backfit analysis this is really going to be almost exactly the same thing as the regulatory analysis. That's why the person who does the regulatory analysis usually just also does the backfit analysis. It's just a lot of reference to the regulatory analysis. And as you can see it's all the attributes that I listed earlier. Next slide, please.

As you saw during Marty's presentation he mentioned that the onsite property and the occupational workers came from the Technical Handbook and not from the MELCOR/MACCS code. I just wanted to provide within the Technical Handbook kind of where these numbers came from.

For the onsite property, option 1, your status quo is assumed was the upper bound of what they said the onsite property costs would be which were about $2 billion in 1993. And escalating using just a CPI, a consumer price index, to 2012 it's about $3.2 billion. Option 2 was what they considered their middle or best estimate. We assume that would be for just normal venting.

And option 3, the filtered vents we thought would be close enough to TMI that the options which were the low estimate or TMI for -- within the Technical Handbook would be similar to having a filtered vent. So, for the onsite property that was $750 million back when -- in 1981, or $1.9 billion today.

For occupational workers during the accident we used the same kind of analysis. The Technical Handbook had an upper, middle and lower or TMI and we followed the same idea.

Just as a quick note, it does assume there's 1,000 workers onsite working on this so they're all getting low dose. And the occupational workers does not include the decontamination cleanup cost of offsite property. That was actually subsumed within the MACCS2 public health, the person-rem code. So any of the decontamination or cleanup offsite was accounted for there. Next slide.

MEMBER SKILLMAN: Aaron, those options on page 109, slide 109 --

MR. SZABO: Yes.

MEMBER SKILLMAN: -- are the same options as indicated on slide 102?

MR. SZABO: Yes.

MEMBER SKILLMAN: Thank you.

MEMBER ARMIJO: Aaron, these numbers seem low to me. Let's take option 1. You -- or any of them. You lose the reactor, right?

MR. SZABO: Yes.

MEMBER ARMIJO: In these events. And replacement cost, is that included or not?

MR. SZABO: Sorry, just -- this is not including replacement energy costs. Sorry.

MEMBER ARMIJO: I mean the reactor, the investment.

MR. MONNINGER: It's just cleanup of the site, decommissioning and cleanup is the onsite property. It's not the replacement power --

MEMBER ARMIJO: Not considered --

MR. MONNINGER: -- or rebuilding it.

MR. SZABO: We do consider replacement energy.

MEMBER ARMIJO: Just the energy.

MR. SZABO: Yes, but that is -- it is part of the onsite property attribute but it is not within this part of the onsite property. This is just the property itself.

MEMBER SHACK: But again, if you're looking at a cost to society why not the cost of the replacement plant?

MR. SZABO: It will be -- it is included in the regulatory analysis. This was just showing these first couple of assumptions, these are assumptions that we do make that I'll be showing later.

However, for the plant itself because we're assuming that we're at -- there's core damage, there's severe accident, that unit itself is already lost. So we wouldn't -- there's no delta replacement energy from your status quo between your options.

So I'll go into this -- well I can go into this now. So your really only delta would be if you have a multi-unit site. This would be the difference between being able to work those other units. That would be the only consideration we would make within using the current framework as a delta between.

MEMBER ARMIJO: Yes, I was off base because if you lose a plant whether you have a filtered vent or a non-filtered vent you've lost the plant so it doesn't make any difference in the -- got it.

CHAIR SCHULTZ: But it is a good point for a sister unit onsite.

MEMBER ARMIJO: If you would somehow lose that you'd know it wasn't through contamination.

CHAIR SCHULTZ: That's a possibility.

MR. SZABO: Next slide. Yes, I'm about to go into -- go to the next slide.

So this goes into our current framework as well as our sensitivity analyses. Just going through the parameters so you can see there's about five different parameters that we've run sensitivities for. I'll just go through them one by one.

The dollar per person-rem, as was mentioned quite a bit yesterday as well as today.

NUREG-1530 is the dollar per person-rem. And it says that currently it's $2,000 per person-rem. There's a currently and ongoing effort to update that number.

Therefore, as just -- we believe as a conservative sensitivity analysis we use the most recent EPA valued statistical life which is $7.3 million as well as the most recent ICRP number 103. And this is using the same -- this is the same analysis that we did for determining the $2,000 per person-rem. The $2,000 per person-rem was just the value of statistical life times a risk cancer factor which was from ICRP number 60. This is just an escalation of that to determine -- to come to the $4,000 which we provide as a sensitivity analysis.

Also, the discount rate, we currently follow OMB Circular A-4 guidance which says that you should net present value, all values at 3 percent and 7 percent. The basis for these numbers, the 3 percent was your return on a government investment and your 7 percent was your return on a private investment. As we've seen --

(Laughter)

MEMBER STETKAR: Sure, you don't have to retire in the next couple of years.

MEMBER ARMIJO: Better check those numbers.

MR. SZABO: Those numbers, you know, might not necessarily reflect the current market. So as a sensitivity we're providing the undiscounted discount rate. And this is also for both benefits and the cost side because for your operation cost you do have to do a net present value for that.

Then, as Marty was talking about, for your CDF, for your initial event probability we used the 2E to the -5th for our current framework as well as the global statistical value just as a sensitivity analysis.

Once again, kind of when Marty was talking about his presentation he ran a Monte Carlo. We used the point estimate as our best estimate. However, we provide a low and a high of the 5th and 95th percentile.

And now onto replacement energy costs. So in the current framework we follow the Technical Handbook which was back in 1997 based on 1995 or earlier numbers which said it was about $15.4 million per year to replace energy.

Just to go into some background about how we do the replacement energy costs. We assume that every unit has a 10-year purchase power agreement. So what we do is we assume that if you have at least 10 years left in operation that you wouldn't necessarily just multiply this 15.4 times 10 because you have to discount the numbers, but it's similar to that. So, you losing a unit today at an undiscounted rate would really cost $154 million. The idea is that within 10 years they would have established new energy sources to replace that energy and would no longer be bound by that.

As stated, four, we assumed that the other site would be lost if you are not able to do a filtered vent. So we believe that there would be enough radiation from either the status quo or just venting without a filter that the other unit would not be operational and thus you would need to replace the purchase power.

Another ongoing effort is we have provided -- we have developed new, updated, regional-based replacement energy costs. And so just a high and low from that as they are sensitivity analysis is just -- it's either $716,000 a year up to $56.3 million. That's the lowest regional -- the lowest low and the highest high. As it's a sensitivity analysis we just wanted to provide the low and the high.

And generally for regulatory analyses under the current framework we do not -- things that are based on policy decisions are usually considered to be too speculative for us to consider. However, as we've seen from recent history the idea of a policy decision to shut down all Mark I and Mark 2 reactors is not unreasonable so we've also decided to provide that just as a sensitivity analysis. Next slide, please.

Just as I mentioned before, the recommendation, however, is based on the current framework. With all these sensitivity analyses we pretty much end up with 107 of them. So that kind of gives you an idea of the general range of where we're going, the highs and the lows. And there is quite a range in that.

And there is no sensitivity provided for the cost. However, we do provide a range for the cost.

MEMBER ARMIJO: Aaron, would you go back to that justification? What makes it reasonable to consider that all the reactors, the Mark I and Mark 2 containments would be shut down by the Agency?

MR. SZABO: Well, we believe that it

wouldn't be an NRC decision. This would clearly be a decision made by politicians as I don't think we would necessarily -- I don't know if we would have the right to.

MEMBER ARMIJO: Okay, so it wouldn't be a regulatory. It would be some --

MR. SZABO: Yes. This would be a policy decision above the NRC.

MEMBER POWERS: I guess what I don't understand is how does that change with whether I have a filter or not.

MR. SZABO: It would be considered a benefit for either venting or -- the idea is that all Mark I and Mark 2 reactors would be shut down if there was a significant release from a severe accident. So if they're able to mitigate the severe accident that it would still ensure enough confidence that the other reactors would still be able to operate.

MEMBER POWERS: At least my recollection of the results that were shown to us just previously is the only ones of those cases that was different was the one where you had an unfiltered drywell vent. Otherwise they were about the same. And so I'm still a little --

MR. SZABO: It would be the same benefit for both, for both option 2 and option 3, both venting -- having a severe accident capable vent and having a filtered vent would provide the same benefit in relation to that.

MEMBER ARMIJO: But you have the German experience where they have filtered vents. They're shutting down all their reactors. So, I mean how does that -- why is that?

MEMBER STETKAR: PWRs and BWRs.

MEMBER ARMIJO: P's and B's and everything. So, you know, it just seems --

MR. MONNINGER: That would argue to move it from a sensitivity to the current framework though, wouldn't it?

MEMBER ARMIJO: I don't know. I'm just trying to find out is it right to -- or at all.

MR. RULAND: The purpose of doing the sensitivity is just to provide information to the decision-makers. And you know, you can agree or disagree with the assumption but that's all, that's the purpose of doing the sensitivity study.

MR. SZABO: So you can ignore it if you don't believe any reactors would be shut down or, you know.

MEMBER BLEY: So this is just a one-liner. The sensitivity study would be how likely would it be that this would happen given the four or five scenarios we've got, or eight, I'm sorry. Whatever the number.

What is a sensitivity study? What I haven't understood is under this case what is the sensitivity study? What will you actually do? What's the sensitivity you'll be looking at? It's not sensitivity to this, this is a result, right?

MR. SZABO: It's a sensitivity in relation to its -- I guess outside our current framework is another way you can frame this. I mean, instead of a sensitivity it's just a -- I guess alternative framework is what you can think of it as.

CHAIR SCHULTZ: You have to presume that in the event of an accident, because we are assuming that the accident occurs, that the vent -- having a vent would make a difference as to whether you shut down all 30 units or not. It's just an economic evaluation of how much it would entail to shut down 30 units versus not doing it in the event that that would make a difference in public reaction.

There's other cases there of course.

One would be for an event to occur without a vent, and then that would cause all vents to be added to Mark I and Mark II's at that point in time.

In other words, there's a number of scenarios that could be envisioned and this is the worst one at least for the Mark I and II's.

MEMBER ARMIJO: Go ahead.

MR. SZABO: Those are the same four. There's quite a bit of sensitivity cases that are going to be -- we're currently working on, are going to be provided. I guess we'll get onto the costs.

We're still going through -- these are preliminary numbers. For option 2 the idea is that these are total costs, by the way, for industry. That would cost about $60 million so about $2 million per plant to install, to update the vents to be severe accident capable. And with our NRC cost as well it comes up to a total of about $68 to $72 million. Next slide.

So, here's the benefits for option 2 based only on the current framework. The ranges are just based on the 3 and 7 percent discount rates. So the public health, the total person-rem averted is 112.

MEMBER CORRADINI: And where does that

come from? Just remind me where that comes from then?

MR. SZABO: That's Marty's -- what Marty had before based on reactor year. So he had I think it was like 4 person-rem averted per reactor year for wetwell.

MEMBER CORRADINI: That's why I was going back to Marty's to find it.

MR. SZABO: Yes. So then you multiply that by the 31 reactors per year and the average life let is 25 years. So I'm not --

MEMBER CORRADINI: Marty had -- oh, I'm sorry. You're right, four. Sorry.

MR. SZABO: So it's that times 31 times 25 gives you about your 112.

MEMBER BANERJEE: Is there any benefit to the goodwill? Like companies say things are worth $1.5 billion goodwill. We have that. Like Proctor & Gamble will say a branding.

MR. SZABO: No.

MEMBER BANERJEE: We have no benefit to goodwill out of this?

MEMBER POWERS: Goodwill is a fudge factor in accounting.

MEMBER BANERJEE: But that's more real

than most of these things. Does it give you any benefit of public perception?

MR. MONNINGER: You could potentially include it within the qualitative arguments if you felt it's --

MEMBER BANERJEE: I don't know, I mean these things are quantitative when it comes to public companies. I mean people put values on them.

MEMBER BROWN: What about the public confidence in the plants? I mean, there's no benefit at all granted for that at all. And yet based on the information, I mean the public confidence in Japan now is zero.

MR. SZABO: Well that's getting into the psychological benefits and there's questions as to whether or not the NRC is allowed to consider psychological benefits. I don't know if there's an attorney here. I know at least some of them would say you can't consider psychological costs or benefits. And that's based on a TMI case from back in the eighties.

MEMBER BROWN: So 30 years of not being able to do anything. Real bad public confidence at that time.

MEMBER BANERJEE: I think that's the

most important factor.

MR. SZABO: I guess it is a factor.

MEMBER BROWN: It's a big factor.

MEMBER SIEBER: It has to reflect itself directly in money. And good public perception of nuclear power will not increase sales. The plant is 100 percent. And so you may get a public benefit out of it but it's not worth -- it does not have a monetary value because it doesn't reflect itself in your financial statement.

MR. SZABO: And in general, I know you're talking about for the operator. It is -- the regulatory analysis does look at it in a societal framework. So really our only -- our delta benefit would be any I guess happiness from the people being more confident in it.

MEMBER CORRADINI: So I guess I'm -- I'm listening to what Sanjoy said. I haven't gotten past -- I still don't understand your 112. But where's the stock price loss in all of this? If I were a utility and I had one of these and I released it offsite what would my stock do? Would it stay where it is? I don't think so. So where's that cost or the negative of that cost reflected in any of this?

MR. SZABO: Well, I guess the -- my off-the-cuff answer, other than it being very speculative trying to come up with any number that, you know, other than having a line stating that we believe that the stock will drop.

MEMBER CORRADINI: You closed 30 BWRs just a minute ago on your sensitivity so it's not anymore nutty than that, excuse my English.

MR. RULAND: Aaron, you know, you don't have to go here, you know.

(Laughter)

MR. RULAND: I mean, this is -- this is very speculative as far as we're concerned.

MR. SZABO: Well, I just also wanted to get into the idea of transfer of payments which is what stocks essentially are. You know, someone has to buy it, you know, to sell someone has to buy. And it really comes -- we're looking at this as a societal whole. So even if your stock's dropping the idea that someone buys it is more of a transfer of payment.

MEMBER CORRADINI: But I mean just -- I'll push it, then I'll shut up. The Seveso accident in Italy, the chemical company went bankrupt. Bhopal, there is no more Union Carbide, okay? There is no more TEPCO. British Petroleum -- I mean, we can pick these accidents all over the place and they don't have to be nuclear and I guess I'm back to Sanjoy. Sanjoy's point said it in good perception. But forget percpetion, let's just deal with money. The company will suffer somehow. That's what I think you're getting at.

MEMBER BANERJEE: Well, the industry does. The Seveso accident led to the Seveso directive.

MEMBER CORRADINI: Right.

MEMBER BANERJEE: Which had an enormous impact.

MEMBER CORRADINI: On loss prevention for the chemical industry.

MEMBER BANERJEE: Hundreds of billions. So I think you have to be -- and then they had to install emergency relief systems which would handle two-phase flows, you know, treatment after that. It's a big deal. They had to do it.

MR. RULAND: Aaron, while these are interesting issues they aren't in our current regulatory framework.

(Laughter)

MEMBER ARMIJO: Could you just flip back

one thing to the previous 112? The cost. Those industry costs, are those the costs for the filtered vent? These are just the costs of the accident.

MR. MONNINGER: This is beefing up the valves for the existing order vent. We assume $2 million per unit.

MEMBER ARMIJO: We're still on option 2 with upgraded hardware. Got it.

MR. SZABO: Let's go back to the previous slide. So these are, as I was saying before, they're kind of just pulled from Marty's probability-weighted numbers and are extrapolated out over all the reactor years and discounted.

And as you can see the offsite property and onsite property provide a total benefit of about $16 and a half to $24 and a half million. However, as you can see the net value of option 2 is about negative $43 and a half to negative $55 and a half million for the industry total. Next slide, please.

Onto filtered vents. So here's -- filtered vent cost is, the assumption is about $15 million per unit.

MEMBER CORRADINI: So, now I'll take the other side of the coin. You guys have used that number three times today. I can't believe it's that cheap. I just cannot believe it's installed safety-grade seismically qualified. That is, that's --

MR. DENNIG: Not safety-grade.

MEMBER CORRADINI: Not safety-grade.

MEMBER BLEY: But it's got to be seismic.

MEMBER CORRADINI: It's got to be seismic. Fifteen million seems like a bargain basement price.

MR. DENNIG: That number is extrapolated from talking to vendors and talking to licensees. And that number includes in at least one case a seismic installation, the $14 million for Point Lepreau is seismic. The extent to which you would get a seismic installation here for that amount of money, I don't know, but that's not currently one of the things that's in the mix as part of the option is to make it --

MEMBER CORRADINI: My only reaction is that looks at least two to three times too cheap.

MEMBER ARMIJO: Yes, I agree with that. Does that include the parts of option 2, the upgrades in the option 2 to make this thing work?

MR. MONNINGER: No, this would be costing this from a clean system. It's not the delta from option 2 to the current. It's costed out on --

MEMBER ARMIJO: But if they actually did it they'd have to make some plant modifications to get this thing in. Anyway, the cost seems low.

MEMBER STETKAR: I don't know where you got your cost information, you know, your actual installed cost information. I'm familiar with a couple of plants in Europe that perhaps buried some of their cost because they were doing major upgrades to other emergency facilities at the same time. So how much they allocated perhaps to this particular feature might not necessarily be all that clear.

MR. BETTLE: Yes, the cost is going to vary considerably from plant to plant. In talking about like upgrading to a filter, the filter vessel itself is probably going to dictate the routing. Some plants might have to pretty much just sacrifice what they currently have and then be better off or a net cheaper arrangement is to go from scratch. So it's going to vary quite a bit if you just focus on that particular number.

Others are probably going to be there. Probably not a whole lot less, but probably in that ballpark. This is basically where the amounts of foreigners -- in foreign countries the licensees were telling us what they spent and putting it in U.S. dollars.

MEMBER STETKAR: Can I ask which particular countries?

MR. BETTLE: Sweden, Switzerland and Canada. Now --

MEMBER STETKAR: I know about Switzerland. I don't want to share information, but.

MR. BETTLE: Yes. The only guesstimate as far as the actual filter vessel that we've gotten, obviously these are a high-cost item and if you want to get a firm quote you're going to have to probably be ready to pony up money.

But you're looking at a ballpark of $3 million for a vessel size to handle just the filter itself, not the whole modification and piping system and valving and so forth. But the filter itself would be about $3 million for 600 megawatts. It's about $6 million for a 1,200-megawatt unit. I say that's not on the basis of a firm quote, so it's just a --

MEMBER STETKAR: That's without the massive reinforced concrete seismically categorized structure to house this thing. If you don't have one.

MR. SZABO: So that gives us the total of about $470 to $480 million for the cost. Moving onto the next slide.

So our benefits. Once again your person-rem for the public is about 212 averted, about 6 to 10 million, you know, slightly higher than what you saw for the severe accident capable.

The onsite property costs are really where you'll see a big delta here. And that's where you have your sites where you are now no longer losing the other unit because you're in pretty much what we assume sort of a TMI-type situation where it's only the one unit is really gone and you're still able to operate the other one. And that provides a total benefit from -- to about $125 to $211 million.

And as stated earlier, you know, that's not quantitatively cost-beneficial. About $250 to $350 million in the negative I don't think surprises anyone.

MEMBER BROWN: So offsite property is only -- that's the contamination and everything else that goes with it. Is that wrapped up in that? And recovery of the land and all that type of stuff. Only $14 or $15 million.

MR. SZABO: Yes, that's equivalent to what the MACCS2 calls the economic consequences. We just call it -- and that's, yes, frequency-weighted, yes. And delta relative to what base would be.

MEMBER STETKAR: Remember the base is really high. This is frequency-weighted delta, right?

MR. SZABO: Yes.

MEMBER BROWN: Which means it really costs $30 billion but it's unlikely to happen so it's only $14 to $20?

MR. SZABO: Delta.

MEMBER ARMIJO: If it happens it's going to be a big number.

MR. SZABO: Yes, this is with 10 to the -5 and the rest of Marty's probability tree.

MEMBER CORRADINI: So what was the frequency used to weight this? I'm sorry.

MR. SZABO: Well, the initial CDF was the 2E to the -5 and then it was -- yes, and then Marty's. It's straight from Marty's earlier reactor year.

MEMBER BANERJEE: So if you take the

frequency out what have you got?

MR. SZABO: It's what the MACCS code was saying earlier.

MR. MONNINGER: Base case was $1.9 billion in cost and the cost for the -- up to the cost for the drywell venting which was about $30 billion. That's the bottom lines on 66 and 67.

MR. SZABO: Your filters drive you into the hundreds of millions if not -- a couple of hundred million if not lower.

MEMBER BLEY: When you make these decisions just doing it on an expected value basis is deceptive sometimes. Every time. And to also see the probability and the real answers, or the probabilities and the real costs is very helpful because when you look at expected number of deaths in an accident and you see 0.0004 that looks like a little number but it's a high probability of zero and a low probability of maybe a lot. And that's a very different picture than you get just seeing the expected value. So, whoever has to make decisions on these things really needs more information than just the expected value. It's very deceptive.

MEMBER STETKAR: The 5 percent probability that you'd lose 40 percent of your net worth is a lot different than your expected value of a slight increase in your net worth.

MEMBER BLEY: I would certainly want to see that.

MEMBER STETKAR: You would certainly want to see that, wouldn't you?

MEMBER BLEY: I just think it's -- I mean, it isn't wrong, but it's deceptive. I think you need both. Here's the expected value and here's what goes into it. A very high probability of no cost or benefits, whichever side we're working on, and a very low probability of something pretty big.

MEMBER CORRADINI: I mean, just to make sure you see where -- since I haven't forgotten the stock price. If you're going to take the cost of the plant, or the cost of the offsite damage and put the expected then at least I'd put in the chance I'd lose the worth of the company with some probability-weighted thing. Because that's just as probable with this thing occurring as onsite damages.

MEMBER ARMIJO: Well, it's happened. At TMI you lost GPU, you lost B&We.

MEMBER STETKAR: And TEPCO.

MEMBER ARMIJO: I mean, whether or not stuff was released into the environment or not.

MR. MONNINGER: To a certain extent I think the staff tried to follow or followed the regulatory analysis that we currently have. And you know, as Bill mentioned we had expected the reg analysis would not show it to be cost-beneficial. So we could do things in here to increase the numbers or decrease the numbers, but you know, given the current way we do our analysis, our tools, et cetera, we don't believe this is, you know, it would significantly influence the numbers. So that's why we think it's very important to have a good discussion on the qualitative arguments that will be influential in development of a recommendation.

MEMBER BLEY: I don't disagree with that but I think you need -- even though the guidance doesn't require it I think you need a quantitative piece that puts into perspective these numbers. What do they mean? Where did they come from? It could be a high probability of $300,000. You know, it just doesn't communicate anything. You can call that qualitative but don't put that quantitative information in the qualitative discussion.

MEMBER BANERJEE: Suppose I was an insurance company, you know, trying to insure these things and this happens. Certainly I know the chemical plant business pretty well. It's not driven by lots of incidents which have very high probability but low loss. The insurance is really driven by low-probability events which have very high loss. So, you know, it's not this averaging sort of way to do it.

MEMBER SIEBER: That's why they put limits on the policies.

MEMBER BANERJEE: Well, they put limits on maybe nuclear policies but.

MEMBER SIEBER: All the policies have a limit.

MEMBER BANERJEE: So yes. Maybe for -- but most of the time this is driven by very low frequency but very high loss. Why don't we look at things that way, more like an insurance company? Suppose you were Zurich Re and had to insure this plant. What would you do?

MR. MONNINGER: I mean, that's something we can look into.

MR. RULAND: No doubt the committee who is going to be writing a letter after our --

(Laughter)

MR. RULAND: -- you know, our final set of -- you know, when we actually present the recommendation. Clearly if you include this in a letter the staff will seriously consider what we need to do.

MEMBER RAY: Why don't you consider the value of the product produced by the plant?

MR. MONNINGER: Well.

MEMBER RAY: What fraction of the total power produced by all the plants that come up with this net value is -- even assuming one were to use these numbers, what percent of that value is this net value loss here? No, the negative net value. The bottom line.

MR. MONNINGER: Right. So, this is the cost offsite from the replacement power.

MEMBER RAY: How many plants are we talking about here in this net value at the bottom?

MR. MONNINGER: It's just -- this is the fleet.

MEMBER RAY: That's right.

MR. MONNINGER: The fleet.

MEMBER RAY: All right. How much -- what is the value of the output of the fleet of plants? Have you ever considered that on an annual basis? I mean, this is trivial.

CHAIR SCHULTZ: Well, it comes into play

with the one sensitivity study that we discussed earlier which is shutting down 30 plants.

MEMBER RAY: But just compare the net value to whatever the heck it is that you're producing with the assets that incur this cost presumably. And you know, like I say, this is just -- take a look at what you're talking about in terms of the market value of the output of the plant compared with the cost of making what Marty showed to be some benefit assuming we're talking about the benefit of the filter here in terms of improved safety. Just this is --

MEMBER STETKAR: But Harold, in some sense here replacement power is not a contributor to that delta.

MEMBER RAY: Correct. I'm just talking about what does the fleet of plants, what is the value of their output compared with the cost of imposing on them a requirement for a filter.

MEMBER STETKAR: Oh, okay, I see.

MEMBER RAY: That's all.

MEMBER STETKAR: I see what you mean.

CHAIR SCHULTZ: It's a different question but it's worthy of consideration.

MEMBER RAY: Yes. I mean, that's the

way of, you know. Sanjoy is talking about insurance. I mean, that's the way a business looks at something like this. How much of the output that I'm -- or the revenue that the plant output produces is this costing me. It's a few minutes.

MEMBER BROWN: How many minutes of power generation.

MEMBER RAY: It's ridiculous.

MEMBER BANERJEE: A power plant of 2.5 gigawatts is at least $1 billion a year in power roughly.

MEMBER RAY: Well, it's been awhile since I -- I don't want to -- but I mean, it's a simple calculation to make. And you know, the revenue that the plant produces is way off the scale compared with the cost, particularly if you put it over -- you amortize the cost of the filter over how many years. You pick a number, 10, 15, 20, 25. It's nothing.

MEMBER ARMIJO: But Harold, none of these options save the plant.

MEMBER RAY: Look, Sam, everybody can have a perspective about whether it's warranted or not from a safety standpoint. We're looking at dollar numbers here and I'm only trying to put the cost of the damn filter in perspective compared to the output of the plant.

MEMBER ARMIJO: I understand, I understand.

CHAIR SCHULTZ: One thing we're -- this presentation does focus on the regulatory analysis. And we're using the approaches that have been established. The next presentation talks about qualitative arguments some of which are quantitative and may include this bullet.

MEMBER RAY: It's the only way I would look at it I'll tell you. Because this is something that may provide a benefit. You certainly don't want to have it have a net negative safety benefit. You know, in other words it needs to enhance the safety of the plant. And if it's something that can be done.

I mean, I think that's the way the Europeans probably approached the problem is this is something that we can do, it has arguably some benefit, all of these calculations I don't think amount to a hill of beans and it doesn't --

(Laughter)

MEMBER RAY: -- it doesn't amount to more than a small percent of the value of the plant output.

MR. RULAND: One of the things that the staff considered when we were doing this analysis is if the staff got too creative when we started doing this analysis and deviated from our process that we've already established the staff would be rightly open for criticism of trying to game the system to get an answer that we wanted.

MEMBER RAY: Yes, but our job is not to look at it the way you are forced to look at it.

MR. RULAND: That's fine.

MEMBER RAY: Okay? I mean, that's why we're her.

MR. RULAND: And I fully appreciate that. And all I'm suggesting is the staff, that's the reason we've done the analysis the way we have done it.

MEMBER CORRADINI: I mean, what Harold's asking I guess is you're just saying on an annual basis what fraction of it it compares to and the answer is a few percent.

MEMBER BROWN: It's not even that much.

MEMBER BANERJEE: No, no, it's point few percent.

MEMBER BROWN: Point zero zero few

percent.

MEMBER BANERJEE: If you take it over 25 years it's nothing.

MEMBER SIEBER: It's pretty cheap compared to the income of the plants.

MEMBER ARMIJO: If you look at it as a businessman this is a cost for public goodwill or something like that.

MEMBER RAY: I can do that. Let's get on with it. Stop this hand-wringing.

MEMBER BANERJEE: Indian Point probably spends more than that on publicity.

CHAIR SCHULTZ: I do feel we're going to get to this when we get to the next presentation.

MEMBER SHACK: Better move on.

MR. SZABO: Next slide. Thank you. I just stated before, option 4, we don't really have any quantitative analysis so we're just kind of provide qualitative arguments. And you know, it is amenable to the site-specific approaches as kind of mentioned previously. I don't want to hash out that conversation again so we're going to skip to the next slide.

(Laughter)

MR. SZABO: So once again, as stated,

the qualitative arguments that Tim's going to be presenting next are going to be provided in the regulatory analysis. And just provide some examples of qualitative arguments that have historically been included is the safety goal policy qualitative goals, the defense-in-depth on uncertainties as well as consistency with standards, as well as there are other options as to -- in relation to qualitative arguments. Onto the last slide.

As stated before, you know, option 2 and option 3 do not appear to be cost-beneficial within the current framework. There are sensitivity analyses that may provide cases that are cost-beneficial. You are changing the global statistical value as a CDF 15 times greater as well as some of the other sensitivities.

And just as a final note there may require some qualitative arguments for just the substantial safety enhancement part, especially with filters in relation to determining that there is a substantial safety enhancement.

I'm now open to any questions.

(Laughter)

CHAIR SCHULTZ: I have a question for clarification. On option 4 are we not saying that what option 4 does is postpone the regulatory analysis on a site-specific basis to some different evaluation? There's not a generic way or a combined integral way to present it as a decision-making. The decision is postponed to an individual site-specific evaluation.

MR. MONNINGER: To a certain extent. Hopefully when we have it developed I think it would be an alternative. Option 1 is not -- then options 2 and 3 in order. Option 4 would be the staff would look at doing some longer-term rulemaking and within that actual rulemaking would be some type of regulatory analysis based upon whatever we would be requiring for the performance-based approach.

So it would be pushing it further down the road as opposed to making a definitive decision today is sort of how we're looking at option 4 to address plant by plant by plant through some performance-based approach. All the Mark I's and II's plant by plant by plant performance-based versus options 2, the severe accident capable vent or filtered vent. We sort of looked at it on an industry-wide approach and would come up with a supporting regulatory analysis for that.

CHAIR SCHULTZ: Other comments or

questions particularly aimed at the regulatory analysis approach? And you've already stated, Aaron, that the qualitative is going to be incorporated in that piece of evaluation which is going to be presented.

MR. MONNINGER: Or the staff could stop at the quantitative, you know, and provide it. But we think it's very important.

CHAIR SCHULTZ: But you provide a justification for incorporating it in the past.

MR. MONNINGER: Yes.

CHAIR SCHULTZ: And you may go forward with what we're going to hear next.

MR. MONNINGER: Yes. That's Tim.

CHAIR SCHULTZ: Hearing none we'll move to the next presentation which is the qualitative arguments. Tim Collins is going to present. We welcome you, Tim. Very timely that you're here for this presentation.

MR. COLLINS: Thank you very much. Well, my portion of the discussion is a summary of the qualitative arguments for -- on the question of filters for the containment venting systems.

As Aaron mentioned, these are considerations that can be included in the regulatory analysis in addition to the numbers that are associated with the cost-benefit analysis. Next slide, Bob.

Okay, this is just a summary of the areas that I'm going to touch on. Most of these have come up in the course of your questions in the course of the day in one way or another but I'll talk a little bit about them more in qualitative terms than in quantitative terms. Next slide.

Okay, the first, probably the most important consideration in the qualitative world is enhancing defense-in-depth. A filtered vent enhances defense-in-depth by improving the containment. And the containment, it's the last barrier to fission product release and it's therefore important for treating uncertainties in severe accident progression in the likelihood of a severe accident, and it's important in keeping us away from the uncertainties that are associated with a large release.

It's important for health effects, it's important for land contamination, environmental consequences. And the containment is in fact the last defense-in-depth measure for protection of the environment.

Now, EP doesn't help the environment one bit. EP is wonderful for health effects, sheltering, relocation, that's fine, but it doesn't do anything for things like land contamination and the attendant consequences that go with land contamination. So I want to talk about how filtering improves the containment from a qualitative perspective. Next slide.

Filtering improves the containment in two ways, directly and indirectly. It directly improves the containment performance clearly by capturing the fission products that would otherwise be released by an unfiltered venting process.

MEMBER POWERS: By that logic why wouldn't you put two filters on the system?

MR. COLLINS: Why wouldn't you put two filters on the system?

MEMBER POWERS: Yes. I mean, you're -- I vent from the wetwell. I will have some radionuclides. They will go into your filter. Some fraction of them will come out so why don't I put two filters on that?

MR. COLLINS: You will have normal containment leakage that at some time would dominate over anything that's filtered out.

MEMBER POWERS: It may dominate over having one filter. I'm asking him on his argument why not two.

MR. COLLINS: I guess I really don't understand the question. If you have a vent and it's unfiltered --

MEMBER POWERS: It's always filtered if you go through the wetwell.

MR. COLLINS: Okay, well let's say you go through the drywell then.

MEMBER POWERS: And if it's sprayed then it's also filtered.

MR. COLLINS: Okay. And in defense-in-depth we try to approach things from protection in the event of failures. What if it is a drywell vent? What if we're venting from the drywell?

MEMBER POWERS: And you sprayed.

MR. COLLINS: No, I'm saying sprays have failed at this point.

MEMBER POWERS: Okay. So I again ask you why not two. If he's going to put one filter on because it would capture some of the radionuclides why not two or three until we hit your natural leakage, wherever that may be. And I'll agree with you that's an excellent place to decide stopping.

But why not go till we get John's limit which is a good -- I mean, it's a good natural limit, I agree with that.

MR. DENNIG: Tim, I think it goes back to the uncertainty in the benefits that you're going to get from the spray, the uncertainty of the benefit that you're going to get from the pool.

In 1150 those uncertainties were estimated and they range from no scrubbing up to 1,000. And they also looked at pool scrubbing and concrete-core interactions in some detail.

And so the issue is largely one of you have processes inside the containment that are driven be melting sequences and uncertainties in core melt progression, and the conditions of the wetwell and the availability of the spray and the efficacy of the spray. And in the perspective of those uncertainties does this provide compensation, does this make things more certain. Is this sort of like the big eraser. You make a lot of mistakes but this would take care of a lot of the uncertainty.

So I think if you have the ideal conditions in the wetwell and if you have the 3,000 or 4,000 gpm spray in a large containment then you get a huge benefit, or a large benefit from those mechanisms. But the analysis that we've done before, and this is for 1150, doesn't show that that in the mean -- the median that that benefit is very large. So, in the face of that uncertainty is this preferable.

The other thing is that I mentioned earlier for the Mark II's part of the reason for not putting a vent on a Mark II is because of the concern about the pool bypass altogether. So there's a question there for Mark II's. If we're not -- if we don't have new analysis that takes away that concern about the bypass by melting through underneath the containment then it seems that our previous analyses show that you have to have a filter. That's what the CPIP said.

MR. COLLINS: I think the question deals with the sufficiency of the filter. At what point do you stop.

MEMBER SHACK: That's defense-in-depth when do you stop is what he's really asking about.

MR. MONNINGER: We talk a lot about defense-in-depth and there's been some efforts within Reg Guide 1.14 to allow the staff some tools for assessing the extent of the robustness of defense-in-depth but it's a very difficult area.

There isn't much guidance out there to use to say what is enough, what is sufficient. Can you really quantify.

MEMBER POWERS: And that is exactly why you have to resort to more quantitative risk assessment methodologies because that's the vehicle for capping defense-in-depth.

MEMBER SHACK: So sayeth the structuralist.

MEMBER POWERS: So sayeth the structuralist.

MEMBER CORRADINI: Can I ask it a different way? What I heard in all the discussion prior, primarily in Marty's case is that when he talk the cumulative of all the things -- I'm not going to talk about the money part -- is that for health impacts this doesn't -- you can't find a way to make the argument.

MR. COLLINS: That's right.

MEMBER CORRADINI: Are there other things that you're going to make the argument, that you might want to make the argument to do it for? Because I don't sense it from a health impact statement.

MR. COLLINS: Given the timing of the

potential release and evacuation the only health -- the majority of the health impacts are from the repopulation when they come back, the re --

MEMBER RAY: Michael, what about the last bullet up there? I mean, to me, you know, having operated a plant the ability to lower the pressure more readily because I have a filter than I would feel otherwise I could do seems like a great benefit. I mean, I ran a large dry containment plant where you couldn't do it at all period.

MEMBER POWERS: I guess I don't know enough about operations here so I look to you guys that know much more. But to me from an offsite standpoint if I said I'm essentially creating a higher level of confidence, assurance that I don't have to deal with offsite emergencies and I improve onsite severe accident capabilities to manage the accident that's a very big thing. You already have a filter.

MEMBER RAY: That's correct. I'm just saying it improves the confidence I would have as an operator to open the vent on the basis that I don't really know how the wetwell is going to work. I have more confidence in this design than I do in the wetwell albeit you know more about it than I do and

I defer to your judgment. But it would improve my confidence to open the vent if I had a filter on the end of the vent to get the pressure down if I thought that was something I needed to do. It's as simple as that.

MR. MONNINGER: We think there's a level between the filtered vent for a decontamination or a decontamination factor and the integral plant systems. We believe there's a level of independence there. The plant, what's held up within the core, what's released, the timing, the core-concrete interaction, the temperatures within the suppression pool, the timings and all. You know, we don't believe you have those issues, those uncertainties in having to know the accident progression, the release pathways, et cetera, with the filtered vent. It provides a level of independence from the accident progression. It may not be fully independent but having it sit out there.

MEMBER STETKAR: You may be talking at odds because as I understand your characterization that's a purely passive containment function filtered vent, is that correct?

MR. MONNINGER: You said purely.

MEMBER STETKAR: Purely passive.

Rupture disk type.

MR. MONNINGER: It could be but there's a bypass around it that you could engage.

MEMBER STETKAR: Harold is thinking about other functions in addition to that.

MEMBER RAY: That's right. I'm just saying that containment pressure is high. I'd like to be able to relieve it. I'm more -- I'm just reading the words off the chart. I have more confidence in doing that if I have a filter on the end and I'm not having to rely on somebody's speculation about how the wetwell is going to do the filtering for me.

MEMBER STETKAR: And in essence it is more integrated to accident progression than what's going on.

MR. MONNINGER: Right. And it would have both -- the thought is it may potentially have both pathways.

MR. COLLINS: Actually, Mr. Ray's point is what I was referring to as indirectly helping containment because --

MEMBER RAY: No, I understand that.

MR. COLLINS: -- it frees the operator to use the vent as a tool to help protect against other challenges to the containment, challenges other than overpressure challenges such as potential hydrogen challenges or liner melt-through challenges. I'll talk about both of those in a couple of slides.

MEMBER POWERS: I guess I'm a bit mystified on the hydrogen challenge.

MR. COLLINS: I'm going to have a slide on that. It's about two down. Okay?

So as far as strengthening the containment goes though I see you get the direct effect of filtering what would otherwise be unfiltered in the vent and then you get the freeing of the operator to help other challenges to the containment, okay?

There's also another -- before I get to those, there is another defense-in-depth benefit from filtering potentially which does touch on health effects. Could you give me the next slide.

Filtering can also enhance defense-in-depth for emergency planning implementation. This would occur if we had an event where the earliest challenge to the containment was an overpressure challenge. In such a case if you had a filtered vent that would provide protection against the overpressure challenge, the early one, but another challenge to containment may be right down the road like a liner melt-through, right? But that would be somewhat later in time. So, the time between the second challenge and the first challenge is additional margin for the completion of sheltering and evacuation. So that's an additional defense-in-depth benefit.

MEMBER ARMIJO: How much of an increase is that?

MR. COLLINS: That would really be -- well, it would be event-dependent, it really would. I mean, if you have an event where you get a little bit of injection, injection gets knocked out and you get another little bit of injection it could be a substantial difference in time.

CHAIR SCHULTZ: That would have to tie into a different emergency planning strategy associated with --

MR. COLLINS: The start of emergency planning wouldn't change. You start at the same time. The question is how much time you have before you have a real challenge to the people where there's a real release. It would be longer. So there's more margin to complete the emergency actions. You wouldn't start them at any different time.

CHAIR SCHULTZ: I understand.

MR. COLLINS: You're just putting off the real challenge to the containment. You eliminate the early challenge, gives you more time before you get the next challenge.

MEMBER POWERS: Let me understand.

CHAIR SCHULTZ: I would pick at this phrase in there, but I'll let Dana go ahead.

MEMBER POWERS: At my plant I'm guaranteed to release heavier-than-air noble gases. Your filter does nothing for that. That shine from that release is guaranteed then to afflict your evacuating population. If I didn't filter I don't have that guarantee that they will be afflicted by a release.

MR. COLLINS: No, you would vent anyway when you get the overpressure challenge initially. You would release more than just the noble gases.

MEMBER POWERS: Whenever that is necessary or happens naturally.

MR. COLLINS: Yes.

MEMBER POWERS: But you're claiming credit for margin where I'm guaranteed to put a shine on those people.

MR. COLLINS: Okay, I guess you would get a lesser effect by having the filters.

MEMBER POWERS: So I'm not sure what I've gained here.

MR. COLLINS: Okay, you're saying you haven't necessarily gained anything in EP space. Okay, I understand what you're saying.

MEMBER POWERS: I'm just not clear what you've gained here, especially when I look at the consequence analyses that were presented earlier. They seem that if I do a wetwell venting I don't seem to see any distinguishable difference between ordinary wetwell venting and venting through a filter system.

MR. DENNIG: Yes, that's for that sequence. For that set of circumstances, for that sequence where you get the factor of 200 or 300 that MELCOR calculated for the pool scrub. In a sequence where you get 10 or less the core is outside the vessel already and you're not getting the blowdown through the T-quenchers and it's going through the downcomers, the median is -- and the uncertainty calculations is around 10 and the range is from, you know, 1 to 1,000.

And so if you get a sequence that puts you up in the high range you're in good shape. If you get a sequence that puts you out of that range where the temperatures and the hydraulic conditions in the wetwell or the level in the wetwell have changed then you don't get that. And so the question is again, it's a hedge against or for sequence independence if you will.

MEMBER SHACK: Which I guess isn't captured in any of the analyses that you've done because you've always assumed you have those kinds of releases.

MR. DENNIG: The cases that were run, there were 30 cases. In all of those cases --

MEMBER SHACK: The PRA feeds all events through that back-end bin whereas in reality it should be on a sequence-by-sequence basis and you may get the effects you're talking about.

MR. DENNIG: Yes. What I've been referring to is the uncertainty analysis that was done in NUREG-1150 for all the sequences that twere modeled for Peach Bottom.

MR. COLLINS: Next slide. Okay, this is where the operator's confidence in having a clean release can help. And this is the hydrogen control example I was talking about.

If the operator is confident that he can vent without a significant offsite release then he can intervene early to vent hydrogen and keep containment pressure low. And if containment pressure is maintained low that would reduce leakage of hydrogen through penetration seals and decreased leakage then reduces the threat of a hydrogen explosion in the reactor building and any consequences that go along with that explosion. And it helps emergency responders who are probably working in the reactor building to try to get some water injected.

MEMBER POWERS: You're drawing a distinction between the -- it is cleaner, you're arguing, to go through an additional filter than just going through the wetwell.

MR. COLLINS: Yes.

MEMBER POWERS: By roughly a factor of 10. But the noble gases are unaffected which would have a most serious impact indeed upon your emergency workers around the facility. They get direct shine. It's pretty significant actually for them. A few hundred million curies of xenon and krypton that you will release.

MEMBER STETKAR: The other question is if they don't release it what will the corresponding doses be. You know.

CHAIR SCHULTZ: If the hydrogen is not controlled.

MEMBER STETKAR: If the hydrogen is not controlled.

MEMBER BLEY: Time delay, it will eventually get --

MEMBER STETKAR: Yes, that's what I'm saying. If indeed that time delay is long enough to provide, you know, some sort of mitigation then it can be a measurable delta.

MEMBER SIEBER: If you use that argument though it seems to me that you need to have the vent system capable of sustaining the hydrogen deflagration or explosion. The condition to me, if you want to use that argument, that you have to design the vent system so that you won't get an explosion or a deflagration which adds some cost to it.

MEMBER SKILLMAN: What you've just introduced in my mind is almost an entirely different way of looking at this. Probably similar to around the table I've been involved in bleeding hydrogen from the pressurizer or from the makeup tank to the gaseous waste holdup tank. I've done it manually, know how to do it. That is an operations action that an operator takes to change chemistry, to change the dissolved hydrogen concentration or maybe take preemptive action for a change that is going to change the size of the bubble. That's actually operating the reactor fueling system.

What you've introduced here is the idea of operating the containment. That's what I interpreted from what you just said. And there's nothing wrong with that from my perspective except that that is introducing a new set of operator actions, a new set of operator behaviors and intelligence as Dr. Powers said, a new path for what could be significant quantities of xenon and krypton.

When one decides to do this one is making a decision to operate the containment. That's different than having a passive membrane first and release material to a filtered chamber. So I think if we go down this path we need to be thinking about a whole new set of training, a whole new set of behaviorals that ensure that this is done the way it is supposed to be done.

MR. MONNINGER: So at risk for potentially being wrong I'm pretty sure the current EOPs for primary containment hydrogen control once you reach 5 or 6 percent within the containment direct you to vent currently. So, you know, those noble gases, those impacts, et cetera, could -- and I'll pull, you know, the EPGs, EOPs to make sure, but I'm pretty confident. You don't just vent for pressure control. You actually vent for hydrogen control. And you can actually read into the primary containment hydrogen control EOPs that would lead one to believe that in the absence of indication of hydrogen you could even potentially vent.

So what I'm trying to say is what we're talking about here isn't potentially any worse than the current state in which they would potentially be releasing these noble gases along with the hydrogen anyway. That's one point.

The second thing I would mention is there is the current proposal in front of us from the BWR Owners Group to proceed with a proposal for early venting with the existing design of the plant. So, I think to a certain extent it depends upon what we're comparing this scenario to. I think a case can be made that the scenario and the consequences and the noble gases already exist. And what the staff is potentially doing would be to make the scenario better. Maybe not perfect, but better. But we can check the --

MEMBER SKILLMAN: I accept your argument and your logic. You're saying hey, maybe it's just an extension of what exists today, perhaps with some enhanced training or some enhanced intelligence. All I'm saying is you're actually talking about operating your containment perhaps differently than what is presently envisioned by the emergency procedures or other procedures that the plant uses. It just strikes me this is different.

CHAIR SCHULTZ: John, in the scenario you painted as you've indicated the advantage of having a clean release for hydrogen control, it's very qualitative.

MR. MONNINGER: Yes.

CHAIR SCHULTZ: In terms of whether it's going to impact operator action or not. Because in what you've just described the operator is directed to perform the release. So in one sense one would say you can't use that as an argument to put a filter on it or not in terms of this increasing confidence.

MR. MONNINGER: Well, I guess --

CHAIR SCHULTZ: How you look at operator action.

MR. COLLINS: Okay, next slide. This goes along the same lines. If the operator is confident of a reduced release then allows early operator intervention to control pressure. And if you can sustain low pressure you're facilitating injection from any low-pressure source which may be available. This increases your chances of early melt arrest and protection of the liner.

Again, it would sustain lower pressure, can reduce the leakage of fission products through the penetration seals. This is the same question that Dr. Powers just raised. If you're releasing the noble gases though what are you trading off there.

So maybe the last bullet is arguable. It facilitates the use of all onsite resources. We have to see. It seems to me if you have a filter on there you've got a tool which you need to use as best you can.

MEMBER POWERS: Well, the imponderable in my mind is this question of am I more confident with a filter or just with my pool. Now, I've done experiments with pools and I'm enormously confident in their ability to decontaminate. I become even more confident, yet further confident if in fact I use the wetwell sprays in conjunction with those pools. So maybe I personally.

I don't know about operators or other people. I don't know about the staff. If there's some increment in their confidence that they have. I mean, I don't know their psychology so I just can't say. But what I do know is that pools are enormously capable of removing aerosols and that sprays are my darlings because they're just wonderful in many, many ways. They -- especially the drywell sprays because they do all kinds of cooling functions in terrible things that are very hot because you'd lost your drywell coolers at this point in the accident. That's a half a megawatt of heat removal that you really need in a very critical location.

Now, what I don't know because I haven't looked lately is in looking at the risk analyses how often do we not have those spray systems. And maybe there is a delta. But in all of the risk analyses that have gone before nobody had highlighted that.

MEMBER STETKAR: I hear people mumbling

down there. I don't recall a lot of this. I suspect a fair fraction of the core damage sequences you may not have the normally installed sprays available. If you think about power failures, dc fires, seismic events, those types of things. You know, it's been -- I don't have the models in front of me. You certainly will have them available for the high-pressure transients, you know, those kind of things.

MEMBER POWERS: And that -- I mean, and all of this may just simply argue that option 2 is the way to go which is not the decision that's being made here. It's developing qualitative arguments to support option 3 right now. And I worry that we heard developing arguments to support option 3 that maybe we could develop arguments that say there are downsides associated with option 3, or there are options that achieve these things that I can do in option 2.

MEMBER RAY: Well, as I said to you, Dana, I'm more looking for what's the downside of putting one of these things in.

MEMBER POWERS: Well, operational complexity is the first thing that comes to mind.

MEMBER RAY: But the cost is not a

significant downside to me. But there may be other downsides and I'm certainly open to hear what they are.

MEMBER SIEBER: One of the things that you point out here is you get early operator intervention to control pressure. There are a lot but -- there's not a lot, but some BWRs, particularly ones with power upgrades that rely on containment pressure to avoid cavitating their pumps, particularly as a result of GSI-191. If I was an operator I would probably think I have to drive down a very skinny road now between too much pressure and too little pressure in order to control my -- what's going on in containment.

And I think that when you put that kind of situation on an operator that's all he'll do. He won't go and do other emergency duties. He'll concentrate on that because that's a difficult task and it's all done manually. And I have --

MEMBER RAY: We already confronted that discussion. Without a severe accident we still have to do that, don't we?

MR. DENNIG: The notion is that you really don't know. In the situations that we're talking about you don't know what your assets are going to be basically. I mean that's the presumption. You may have a lot of things, you may have no things. What are your assets, how are you going to work. We focused on the severe accident management where you've gotten where you are because you don't have anything. You don't have very much to work with. You have to cobble something up.

So, all the features, the drywell spray, the wetwell spray, core spray, all those things are dependent on ac power, emergency ac power, and you may not those. We're going to be damaged in some way. So, the context is what do I know about my assets, what am I going to have, what can I discern of the conditions inside the containment and in light of the information I have and the assets I have what do I do.

MEMBER BANERJEE: What does early mean here? How early?

MR. COLLINS: He could vent before he reaches the containment design pressure or before he reaches a rupture disk set point.

MEMBER SIEBER: Or before you get enough hydrogen concentration to blow the reactor building up.

MEMBER BANERJEE: So, let's take a

scenario.

MEMBER SIEBER: That to me is the driving issue is hydrogen buildup.

MEMBER BANERJEE: Can you sort of take a scenario what is the earliest time that this could happen? Are we talking about hours, days?

MEMBER SIEBER: Depends on the accident.

MR. MONNINGER: I mean for this, if we went to the MELCOR calculations, you know, you would be 16-18, you know, probably --

MEMBER STETKAR: That's not the earliest time.

MR. MONNINGER: For the MELCOR calculations.

MEMBER STETKAR: But the MELCOR calculations is not the earliest time in the real world.

MR. MONNINGER: Right, right.

MEMBER BANERJEE: But what is the earliest? Is it 12 hours, 15 hours?

MEMBER STETKAR: I don't do those calculations, but the MELCOR calculations --

MEMBER SIEBER: Beyond the first shift I'll bet you. When you first start considering.

MR. DENNIG: Between 10 and 12 hours.

MR. MONNINGER: I mean, you could take the MAAP, the EPRI work and see, you know. But there's even sequences that would be even earlier than that. You're a boil-down sequence. I mean, your LOCA if nothing else you're not boiling down. You've got the pot of water there, you've got ATWS.

CHAIR SCHULTZ: In terms of timing think of the progression at Fukushima.

MEMBER SIEBER: An active break in the coolant system I think would bring you there pretty fast.

MEMBER BANERJEE: So it's a few hours.

CHAIR SCHULTZ: There may things that you plan to do earlier than that certainly.

MEMBER BANERJEE: You could stress the operator.

CHAIR SCHULTZ: That's the question as we talked on the previous slide. Is that a stressor to the operator or is that an advantage to the operator?

MEMBER SIEBER: Depends on the operator. Different operators act different ways.

MEMBER BROWN: It could be more of a stressor if he figures out he can't do anything at all and the pressure is building up.

CHAIR SCHULTZ: Exactly.

MEMBER BROWN: So which way does the stressor go depending on what the specific event is.

MEMBER BANERJEE: So in a sense you've given the operator another tool in the repertoire of whatever they can do.

CHAIR SCHULTZ: I think that's what Bob was getting to, Bob Dennig was getting to with respect to the operator options.

MEMBER STETKAR: But that's what I mentioned earlier. I think it would be really interesting to look at plants that have implemented the filtered vents to see whether, first of all, they've actually changed their operator guidance, their philosophy for dealing with these accidents. If they have it would be really interesting to see how that's changed. Have they put higher priority on venting earlier? Have they put lower priority on trying to estimate what the offsite dose might be before they make a decision to vent? And I don't know the answer to those questions.

But I mean a lot of those things can feed into some of these qualitative arguments just from the experience of people who have done it. You don't need to speculate because actual people in

Europe who have plants that look an awful lot like our plants have done this.

MEMBER BANERJEE: They also require containment overpressure?

MEMBER CORRADINI: Require or allow?

MEMBER BANERJEE: And allow.

MEMBER ARMIJO: Once you allow it, it's required.

MEMBER SHACK: Well, I mean we focused too on the early use of this but to me one of the attractive features is that you always have a vent available. I might lose the wetwell vent in the number of sequences.

MEMBER SIEBER: Yes, or it may not do you any good.

MEMBER SHACK: And here I would have it.

MEMBER ARMIJO: You'd have the drywell vent.

MEMBER SHACK: Well, I mean -- but I mean I would always have a filtered vent available.

MR. COLLINS: You just went to my next slide.

MEMBER ARMIJO: But Dana said, okay, you can spray for the drywell venting. And you're saying okay but --

MEMBER SHACK: -- no ac power.

MEMBER ARMIJO: Well, you know, maybe you'd better spend -- your money is better spent putting $30 million into assuring that you have power for your sprays.

MEMBER SIEBER: So you buy another diesel and it doesn't work.

MEMBER ARMIJO: Where are you going to spend your money, on the existing equipment or a new piece of equipment that's sort of like a panacea, it's going to solve all your problems? Things never quite work that way. It just seems to me we haven't looked hard enough at how to make the best use of existing equipment. That's where option 2 I guess was going. Maybe broader.

MEMBER POWERS: One other question I have more on philosophical basis for your study because I don't know. I like confidence. I need a filter. If I look at the risk profiles of our plants I certainly see that seismic events are commensurate with internal events as initiators. And most of your sequences appear to be internal event sequences. If I have a seismic initiator and it's sufficient to disrupt my plant what does it do to the filtration system? Or is that outside of scope?

MR. MONNINGER: I think we would have to -- if the recommendation was to proceed with filters we would have to explicitly say whether the staff believes it is merited to withstand seismic conditions or not.

I mean if we're banking on it to provide that level of protection post seismic we would provide some level of need for designing and withstanding seismic events. But I don't think we're at that point yet. I'm not sure if that helped.

MEMBER SHACK: Well, you said earlier -- somebody said earlier in the meeting that the vent and the -- presumably I carry that over into the filter would be seismically qualified. It wouldn't be something else but it would be seismically qualified.

MR. MONNINGER: I think they might have said the European.

MEMBER SHACK: It wouldn't be safety.

MR. MONNINGER: The Europeans were -- and Bob can talk.

MR. DENNIG: The European installations are -- except for single-failure they are safety-grade seismic the same as the plant. It's across the board. It matches up that way except for the single-failure notion.

One way to look at this is that given that you have a containment that is of a size that you know that it's too small and you have to vent it, you're going to have to vent it, is it beneficial to have that vent filtered or to just take whatever release that you get under the circumstances. But keeping it all inside the containment isn't one of the options.

MR. COLLINS: Next slide.

CHAIR SCHULTZ: Let's see your next slide.

MR. COLLINS: Which is what Dr. Shack was just talking about. To have confidence again in your filtration system and you can use the drywell as a venting source as well as the wetwell.

And we also note that the current SAMGs direct the operators to flood the drywell floor which will eventually flood up the wetwell and block off the wetwell vent. So the current strategies would have them switch to a drywell vent. In this case you'd have the same protection whether it was coming off the wetwell or the drywell.

Also, if you have a filtered system I think you'd be more confident putting a rupture disk on the system because you have minimal consequences of an inadvertent actuation. Okay, next slide.

MEMBER SIEBER: If you have a rupture disk that means you have no containment overpressure to provide MGSH from then on.

MEMBER RAY: You've got an isolation valve, Jack, but you'd have to close it, that's for sure.

MEMBER SIEBER: Right, manually.

MEMBER RAY: That's right.

MR. COLLINS: Now, the second-to-last item is consequence uncertainties. Once fission products escape from the containment land contamination comes into play regardless of what EP actions you've taken into account. And the amount of land contamination to a large extent is dependent upon the magnitude of the release and the weather.

And the consequences associated with land contamination are dependent on other factors as well. The longer term weather patterns affect it, the local hydrology, whatever the land use is and what the public response is. And so the total consequences if we try to do total economic consequences are really, really uncertain. Can I go the next slide as well because there are more consequence areas?

There's also the uncertainties in consequences with regard to public response. I mean, public anxiety can lead to things like impacts on your energy supply chain. This is what happened in Germany. They're closing down the nuclear power stations. The Japanese are threatening to close down their power stations.

I mean, when people get -- have to be relocated for long periods of time, potentially permanently, that has big socioeconomic impacts which can affect things like the energy supply chain. So a large release puts us in a condition where we have little control over the potential non-health effect consequences.

MEMBER ARMIJO: I think that holds for any release. I think the German experience which was shocking to me that even though they have all the bells and whistles, they're still shutting down all their plants. You know, that's fact.

MR. COLLINS: I wonder if -- what the view of Fukushima would be if they hadn't had large releases but they had melted down three cores. I wonder if that would be viewed as a success or a failure.

MEMBER ARMIJO: I think they'd still shut down all the plants.

MR. COLLINS: I wonder. If there had been no release from that event after the horrific tsunami, right? You could say despite the fact that we had this horrific event, melted the cores, the people were protected, the land was protected. Would we call that a successful failure?

MEMBER ARMIJO: Or when people were protected at Fukushima they certainly evacuated and were inconvenienced and frightened, but their health and safety was protected. That didn't count for beans.

MEMBER POWERS: That raises the question of I wonder what the magnitude of release would have been if we had done a wetwell vent following the guidelines that we think we have in place at our plants.

In fact, I think that we see in the analyses that the suppression pools work pretty damn well for limiting the radionuclide release. When they were allowed to do so.

MR. DENNIG: The first 4 days at

Fukushima were wetwell vent releases. So you can look at what the releases were during that period of time if you want to get a sense of what value the wetwell was.

MR. MONNINGER: I think there's a question with regard to what happened to Unit 2. And they talk about the potential preponderance of the release or the land contamination coming from Unit 2. I think there's a question out there as to where that Unit 2 actually released from.

MEMBER POWERS: I think that's true.

MR. MONNINGER: For Unit 2.

MEMBER POWERS: And I certainly don't know the answer. And I don't know of anybody that does, but maybe there are people that do. But I don't.

MR. COLLINS: There's also consideration of our international practices. A requirement for filtering the containment systems has been in place at several European countries for many years, and other countries are now adding the requirement. Canada, Taiwan, Japan.

And if we went forward with a requirement it would be directly responsive to a recommendation from the recent meeting of members of the Convention on Nuclear Safety where they recommended measures to ensure containment integrity and filtration strategies and hydrogen control. So another consideration.

MEMBER POWERS: But aren't you already in compliance with that? If I wetwell vent I have a filtration strategy. If I inert I have a hydrogen management for containment. So aren't you fully in compliance with that?

MR. COLLINS: I don't know how the judgment is made as to whether we're in compliance with those practices or not. Certainly enhancing the filtration capability and the hydrogen management would be consistent with what they're recommending.

MEMBER POWERS: Well, enhancing is not required here. It says measures to ensure containment integrity, filtration strategy and hydrogen management for containment. It seems to me like you have all of those already in these particular plants.

MR. COLLINS: The recommendation is to upgrade, right?

MEMBER ARMIJO: Your option 2 is in fact an upgrade, isn't it?

MR. MONNINGER: Yes.

MEMBER ARMIJO: So that would be consistent with that guidance. Maybe not the one you want to do or you think is the best, but it would be consistent.

MR. MONNINGER: We hadn't concluded on any of the options yet.

MEMBER ARMIJO: Yes. Or what seems to be the preferred.

MR. DENNIG: Option 2 does have the downside of looking like you're saving the site, protecting the site and dumping to the environment. You are reliably able to open that vent to vent to the environment, but it's not going to affect the site of the reactor building or the response. So it does have that downside.

MEMBER BANERJEE: Does that statement only apply to BWRs or to PWRs as well?

MR. MONNINGER: It applies to PWRs as well.

MEMBER BANERJEE: So, if I understand it, most of the members are upgrading their PWRs as well. Very few aren't.

MEMBER CORRADINI: France is. I'm not sure others are.

MEMBER BANERJEE: Even the Chinese are.

MEMBER STETKAR: Yes, if you looked at that chart.

MEMBER CORRADINI: The chart shows the Chinese are doing their CANDUs. It's not showing anything else from the chart.

MR. DENNIG: I'll get you the information on the PWRs. They're doing forward build on the PWRs. They're installing filters.

MEMBER CORRADINI: I guess I don't want to be argumentative, but the current plants under construction along the coast have no filtered vents. The plants that are being planned inland will have filtered vents, at least that's what they told me when I was there 3 weeks ago. So it's different because most of the plants in construction are along the coast.

MR. DENNIG: Okay, I'll get you the list that I have.

MEMBER BANERJEE: Well, whatever it is, it applies really in general.

MEMBER CORRADINI: I guess I asked it once earlier but I come back to it which is -- maybe this is the wrong way of saying it, but it seems staff is not looking at option 4 at all. You have it there as -- I look at it as do nothing, 2, 3 and some sort of performance-based. But it seems to me the performance-based approach gives you flexibility to come up with this performance standard and let the industry be somewhat innovative on how they want to approach it.

And you can designate the attributes you want in that performance standard such that you can demand diversity, you can demand a number of things and still let the industry decide, and it would probably be on a site basis, what they need to do for some sort of goal to be determined. I'm not going to tell you guys what your goal is because that also fits into all your -- but I guess I'm not sensing that option 4 --

MEMBER RAY: That's a two-edged sword, Mike, from the industry standpoint.

MEMBER ARMIJO: Maybe.

MEMBER CORRADINI: I'm sure it is in some sense. But it just seems to me, I sense there's no appetite for option 4. It's always in your slides but I just don't sense that there's a lot of thrill there.

MEMBER REMPE: There's no health benefit so it would be something for diversity? I mean, what would be the --

MEMBER CORRADINI: Well, we were in another subcommittee meeting last night, or yesterday for a good 5 hours. I could come up with a couple of reasons to do it.

MEMBER REMPE: The land contamination is what you're thinking of?

MEMBER CORRADINI: Yes.

MR. MONNINGER: And you know, staff appetite for it. I mentioned we're maybe 90 percent looking at options 2 and 3. And you're right, conceptually we're probably only 10 percent there on option 4. We hadn't put the time and effort, but it is, you know, something out there. We believe it would still be within our paper. We're not wedded to giving the Commission 1, 2, 3, or 4, but you know, to the extent that we can develop it between now and then we'll include it. We may come up with two more options.

One thing I would mention, these qualitative arguments, if you go back to our quantitative analysis, neither option 2 or option 3 makes it on the cost-benefit. So, if the staff -- we would need qualitative arguments for option 2 or option 3 if that was a recommendation. It may be a little easier on option 2 because it's probably closer to some type of line than it is for option 3 but we would need additional argument.

MEMBER SHACK: Well, you probably need it for option 4 too I would suspect.

MR. MONNINGER: Yes.

MR. DENNIG: Once again I think we have a different time line for Mark II's than we do for Mark I's just because of the pool bypass that we've identified earlier in the CPIP where we said that a wetwell vent was not something to do because of that probability of the pool bypass and the lack of a scrub. So, to a certain extent that augurs for a filter on Mark II's unless we have different research that says that that's a different situation.

MEMBER BANERJEE: Can't you make some of these qualitative arguments quantitative?

MR. MONNINGER: We could potentially but I guess --

MEMBER BANERJEE: They seem overwhelming compared to the quantitative arguments.

MEMBER SIEBER: Yes, but there's no point of proof. You have to -- the point of proof has to come from the regulatory analysis and you fail there.

MR. MONNINGER: I think one of the things with the qualitative arguments that we're sensitive to is we'll put them together and we want to be as specific as possible for this. We don't want to come up with qualitative arguments that can be used for any staff flavor-of-the-day type recommendations for improvement. So that's, you know, it's difficult and there's, you know, once you have a qualitative argument there's just so much you can say. We don't --

MEMBER BANERJEE: That's why I'm wondering whether you can make them more quantitative.

MR. MONNINGER: And I'd have to look at Marty and Sud and Research to see what we could actually do. We can but do we have the tools, do we have the complete level 3 PRAs. You know, a lot of the focus on the traditional PRAs are in the early time frame. But when it comes to land contamination it's not just potentially that core damage accident in the early time frame that you're worried about. It could be the one at 12, 24, 36, or 48 hours.

MR. COLLINS: There's so much uncertainty in the analysis we're doing already if we try to make this quantitative it's going to just be more uncertain.

MEMBER SIEBER: I don't think you can do it.

MEMBER CORRADINI: But let me now -- now that I said one thing let me turn around and say something else. What's the rush to judgment on what to do with this? I sense a rush. Is this because it's defined as a Tier 1 activity and you must come to a judgment soon? It seems to me this is a fairly big change such that you want to do it right with enough thinking that you might want to wait till some sort of level 3 PRA results come in.

MR. MONNINGER: It's a Tier 1 item so we owe recommendation to the Commission end of November. That recommendation could be to do nothing.

MR. RULAND: Not only was this a Tier 1 item, the staff actually requested a delay. So, the staff believed they needed to delay this because we had additional work to do. So I would argue the staff has not been rushing this.

MR. MONNINGER: We've actually had two delays because this was originally part of the Tier 1 in those orders that went to the Commission in

February and March. However, we said it's complex and can we deliver it to you in July. And then we didn't make July and we've requested a second extension. So you could argue that this recommendation was actually due back in February.

MEMBER CORRADINI: So you're late.

(Laughter)

MR. RULAND: No, we are on time.

MR. MONNINGER: With all our schedule extensions we are on time.

MEMBER REMPE: Do you think you're ready or do you need another extension?

MR. MONNINGER: Personally, you know, personally I mean with all the work that's been done over the years, what's been done internationally I don't think if we studied it for 2 or 3 more years we would be at a significantly different state in developing our recommendation. I don't think that our quantitative analysis would significantly change over the next 2 to 3 years. That's my personal opinion.

MEMBER SIEBER: You might make it more precise but I don't think you're going to come up with a different answer.

MR. RULAND: Yes, we believe that's the

case.

CHAIR SCHULTZ: Are there other questions from the committee to Tim Collins on his presentation? With that I'd like to thank you, Tim, for the discussions that you've initiated.

One more piece on the agenda before we move to public comment and that's, Bob, your discussion associated with next steps.

MEMBER SIEBER: One slide.

MR. FRETZ: It's one slide. Again, as we started out the whole presentation was that our assessment continues. We really are not done yet so we will hopefully take whatever insights we have gained from today as well as some of the other evaluations and develop the recommendations.

Our plans are to engage the steering committee this month and to present our conclusions later this month.

CHAIR SCHULTZ: There was more detail in your earlier slide. We'll take this.

(Laughter)

CHAIR SCHULTZ: With that I'd like to ask for public comments. First, from within the room. We will be opening the phone line so that those on the phone line could make comments if they so desire. I'm looking for people within the room that would like to make public comments. Seeing none I'd like to open the phone line for public comments.

MR. GUNTER: Paul Gunter.

CHAIR SCHULTZ: Paul, I thought you might be on the phone.

MR. GUNTER: Thank you.

CHAIR SCHULTZ: Please go ahead.

MR. GUNTER: Thank you again for the opportunity. My name is Paul Gunter. I'm with Beyond Nuclear. We're out of Takoma Park, Maryland.

My question concerns option 1 and it's directed to staff. My understanding is option 1 applies basically to -- for the Enforcement Action 2012-050. And I've been trying to understand that the current order does not require for seismic-rated changes to the hardened vent. And the interim staff guidance speaks to what they call seismically robust. And I'm wondering if staff can provide some -- just a description of the differences between seismically rated and seismically robust.

CHAIR SCHULTZ: Paul, two things. One, I'm going to ask you to do two things. The first is in the format for the subcommittee what you're provided the opportunity for is a public comment, not a question to the staff.

MR. GUNTER: Okay.

CHAIR SCHULTZ: So if you can first just rephrase what you've stated as a comment we'd certainly take it into consideration. And could you please be sure you're speaking clearly as you can into your phone. It's coming over a bit unclear. So in terms of your diction and so forth.

MR. GUNTER: Yes, I'm on a cell phone.

CHAIR SCHULTZ: Okay, so take that into consideration, please, and rephrase as a comment. Thank you.

MR. GUNTER: Thank you. Again, my concern regards the issue of seismic qualification. And given, you know, sitting through this discussion it seems as likely that, you know, the order that's moving forward is what's going to stand. But the current order does not -- it explicitly states that the enhanced hardened vent will be seismically robust. And it's my concern and it's the concern of a number of members of the public that there is a differentiation between seismically robust and seismically qualified.

It was expressed earlier on in the

subcommittee meeting that there was clearly a need for a seismically qualified hardened vent. But the order that stands, the order that's moving forward now and the order that the licensees are currently basing their designs basically writes out seismically qualified vent.

And you know, the concern is that we don't really understand or see how seismically robust is defined. And I think that that needs to be publicly stated. Thank you.

CHAIR SCHULTZ: Thank you for your comment. If you could put your phone on mute so that other members of the public calling in can make their comments we'd appreciate it. Thank you. Thank you, Paul.

MR. LEYSE: Yes, this is Mark Leyse.

CHAIR SCHULTZ: Mark, could you hold on just a moment? I know you've provided us a slide to look at and that's coming up on the screen momentarily. I'll take your comment next.

MR. LEYSE: Okay, thank you.

CHAIR SCHULTZ: Okay, the slide that you provided is on the screen here and everyone in the room can see it. So go ahead and proceed.

MR. LEYSE: Thank you. Okay. Yes. I

would like to thank the ACRS for giving me the opportunity to speak, to fill in for Robert Leyse.

The slide which you have on the screen are five questions which he had. And I think the primary question is the fifth question talking about what would the minimum diameter of the vent need to be.

CHAIR SCHULTZ: Mark, excuse me. Can you identify yourself?

MR. LEYSE: Sure.

CHAIR SCHULTZ: Thank you.

MR. LEYSE: Mark Leyse, L-E-Y-S-E.

CHAIR SCHULTZ: And proceed, thank you.

MR. LEYSE: You're welcome. Yes. First, I want to point out that in the September 5th, 2012 ACRS meeting Dana Powers said that, quote, "Neither MELCOR nor MACCS have a very firm experimental base for modeling core degradation in BWR accidents," end of quote.

And today I want to supplement that. I would like to discuss the fact that the NRC's MELCOR and EPRI's MAAP codes under-predict the rates of hydrogen production that would occur in a severe accident, especially the rates of hydrogen production that would occur if there were a re-flooding of an overheated core which did occur in the Three Mile Island accident. There was a phase where the overheated core was re-flooded. In such case there's massive hydrogen generation.

Anyway, the MELCOR code uses the Urbanic-Heidrick correlation to help predict zirconium steam reaction rates. And that correlation is used between the temperatures of 15, 20 and 2,880 degrees Fahrenheit. So that's a pretty significant temperature range for a severe accident.

In a 2001 OECD Nuclear Energy Agency report, the title is "In-Vessel and Ex-Vessel Hydrogen Sources," it states that computer codes using the available zircaloy steam oxidation correlation such as the Urbanic-Heidrick correlation under-predict hydrogen production in severe accident scenarios in which there would be the re-flooding of an overheated core.

So the NRC's calculations with MELCOR using the Urbanic-Heidrick correlation under-predicts hydrogen production rates in severe accident scenarios in which there would be a re-flooding of an overheated core. And the EPRI's MAAP code would also under-predict hydrogen production rates.

And there are plenty of other papers that reiterate this same point. A 1999 paper titled, "Current Knowledge on Core Degradation Phenomena: A Review." That's from the Journal of Nuclear Materials. That states, quote, "No models are yet available to predict correctly the quenching processes in the CORA and LOFT-LPFP2 tests. No experiments have been conducted that are suitable for calibrating the models. Since the increased hydrogen production during quenching cannot be determined on the basis of the available zircaloy steam oxidation correlation new experiments are necessary," end of quote.

Computer safety models also failed to predict hydrogen production in the initial quench facility experiments. A 1997 Oak Ridge National Laboratory report explicitly states that, quote, "In the initial quench facility experiments conducted at Karlsruhe, Germany the hydrogen generation could not be determined by available zircaloy steam oxidation correlations," end of quote.

In a BWR severe accident hundreds of kilograms of non-condensable hydrogen gas would be produced up to over 3,000 kilograms at rates as high as between 5 and 10 kilograms per second. That's if there were the re-flooding of an overheated reactor core.

So I want to just point out that a reliable hardened vent piping would possibly need a greater diameter in thickness than those of the hardened vents that are presently installed in U.S. BWR Mark I's which are typically 8 inches in diameter. And the hardened vent needs to be designed so it would perform well in scenarios in which there would be a rapid containment pressure increase, for example, in the scenarios in which there would be the re-flooding of an overheated reactor core.

Lastly, I want to say that the safety analysis conducted by the NRC with MELCOR and EPRI with MAAP regarding filtered vents for BWR Mark I's and Mark II's need to be conservative, not non-conservative. And it seems to me that the results of the MELCOR calculations that the NRC has are non-conservative, and that their results are misleading because the code under-predicts the hydrogen generation rates that would occur in an actual severe accident.

Among other things, this would affect the time that the containment would need to be vented, especially in those scenarios in which there was a rapid pressure increase in the primary containment from rapid hydrogen generation.

So I would urge the staff and ACRS to please keep in mind that these calculations are non-conservative. Please keep that in mind when you review the MELCOR results of your calculations. Thank you.

CHAIR SCHULTZ: Mark, thank you for your comments. We appreciate them and I appreciate you sending the information before the meeting so that we can see the questions that you wanted to present to us today.

MR. LEYSE: Yes. May I just add that I just threw a lot of information at -- you know, I was stepping in for my father, Robert Leyse. And some of the information that I've just cited, there are actually references at the end of the transcript for the July 11, 2012 ACRS meeting.

There are about three slides and it has -- duplicates some of the information. And there's also at the end of that transcript a short paper I wrote for NRDC that's called "Post-Fukushima Hardened Vents with High-Capacity Filters for BWR Mark I's and Mark II's." That's also at the end of the July 11 transcript. So that has some more of the information.

CHAIR SCHULTZ: You just referenced that on this transcript for us and so that will direct whoever is interested back to that set of data. I do recall that and we have incorporated that into that transcript as you've identified. Thank you.

MR. LEYSE: Which I really appreciate.

CHAIR SCHULTZ: Okay. Are there other members of the public that would like to make comments at this time? It would be on the phone line. So if you're on the phone line and would like to make a comment please identify yourself.

Hearing none I'll close the public comment section of the meeting and ask members of the committee for comments that they would like to add at this time. Jack, do you have any final comments? Sanjoy?

MEMBER BANERJEE: No.

MEMBER SKILLMAN: No, thank you.

MEMBER BLEY: Other than thanking the staff for a really good discussion today, nothing additional.

CHAIR SCHULTZ: Dana?

MEMBER POWERS: I have provided you

comments as we went along but I would echo the presentations were just really first rate. I may not agree with everything but it was very clear what you were saying.

(Laughter)

CHAIR SCHULTZ: Harold?

MEMBER RAY: No further comments, thank you.

CHAIR SCHULTZ: Mike?

MEMBER CORRADINI: Nothing, just again thank the staff. I think it was a very good day. We learned a lot.

CHAIR SCHULTZ: Joy?

MEMBER REMPE: I'd like to thank the staff also, but I also would like to remind them to please expedite some of the documents before the next meeting because we don't all take the Evelyn Wood speed reading class. And it would be nice to have a little more time to digest it.

MEMBER POWERS: Just be aware that she'll ask a lot of questions as a result. So you want to be careful about what you provide.

MEMBER REMPE: Never as many as you, Dana.

MEMBER CORRADINI: Make sure you

optimize them.

MR. MONNINGER: We'll make sure we send the research report so that's where all the questions go.

CHAIR SCHULTZ: Charlie?

MEMBER BROWN: Just echo the credit. No addition -- to the staff. And no other technical. I made my piece.

CHAIR SCHULTZ: Bill?

MEMBER SHACK: No. Excellent presentation, excellent discussion. I'm looking forward to reading the paper. It should be a real page-turner.

(Laughter)

CHAIR SCHULTZ: John?

MEMBER STETKAR: Nothing more, thanks.

MEMBER ARMIJO: Nothing more. A good, good presentation, a lot to think about. Thank you.

CHAIR SCHULTZ: Well again I'd like to just summarize in thanking the staff, all of the staff who made presentations today consistently of high quality. And I think, well, you realize more than anyone how difficult those issues that you have been directed to tackle have been. And in regard to the presentation today as well as the work that has been completed it was -- it is of very high quality.

Remaining as you can see from our discussion and our questions and our considerations there are still a lot of dynamics associated with both the determination of the regulatory evaluation and the decision-making that will follow.

One of the key areas that I think the committee has stressed today is we've heard a lot about the the upside benefit in terms of the potentials that might move forward from a filtered vent. We are equally as concerned about potential downside risk associated with any change, whether it be physical or operational in association with plant modification or procedure modification.

That's not stating anything that we don't already know but there are things on the transcript that are certainly worthy of further consideration by the group that is performing the evaluation, documenting the work that has been done and the steering committee that's going to be helping to assess and evaluate what will be presented to the Commission. So again, we look forward to more information and we'll be also providing further considerations. And we can talk as we go forward.

So thank you very much again and we look forward to information. With that I'll close the meeting. Oh, excuse me.

MR. RULAND: Mr. Chairman, just one final comment. On behalf of the staff I'd like to acknowledge the recognition of the staff's effort. I think it showed. This has been really a huge effort.

And if you think about the NRC and all the regulatory issues we've faced over the years I would think that this is one of the most challenging and probably one of the more significant actions that the staff and the Commission has contemplated over the last 5 to 10 years.

And I think you gave us a sufficient amount of attention and clearly you see it too that way. And so I'd just like to acknowledge that and I'd just like to commend the staff from me personally. Thank you.

CHAIR SCHULTZ: I appreciate you providing that on the record. With that I'll thank the staff once again and close the meeting.

(Whereupon, the foregoing matter went off the record at 5:55 p.m.)

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Filtered Containment Venting Systems

Bob Fretz, Senior Project Manager
Japan Lessons Learned Project Directorate
Office of Nuclear Reactor Regulation

Advisory Committee on Reactor Safeguards
Fukushima Subcommittee
October 3, 2012

Purpose

- To present the staff's preliminary regulatory analysis of the need for filtered venting systems in BWR Mark I and Mark II containments

Proposed Schedule

- 8:40 – 9:00 Introduction
- 9:00 – 9:45 Design and Regulatory History, and Foreign Experience
- 9:45 – 10:30 FCVS in Severe Accident Management
- 10:30 – 11:00 MELCOR Analysis
- 11:00 – 12:30 MACCS2 Analysis
- 12:30 – 1:30 Break
- 1:30 – 2:30 Risk Evaluation
- 2:30 – 3:30 Regulatory Analysis
- 3:30 – 4:30 Qualitative Arguments
- 4:30 – 5:00 Next Steps

Discussion Outline

- Project Plan
- SECY Paper
    1. Design and Regulatory History
    2. Foreign Experience
    3. Analysis of FCVS in Severe Accident Management
    4. Technical Analyses (MELCOR/MACCS/PRA)
    5. Stakeholder Interactions
    6. Evaluation of Options
- Next Steps

Project Plan - Highlights

• November 30	SECY Paper to Commission
• November 20	SECY Paper to EDO
• November 1	ACRS Full Committee
• October 31	ACRS Subcommittee
• October 30	Draft Rev. 2 CP to SC
• October 16	Draft Rev. 1 CP to SC
• October 4	Public Meeting
• October 3	ACRS Subcommittee

SECY Paper Approach

- Purpose of Paper

  "The purpose of this paper is to provide the U.S. Nuclear Regulatory Commission (NRC) with information and recommendations from the NRC staff regarding the imposition of new requirements related to containment venting systems for boiling water reactors (BWRs) with Mark I and Mark II containments."

- Options

  1. No Change
  2. Severe Accident Capable Vent
  3. Filtered Vent
  4. Performance-Based Approach

SECY Paper Outline

- SECY Paper with Summaries of Enclosures, Options, and Recommendations
  - Enclosures
    1. Design and Regulatory History
    2. Foreign Experience
    3. Analysis of FCVS in Severe Accident Management
    4. Technical Analyses (MELCOR/MACCS/PRA)
    5. Stakeholder Interactions
    6. Evaluation of Options

Current Status

- Technical and policy assessments and evaluations ongoing
- Preliminary results being shared, subject to change
- Continuing to engage Steering Committee on path forward
- Staff recommendations will be made when technical evaluations and policy assessments are complete

Design and Regulatory History, and Foreign Experience

Bob Dennig
Office of Nuclear Reactor Regulation
Containment and Ventilation Branch

Design and Regulatory History

- Mark I Containments
  - WASH-1400 & NUREG-1150 found that Mark I containments could be severely challenged if a severe accident occurred
  - Relatively small volume
    - Gas and steam buildup affect pressure more dramatically
  - BWR cores have ~3 times the quantity of zirconium as PWRs
    - Potential for hydrogen gas and containment pressurization

Design and Regulatory History

- Mark I Containments
  - Containment Performance Improvement Program
    - Determine what actions, if any, should be taken to reduce the vulnerability to severe accidents
    - Staff recommended
      - Improve hardened vent
      - Improve RPV depressurization system
      - Provide alternate water supply to RPV and drywell sprays
      - Improve emergency procedures and training
    - Commission approved hardened vent
    - Other recommendations evaluated as part of IPE program

Design and Regulatory History

- Mark II Containments
  - Similar to Mark I, the most challenging severe accident sequences are station blackout and anticipated transients without scram
  - Risk profile dominated by early failure with a release that bypasses the suppression pool
  - Hardened venting was considered not beneficial because of unacceptable offsite consequences without an external filter like MVSS
  - Staff did not recommend generic backfit of hardened vent, but recommended a comprehensive evaluation as part of the IPE program

Design and Regulatory History

- Filtered Containment Vents
  - TMI Action Item – 10 CFR 50.34(f) “provide one or more dedicated containment penetrations, equivalent in size to a single 3-foot diameter opening, in order not to preclude future installation of systems to prevent containment failure, such as a filtered vented containment system”
  - Shoreham supplemental containment venting system
  - During the CPIP, possibility of filters for Mark I and Mark II containment vents was raised, but not pursued
  - Significant advancements in containment venting filter technology have occurred over the past 25 years

Design and Regulatory History

- What we have today…Order EA-12-050 requires
  - Reliable hardened vent capable of performing during a prolonged SBO (designed for use prior to the onset of core damage)
  - Severe accident conditions not considered
  - Designed to minimize operator actions
  - Discharges effluent to a release point above main plant structures

Foreign Experience

- Staff visited Sweden, Switzerland, and Canada
- Commission Paper will summarize FCVS regulatory and technical bases, and status of FCVS in other countries
- Insights from visits and public meetings consistent with previous findings
  - 1988 CSNI Report 156, Specialists' Meeting on Filtered Containment Venting Systems
- Together, FCVS and containment flooding scrub fission products from core debris and remove decay heat

Foreign Experience

- Government decree and/or regulator's order after TMI, Chernobyl, or Fukushima
  - Some plants installed or committed to install FCVS prior to requirement (e.g., Germany and Japan)
  - Regulator and industry develop guidance following regulatory decision (e.g., Sweden)
  - Some countries have periodic backfit reviews
    - Actual accidents more influential to decision (e.g., Switzerland)
  - Severe accidents were not part of the design basis when the decision was made

Foreign Experience

- Technical Bases Summary
  - Manage severe accident overpressure challenges
  - Defense-in-depth to address uncertainties associated with severe accidents
  - Significantly reduce offsite release and land contamination
- After Barsebäck filter was installed, subsequent filter costs considered low to modest

Foreign Experience

- Quantitative Bases Summary
  - Sweden land contamination goal
  - Require a Level 3 PSA
    - Level 1 frequencies low but not sufficient
    - After the decision, ensure equipment performance is acceptable generically and on plant-specific basis
      - Acceptable not judged quantitatively – "significantly reduce", "almost eliminate", etc.
      - Factored into emergency planning

Status of FCVS Internationally

Country	Boiling Water Reactors (BWR) by Containment Types						PWR	PWR/ VVER	PHWR	PHWR/ Candu	LWGR RBMK/ EGP
	GE Mark I	GE Mark II	ABB Mark II	GE Mark III	Other	ABWR					
Belgium							7				
Bulgaria								2			
Canada										18	
China							13			2	
Czech Republic							6				
Finland			2					2			
France							58				
Germany					2		11				
Hungary							4				
India	2								16		
Japan	8	7		3	4	3	24				
South Korea (ROK)							19		4		
Mexico		2									
Netherlands							1				
Romania									1	1	
Russia								17			15
Slovakia								4			
Slovenia							1				
South Africa							2				
Spain	1			1			6				
Sweden			4		3		3				
Switzerland	1			1			3				
Taiwan	2			2			2				
Ukraine								15			
United Kingdom							1				

#	FCVS installed and operational, or Committed to installing FCVS
#	Considering installing FCVS
#	No FCVS; has not committed to installing FCVS
#	FCVS Status Unknown

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

Foreign Experience

FCVS Status at Non-U.S. BWR Facilities

FCVS Status	GE Mark I	GE Mark II	ABB Mark II	GE Mark III	Other	ABWR	Totals	
FCVS Operational	1	0	6	1	5	0	**13**	30%
Committed	6	7	0	5	4	3	**25**	57%
Considering	1	0	0	1	0	0	**2**	5%
No FCVS	2	2	0	0	0	0	**4**	9%
Non-U.S. Totals	**10**	**9**	**6**	**7**	**9**	**3**	**44**	

FCVS in Severe Accident Management

Jerry Bettle
Office of Nuclear Reactor Regulation
Containment and Ventilation Branch

FCVS in Severe Accident Management

- Reviewed spectrum of plant procedures
- EOPs and SAMGs describe multiple containment vent pathways
- EDMGs provide portable pumps for RPV/DW injection
- Existing guidance provides for containment venting and injecting water to the reactor cavity
- EOPs focus on preventing core damage
- Decision to vent may be complicated with an unfiltered vent

FCVS in Severe Accident Management

- DW Sprays for Decontamination
  - Spray headers designed for DBA purposes (pressure control and heat removal) with flow rates of 1,000's GPM (provide estimated DFs around 10)
  - Portable pumps with flow rates in low 100's GPM result in spray nozzle dribble and DFs much less than full flow DFs
    - Good for cavity flooding
    - Not as effective for decontamination

FCVS in Severe Accident Management

- Suppression Pool for Decontamination
  - SRV discharge via T-quencher in bottom of subcooled suppression pool provides an aerosol DF of 100 to 300
  - Downcomer pipes which discharge higher in the suppression pool at or near saturation temperatures provide DFs of 10 or less

FCVS in Severe Accident Management

- EPRI Investigation of Strategies for Mitigating Radiological Releases in Severe Accidents
  - Employs a portable pump to flood drywell cavity and maintain suppression pool subcooling
  - Controls containment pressure near design value for holdup, settling, plate-out, spray effect, and high velocity discharge into suppression pool
  - Cycles containment vent valves to maintain containment pressure band (substantial reliance on instrumentation, valves/actuators, and operator actions)
  - Swap-over from WW to DW vent after 20 hours as containment floods up

FCVS in Severe Accident Management

- Staff preliminary assessment of EPRI investigation
  - Did not address potential increase in penetration leakage due to increased heat, radiation, and pressure
  - Did not address operation of valve, including instrumentation, procedures and human performance
  - Did not address water vapor condensation in vent line and potential for hydrogen buildup

Options Identified by Staff

- No Change (Option 1)
- Severe Accident Capable Vent (Option 2)
- Filtered Vent (Option 3)
- Performance-Based Approach (Option 4)

Option 2 - Severe Accident Capable Vent

- Upgraded reliable hardened vent for severe accident conditions and service
  - Higher temperatures and pressure
  - Hydrogen considerations in the vent line (inerting considerations)
  - Severe accident capable vent valves
  - Shielding for operator actions and personnel access to reactor building and/or remote manual operation of vent valves

Option 2 - Severe Accident Capable Vent

- Capable of safely handling hydrogen – Protect the reactor building and mitigate early hydrogen pressurization
- Capable of safely handling fission products – Maintain reactor building integrity for access to instrumentation and equipment, and facilitate operator actions
- Wetwell vent path only (did not consider consequences of swap-over to drywell vent)
- Protects containment by venting even after core damage
- Success depends on uncertain accident progression, decontamination in the suppression pool, and drywell sprays
- Upgrading existing Mark I vent path may require more work than expected for the reliable hardened vent

Option 3 - Filtered Vent

- Significant enhancement in severe accident containment performance
  - Benefits of Option 2 plus defense in depth enhancements
- No identified technical or safety problems
- Venting with a filter results in a much smaller release compared to without a filter
- Proven, feasible option that has been implemented in several countries

Option 3 - Filtered Vent

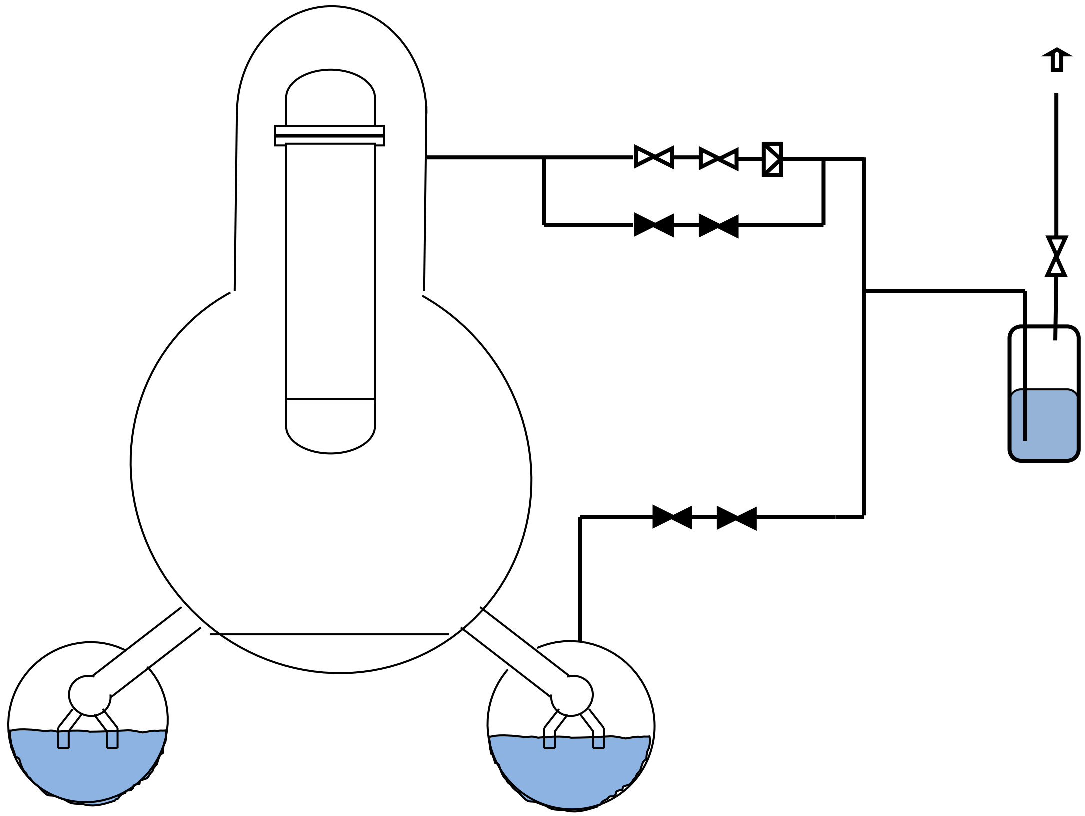
- External Filter System
  - Vent line branch from wetwell with normally closed valves are most compatible with early venting
    - May eventually be submerged and unusable due to drywell water injection
  - Vent line from drywell with two branches (one with rupture disk and normally open valve for passive venting, and the other with normally closed valves for early manual venting)
    - Supports drywell floodup and avoids shifting from wetwell to drywell venting and reliance on operator action to preserve containment function for 24+ hrs

Option 3 - Filtered Vent

- External Filter System
  - Staff would develop a technical basis to require a minimum DF or other performance requirement
    - e.g., DF > 1,000 aerosols (including submicron),
    - e.g., DF > 100 elemental Iodine
  - Engage stakeholders to develop appropriate performance criteria
  - May require active and passive features for prolonged SBO under severe accident conditions

Option 3 - Filtered Vent

- External Wet Filter System



Option 4 - Performance Based

- Potential approaches
  - Each plant meets a defined DF for a defined source term
  - Each plant meets criteria defined for combination of event frequencies and DF
  - Each plant performs a site-specific cost/benefit analysis
- Could potentially address forthcoming industry “filtering strategy” proposal (anticipating industry submittal)

Technical Analysis of Options 1, 2, & 3

- NRR identified a number of accident sequences (i.e., cases) to be evaluated by RES in support of conducting a Regulatory Analysis
  - Base cases were intended to be representative of options considered
  - Sensitivity cases also evaluated
- MELCOR calculations
  - Calculations informed by SOARCA and Fukushima
  - Various prevention and mitigation actions
- MACCS calculations
  - Venting with and without filter
- Event sequences and probabilities
- Consequence and frequency estimates

MELCOR Analysis

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Office of Nuclear Regulatory Research
Fuel and Source Term Code Development Branch

Insights on BWR Mark I Response

- SOARCA Peach Bottom Analysis
  - Base case SBO sequences with no sprays or venting
  - Primary containment vessel failure modes
    - DW liner shell melt-thru and over-pressure
  - Reactor building accident response
    - Blow-out panels open, local H_2 combustion, and roof failure
- Fukushima
  - Long term SBO with protracted RCIC operation
  - Primary containment vessel failure modes
    - Over-pressurization with leakage thru drywell head and containment penetrations?
  - Reactor building accident response
    - Significant combustion events

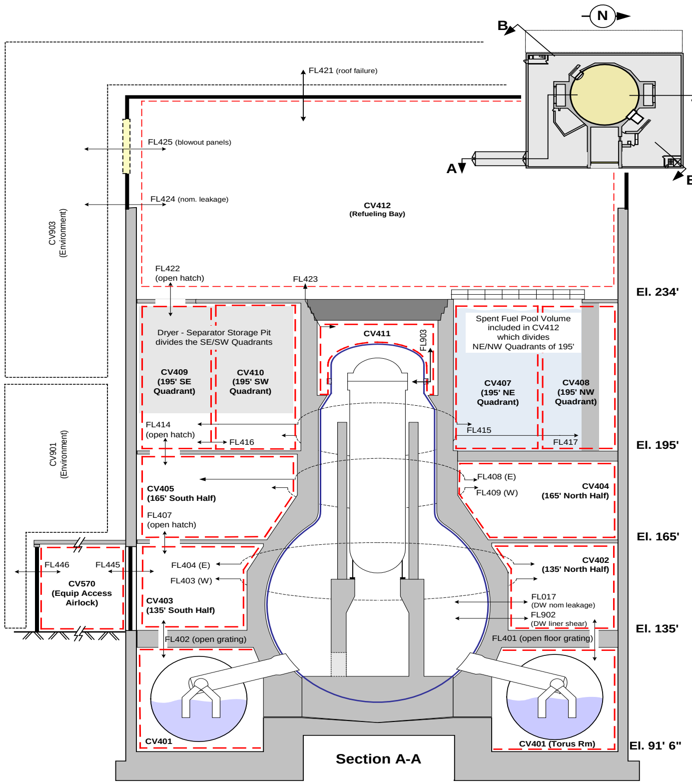
Filtered Vent MELCOR Analysis

- Based on SOARCA MELCOR modeling
- Accident sequences
  - Informed by SOARCA and Fukushima
  - Long-term SBO (base case 16 hr RCIC)
- Mitigation actions
  - B.5.b and/or FLEX provide core spray or drywell spray (300 gpm)
  - Containment venting
- Sensitivity analysis
  - Spray flow rate and timing, wetwell versus drywell venting, and RCIC duration

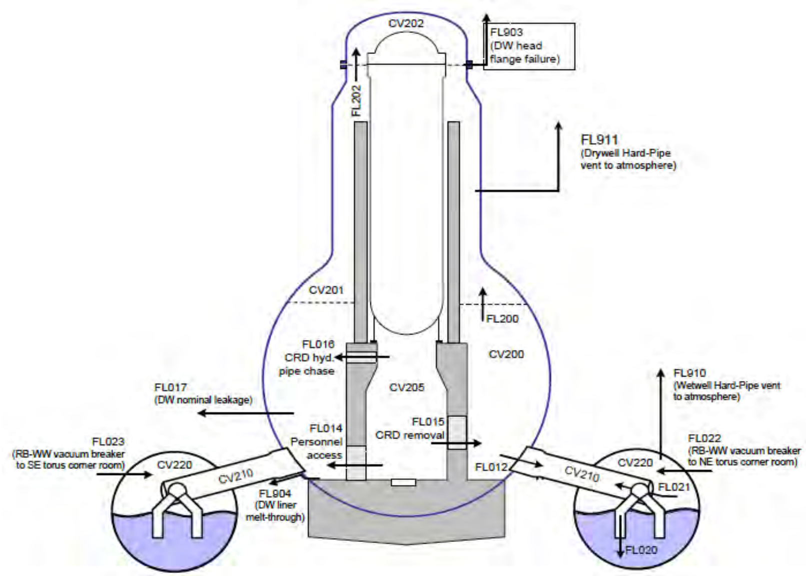
Insights from MELCOR Calculations

- Water on the drywell floor is needed to prevent liner melt-through
  - Also scrubs fission products and reduces drywell temperature
- Venting prevents over-pressurization failure
  - Wetwell venting is preferable to drywell venting
- Need combination of venting and drywell flooding
  - More reduction in fission product release
  - Maintain reactor building integrity

MELCOR BWR Nodalization



Reactor Building Nodalization



Containment Nodalization

Examples of MELCOR Results

Event Timing (hr.)	Case 2 RCIC only	Case 3 RCIC + wetwell vent	Case 6 RCIC + core spray	Case 7 RCIC + core spray + wetwell vent
Station blackout	0.0	0.0	0.0	0.0
RCIC flow terminates	17.9	17.9	17.9	18.0
Core uncovery	22.9	22.9	22.9	22.9
Relocation of core debris to lower plenum	25.9	25.9	25.9	25.8
RPV lower head failure	37.3	34.3	36.7	33.8
Drywell pressure > 60 psig	22.8	22.8	23.3	23.2
Drywell head flange leakage (>80 psig)	25.5	---	25.4	---
Drywell liner melt-through	40.3	36.6	---	---
Calculation terminated	48	48	48	48

Examples of MELCOR Results

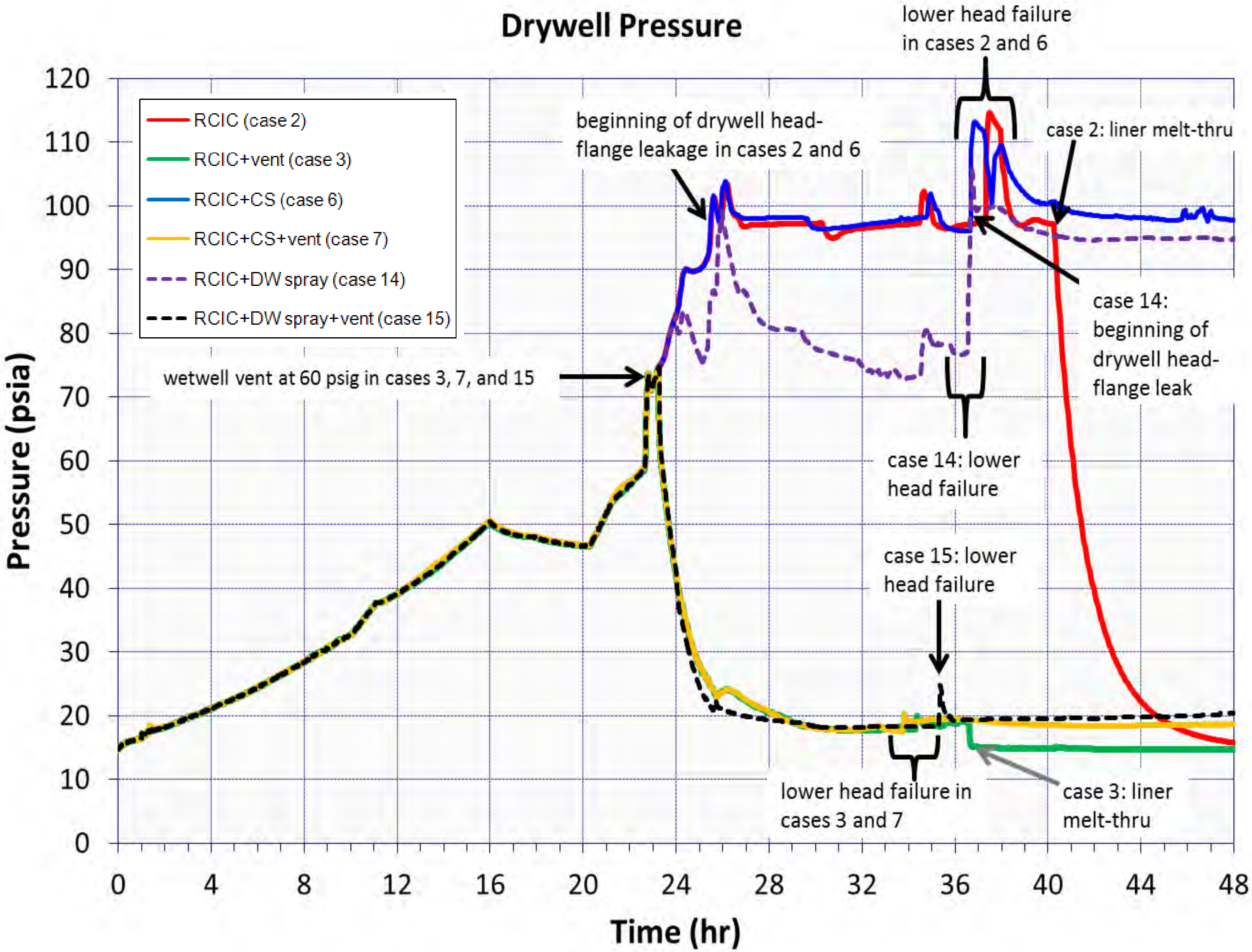
Event Timing (hr.)	Case 12 RCIC + drywell vent	Case 13 RCIC + drywell spray + drywell vent	Case 14 RCIC + drywell spray	Case 15 RCIC + drywell spray + wetwell vent
Station blackout	0.0	0.0	0.0	0.0
RCIC flow terminates	17.9	17.9	17.9	18.0
Core uncovery	22.9	22.9	22.9	22.9
Relocation of core debris to lower plenum	28.3	28.7	25.7	25.6
RPV lower head failure	34.2	34.7	36.6	35.3
Drywell pressure > 60 psig	27.7	27.7	23.2	23.3
Drywell head flange leakage (>80 psig)	---	---	25.8	---
Drywell liner melt-through	34.8	---	---	---
Calculation terminated	48	48	48	48

Examples of MELCOR Results

Selected MELCOR Results	Case 2 RCIC only	Case 3 RCIC + vent	Case 6 RCIC + core spray	Case 7 RCIC + core spray + vent
Debris mass ejected (1000 kg)	286	270	255	302
In-vessel hydrogen generated (kg-mole)	525	600	500	600
Ex-vessel hydrogen generated (kg-mole)	461	708	276	333
Other non-condensable generated (kg-mole)	541	845	323	390
Cesium release fraction at 48 hrs.	1.32E-02	4.59E-03	3.76E-03	3.40E-03
Iodine release fraction at 48 hrs.	2.00E-02	2.81E-02	1.70E-02	2.37E-02

Examples of MELCOR Results

Selected MELCOR Results	Case 12 RCIC + drywell vent	Case 13 RCIC + drywell spray + drywell vent	Case 14 RCIC + drywell spray	Case 15 RCIC + drywell spray + wetwell vent
Debris mass ejected (1000 kg)	345	351	267	257
In-vessel hydrogen generated (kg-mole)	714	793	614	650
Ex-vessel hydrogen generated (kg-mole)	774	410	327	276
Other non-condensable generated (kg-mole)	922	485	383	270
Cesium release fraction at 48 hrs.	1.93E-01	1.86E-01	1.12E-03	3.01E-03
Iodine release fraction at 48 hrs.	4.90E-01	4.84E-01	5.41E-03	1.86E-02



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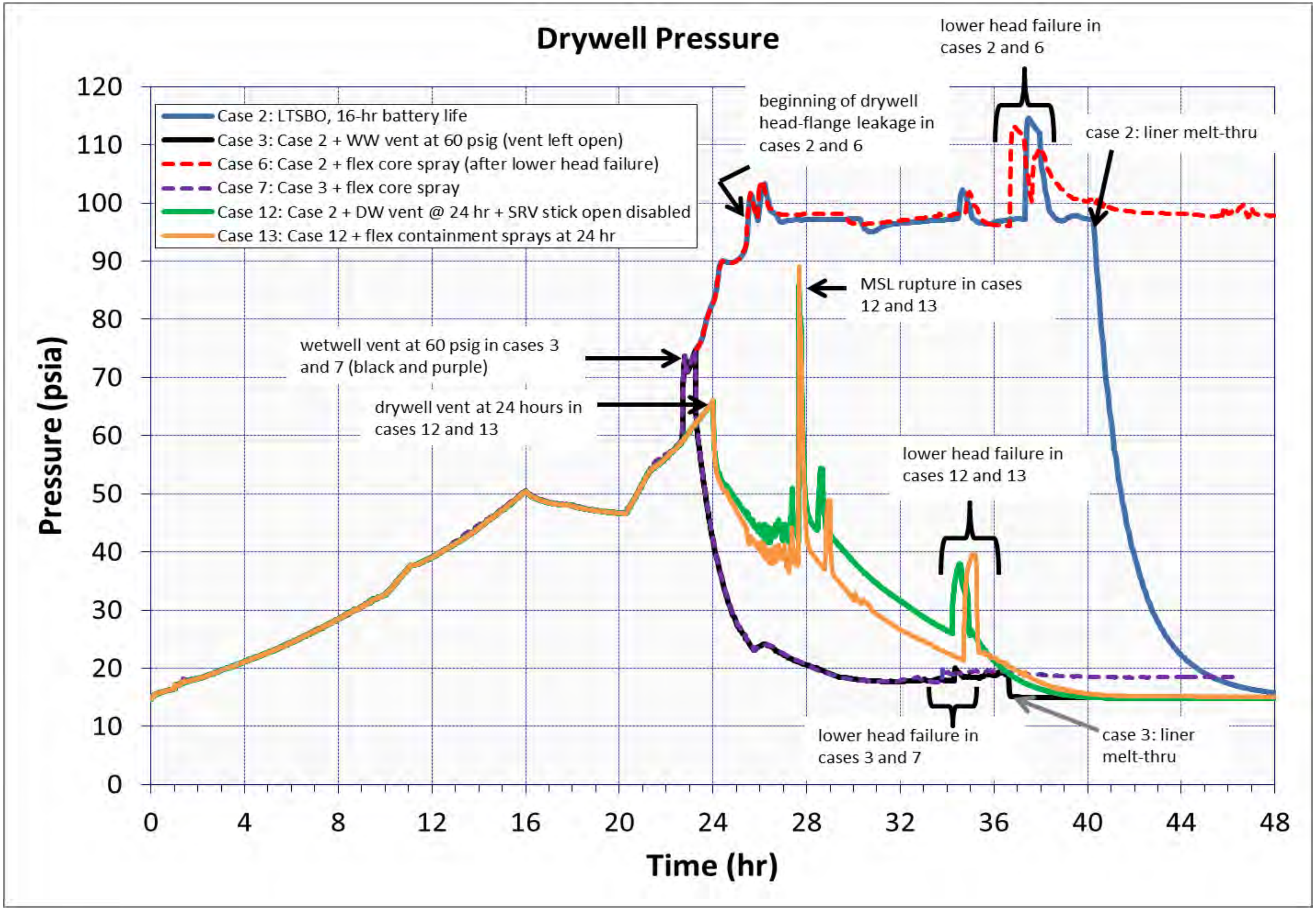
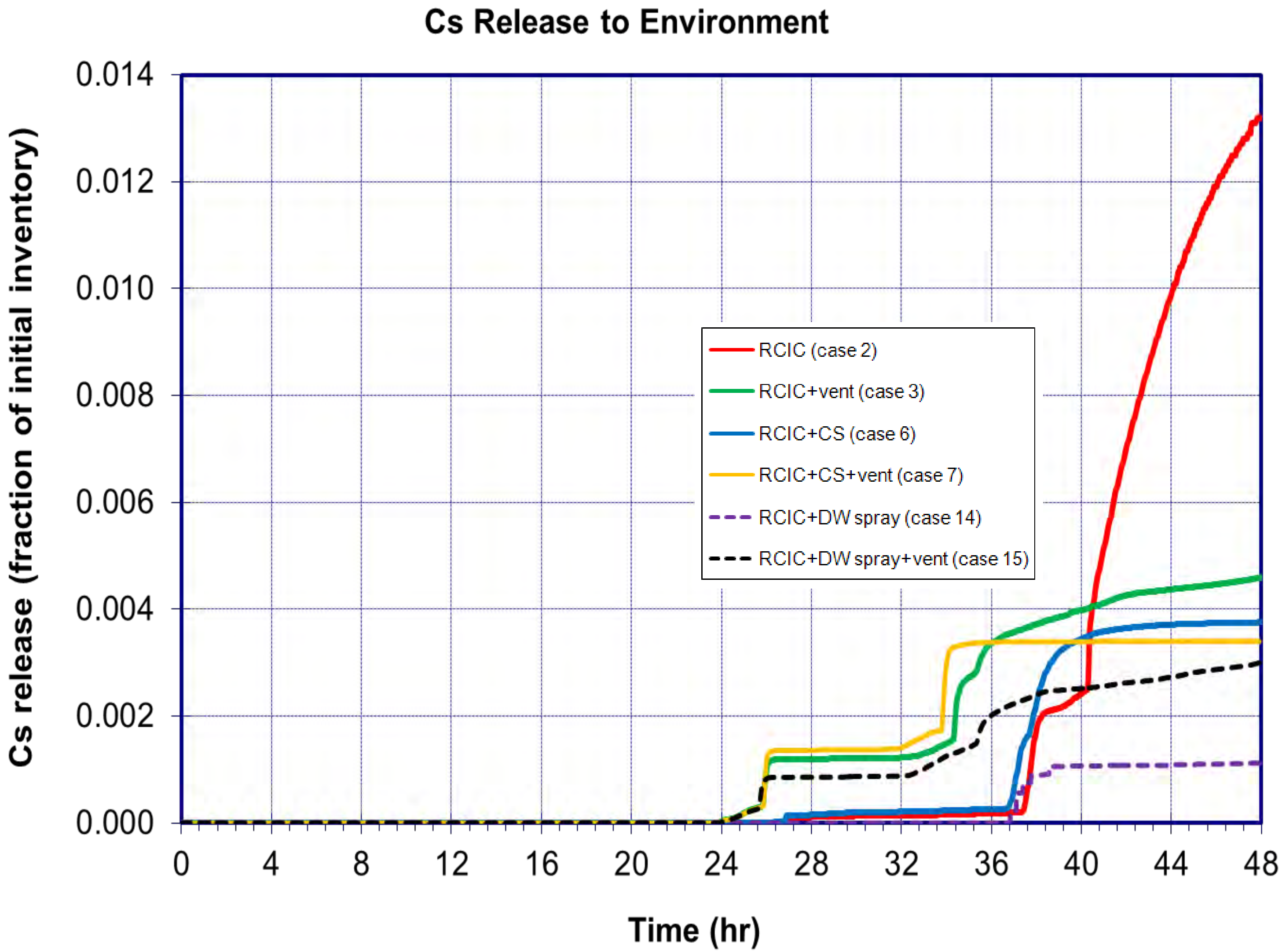


Drywell Pressure
Case 2: LTSBO, 16-hr battery life
Case 3: Case 2 + WW vent at 60 psig (vent left open)
Case 6: Case 2 + flex core spray (after lower head failure)
Case 7: Case 3 + flex core spray
Case 12: Case 2 + DW vent @ 24 hr + SRV stick open disabled
Case 13: Case 12 + flex containment sprays at 24 hr
lower head failure in cases 2 and 6
beginning of drywell head-flange leakage in cases 2 and 6
case 2: liner melt-thru
MSL rupture in cases 12 and 13
wetwell vent at 60 psig in cases 3 and 7 (black and purple)
drywell vent at 24 hours in cases 12 and 13
lower head failure in cases 12 and 13
lower head failure in cases 3 and 7
case 3: liner melt-thru
Pressure (psia)
Time (hr)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
4
8
12
16
20
24
28
32
36
40
44
48



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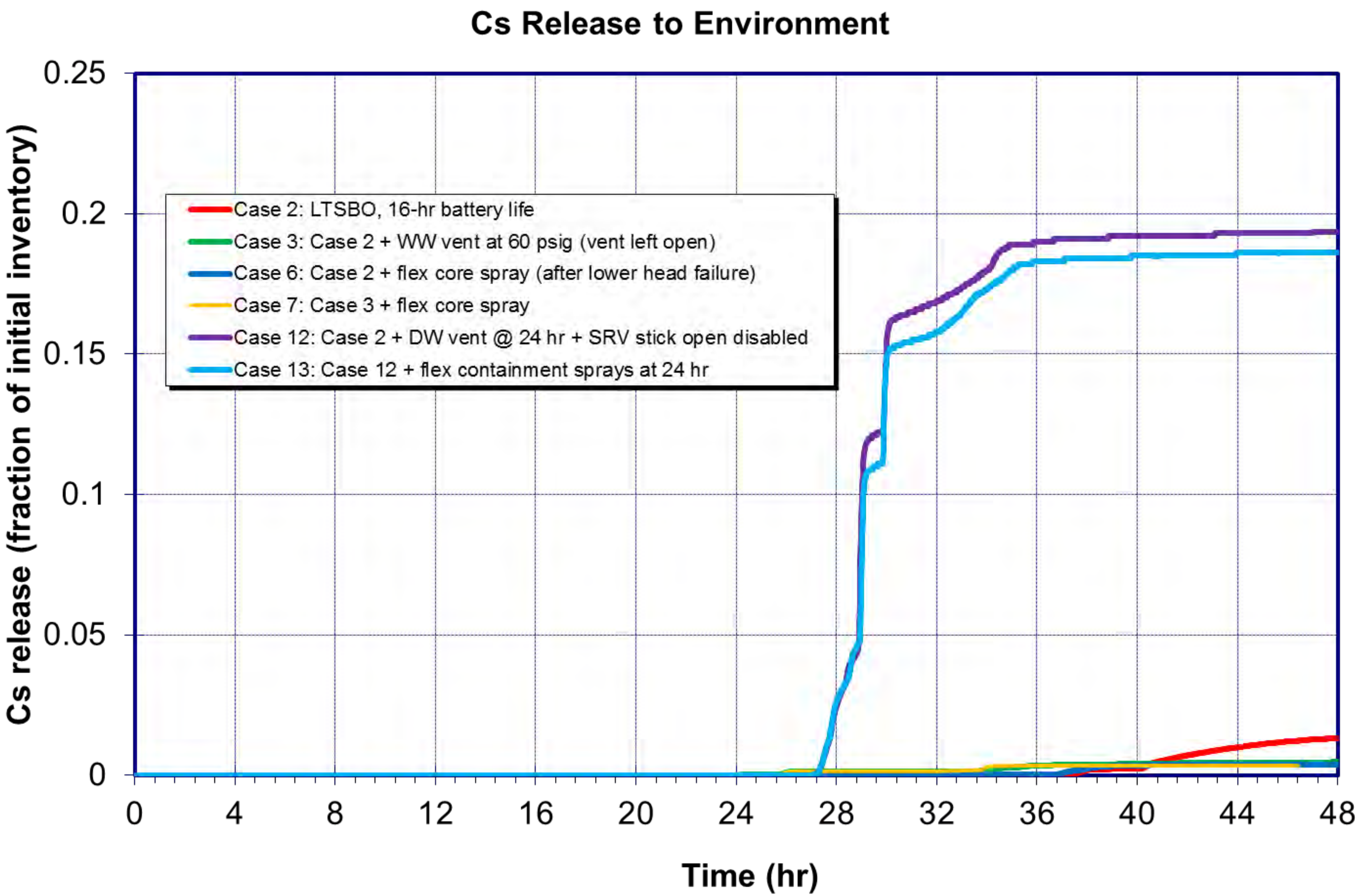

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MACCS2 Analyses Supporting Filtered Containment Venting Systems Commission Paper

Tina Ghosh

Office of Nuclear Regulatory Research

Nathan Bixler

Sandia National Laboratories

Outline

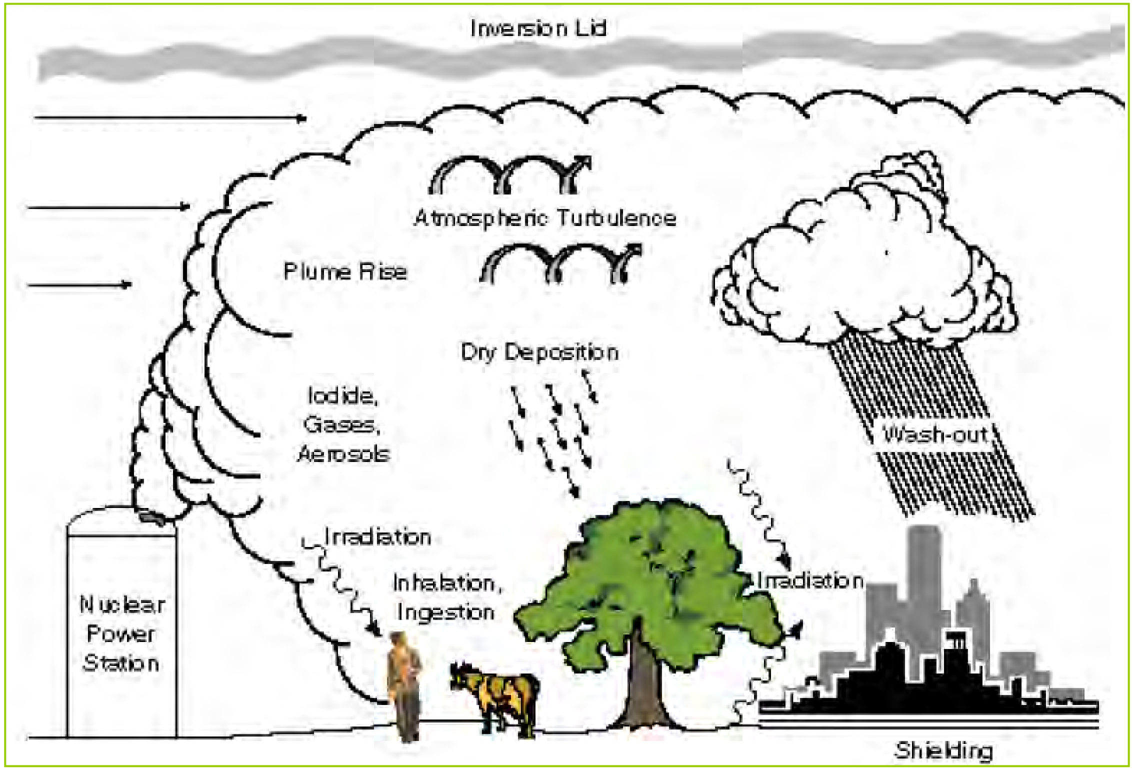
- Overview of MACCS2
  - MACCS2 Modules
    - ATMOS: Atmospheric Modeling
    - EARLY: Emergency Phase Modeling
    - CHRONC: Long Term Phase Modeling
  - MACCS2 Uses
  - References
- MACCS2 analysis for filtered containment venting systems
  - Scope of analysis
  - Inputs
  - Results of calculations, venting with and without filter

Overview of MACCS2

- MACCS2: MELCOR Accident Consequence Code System 2
  - Level-3 PRA tool to assess the risk and consequence associated with a hypothetical release of radioactive material into the atmosphere
  - First released in 1997
  - Evolved from series of codes: CRAC, CRAC2, MACCS, MACCS2
  - Estimates consequences
    - Health effects – numbers and risks
    - Economic impacts – land areas and costs
  - No equivalent industry code
- WinMACCS Graphical User Interface
  - Assist the user in creating MACCS2 inputs
  - Preprocessor for MACCS2 input
  - Postprocessor for MACCS2 output
  - Allow uncertainty mode sampling
- Use of MACCS2 in State-of-the-Art Reactor Consequences Analyses study peer-reviewed by independent panel of experts

Pathways to Receptors from Atmospheric Release

MACCS2 models the radioactive transport through the atmosphere (e.g. plume rise, dispersion, dry and wet deposition)



MACCS2 estimates the health effects from: inhalation, cloudshine, groundshine, skin deposition, and ingestion (e.g. water, milk, meat, crops)

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MACCS2 Modules

- ATMOS
  - Not associated with a phase
  - Atmospheric transport and deposition
- EARLY (1 day to 1 week)
  - Emergency-phase
  - Prompt and latent health effects
  - Effects of sheltering, evacuation, and relocation
- CHRONC
  - Intermediate phase (0 to 1 year)
  - Long-term phase (0 to 317 years; 30-50 years typical)
  - Latent health effects
  - Effects of decontamination, interdiction, and condemnation

ATMOS Module

<u>Atmospheric Transport and Dispersion (ATD) Estimates</u>

- Dispersion based on Gaussian plume segment model
  - Provisions for meander and surface roughness effects
  - Phenomena not treated in detail in this model: irregular terrain, spatial variations in wind field, temporal variations in wind direction
  - A study (NUREG/CR-6853) comparing the MACCS2 ATD model with two Gaussian puff codes and a Lagrangian particle tracking code showed that the MACCS2 mean results (over weather) were within a factor of 2 for arc-averages and a factor of 3 at a specific grid location out to 100 miles from the point of release.
- Multiple Plume Segments (up to 200)
- Plume rise from initial release height
- Effects of building wake on initial plume size
- Dry and wet deposition
- Radioactive decay and ingrowth (150 radionuclides, 6 generations)

ATMOS Module (continued)

- MELCOR source term is input via MELMACCS
- Meteorological data required
  - Wind speed and direction
  - Pasquill stability category
  - Precipitation rate
  - Seasonal AM and PM mixing-layer height
- User selectable meteorology sampling options
  - Single weather sequence
  - Multiple weather sequences
    - Statistical sampling to represent uncertain conditions at the time of a hypothetical accident
- Outputs
  - Dispersion parameters, χ/Q, fraction remaining in plume
  - Air and ground concentrations

EARLY Module

- Emergency-phase consequences
  - Acute and lifetime doses for following dose pathways
    - Inhalation (direct and resuspension),
    - Cloudshine
    - Groundshine
    - Skin deposition
  - Associated health effects
    - Early injuries/fatalities from acute doses
    - Latent health effects from lifetime committed doses
- Doses are subject to effects of
  - Sheltering
  - Evacuation
    - Speed can vary by phase, location, precipitation
  - Relocation criteria for individuals
    - Based on projected dose
- Outputs
  - Doses, health effects, land contamination areas

CHRONC Module

- Intermediate Phase (optional, 0 to 1 year)
  - Dose pathways
    - Groundshine
    - Resuspension inhalation
  - Continued relocation is only protective action
- Long-Term Phase (up to 317 years, 30 to 50 typical)
  - Dose pathways
    - Groundshine
    - Resuspension inhalation
    - Ingestion
  - Protective actions
    - Based on habitability and farmability
    - Actions include
      - Decontamination
      - Interdiction
      - Condemnation

CHRONC Module (continued)

Decision logic for long-term protective actions

- Habitability criterion initially met?
  - No actions required
  - Population home at beginning of long-term phase
- Decontamination sufficient to restore habitability?
  - First-level decontamination performed if sufficient
  - Sequentially higher levels of decontamination performed if required
  - Population returns home following decontamination
- Decontamination plus interdiction sufficient to restore habitability?
  - Highest-level decontamination performed
  - Property is interdicted up to 30 years
  - Population returns home following decontamination plus interdiction
- Property is condemned when
  - Habitability cannot be restored within 30 years
  - Cost to restore habitability > value of property

CHRONC Module (continued)

- Economic costs
  - Per diem and lost income for evacuation/relocation
  - Moving expense lost income for interdicted property
  - Decontamination labor and materials
  - Loss of use of property
  - Condemned property
  - Contaminated crops and dairy
- Output
  - Doses by pathway and organ
  - Latent health effects
  - Economic costs

MACCS2 Uses

- PRAs and other severe accident studies (e.g., SOARCA)
  - Risks from operating a facility
  - Relative importance of the risk contributors
  - Insights on potential safety improvements
- NRC Regulatory Analyses
- NEPA Studies (National Environmental Policy Act) such as: License extension and new reactor applications
  - Environmental Impact Statements (EISs)
    - the results of the calculations are typically used to compare the accident risks posed by various alternatives
  - Severe Accident Mitigation Alternatives (SAMAs) and Design Alternative (SAMDAs) analyses required for license renewal and for new licenses
- DOE Applications: Authorization basis analyses performed for DBAs
  - the analyst is interested in conservatively calculated, bounding dose estimates for well-defined DBA and beyond-DBA accident scenarios. The results of this analysis are used to determine if the safety basis of the facility is adequate for operation (DOE 1989, 1992b)
- MACCS2 has an international usership (US plus over 10 other countries)

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Scope of Analysis for Filtered Vents

MACCS2 used to calculate:

- Offsite population doses
  - Includes doses to public as well as off-site decontamination workers
- Individual latent cancer fatality risk and prompt fatality risk
- Land contamination
  - For different thresholds of Cs-137 concentration in soil (Ci/km^2)
- Economic cost
- For 50-mile radius around plant

Inputs

- Work is based on the SOARCA project, which is documented in NUREG-1935 and NUREG/CR-7110 Volume 1
- Started with SOARCA inputs for Peach Bottom Atomic Power Station pilot plant (with exception of source term, and ingestion pathway modeled)
- Habitability (return) criterion used is 500 mrem/year, per Pennsylvania State guideline
- Statistical sampling of weather sequences used to represent uncertain conditions at the time of a hypothetical accident (~1,000 weather trials)
- Linear-no-threshold dose response model

Inputs – Six Emergency Phase Cohorts

- Cohort 1: 0 to 10 Public
- Cohort 2: 10 to 20 Shadow
- Cohort 3: 0 to 10 Schools and 0 to 10 Shadow
- Cohort 4: 0 to 10 Special Facilities
- Cohort 5: 0 to 10 Tail
- Cohort 6: Non-Evacuating Public (assumed to be 0.5%)

Inputs – Decontamination Factor of Filters

- Neither MELCOR nor MACCS2 models mechanistically the decontamination effect of an external filter
- A prescribed decontamination factor (DF) value is assigned for an external filter
- This DF is applied to only a portion of the total fractional release - the portion which is released through a flow path connected to venting
- For the MACCS2 input, the MELCOR source term from the relevant flow path was reduced by the DF

MACCS2 Results Per Event

Event	Base case Case 2	Base case with WW venting Case 3 Unfiltered Filtered DF = 10	Base case with core spray Case 6	Base case with WW venting and core spray Case 7 Unfiltered Filtered DF = 10
Population dose 50 mile radius *per event* (rem)	**510,000**	**400,000** **180,000**	**310,000**	**240,000** **37,000**
Population weighted latent cancer fatality (LCF) risk 50 mile radius *per event*	**4.8E-05**	**3.3E-05** **1.3E-05**	**2.5E-05**	**1.6E-05** **2.2E-06**
Contaminated area (km^2) with level exceeding 15 $\mu Ci/m^2$ *per event*	**280**	**54** **8**	**72**	**34** **0.4**
Total economic cost 50 mile radius *per event* ($M)	**1,900**	**1,700** **270**	**850**	**480** **18**

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MACCS2 Results Per Event (continued)

Event	Base case with drywell venting Case 12 Unfiltered Filtered 1 DF=1,000 Filtered 2 DF=5,000	Base case with DW venting and DW spray Case 13 Unfiltered Filtered DF=1,000	Base case with drywell spray Case 14	Base case with WW venting & drywell spray Case 15 Unfiltered Filtered DF = 10
Population dose 50 mile radius *per event* (rem)	3,800,000 230,000 210,000	3,900,000 60,000	86,000	280,000 43,000
Population weighted latent cancer fatality (LCF) risk 50 mile radius *per event*	3.2E-04 1.6E-05 1.4E-05	3.3E-04 3.7E-06	6.4E-06	2.1E-05 2.7E-06
Contaminated area (km^2) with level exceeding 15 μCi/m2 *per event*	9,200 28 25	8,800 2	10	28 0.3
Total economic cost 50 mile radius *per event* ($M)	33,000 390 370	33,000 38	116	590 20

Insights from MACCS2 Calculations

- The health effect of interest is latent cancer fatality risk, which is controlled in part by the habitability (return) criterion
  - Essentially no prompt fatality risk
- In terms of long-term radiation, the most important isotope is Cs-137, and most of the doses are from ground shine
- There is a non-linear relationship between decontamination factor and both land contamination area and health effects

Severe Accident Containment Vent Risk Evaluation

Marty Stutzke

Office of Nuclear Regulatory Research

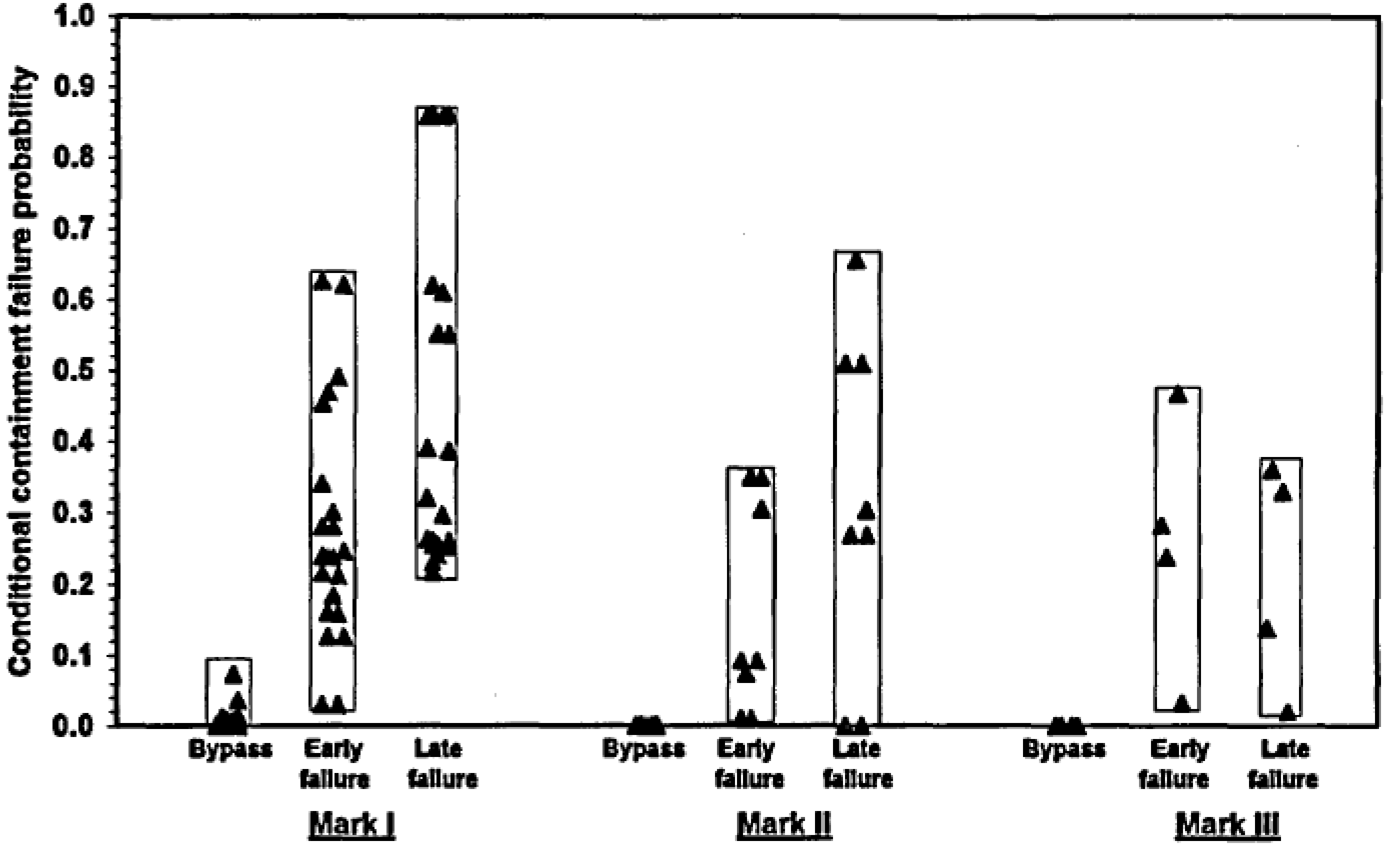
Outline

- Purpose
- Conditional Containment Failure Probability
- Insights from Severe Accident Mitigation Alternatives (SAMA) Analyses
- Technical Approach
- Results
- Uncertainties

Purpose

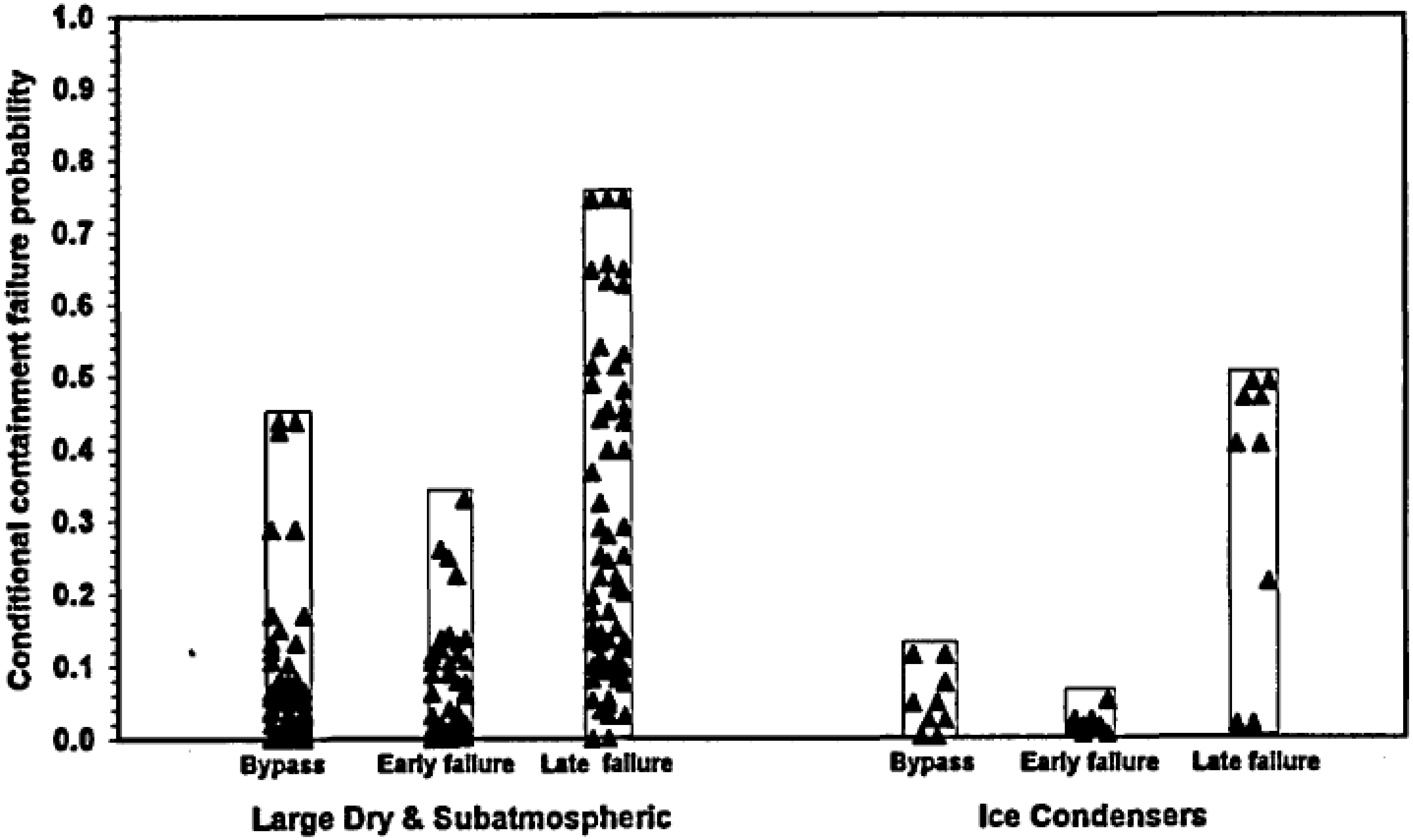
- To estimate the risk reduction resulting from installation of a severe accident containment vent for use in regulatory analysis
  - 50-mile population dose (Δperson-rem/ry)
  - 50-mile offsite cost (Δ$/ry)
  - Onsite worker dose risk (Δperson-rem/ry)
  - Onsite cost risk (Δ$/ry)
  - Land contamination (Δconditional contaminated land area)

Conditional Containment Failure Probability (BWR Individual Plant Examinations)



Source: NUREG-1560, Figure 12.3

Conditional Containment Failure Probability (PWR Individual Plant Examinations)



Source: NUREG-1560, Table 12.17

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Conditional Containment Failure Probability (ILRT Extension License Amendments)

Plant	Type	ILRT Interval	Accident Phenomena	Bypass (ISLOCA)	Isolation Failures	Total CCFP
Cooper	Mark I	3 in 10y 1 in 10y 1 in 15y	94.6% 94.6% 94.6%	0.0% 0.0% 0.0%	1.0% 1.0% 1.0%	95.6% 95.6% 95.6%
Nine Mile Point 1	Mark I	3 in 10y 1 in 10y 1 in 15y	62.4% 62.4% 62.4%	2.7% 2.7% 2.7%	9.7% 9.7% 9.8%	74.8% 74.9% 74.9%
Peach Bottom	Mark I	3 in 10y 1 in 10y 1 in 15y	61.1% 61.1% 61.1%	2.4% 2.4% 2.4%	2.7% 3.4% 4.0%	66.2% 67.0% 67.5%
Pilgrim	Mark I	3 in 10y 1 in 10y 1 in 15y	97.7% 97.7% 97.7%	0.6% 0.6% 0.6%	0.0% 0.1% 0.1%	98.3% 98.3% 98.4%
Vermont Yankee	Mark I	1 in 10y 1 in 15y	86.8% 86.8%	1.1% 1.1%	0.1% 0.2%	88.0% 88.1%
LaSalle	Mark II	3 in 10y 1 in 10y 1 in 15y	82.9% 82.9% 82.9%	2.4% 2.4% 2.4%	0.4% 0.6% 0.8%	85.7% 85.9% 86.1%
Limerick	Mark II	3 in 10y 1 in 10y 1 in 15y	62.4% 62.4% 62.4%	1.3% 1.3% 1.3%	0.7% 1.5% 2.0%	64.4% 65.2% 65.7%

Consideration of Filtered Containment Vents in SAMA Analyses

(As of February 2012)

Plant Type	Filtered Containment Vent Not Considered	FCV Considered (Screening Analysis)	FCV Considered (Detailed Analysis)	License Renewal Granted, but Limited SAMA	License Renewal Application Not Submitted	Total
BWR Mark I	5	11	5	1	1	23
BWR Mark II	1	3		2	2	8
BWR Mark III			1		3	4
PWR large dry containment	22	10	14		9	55
PWR subatmospheric containment			5			5
PWR ice condenser		2	4		3	9
Total	28	26	29	3	18	104

Screening Analysis: cost of implementation > plant-specific maximum possible monetized averted risk

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Detailed SAMA Analyses of Filtered Containment Venting

Plant	Offsite Dose Reduction	Estimated Benefit	Notes
FitzPatrick	3.73%	$4,090	Successful torus venting accident progression source terms were reduced by a factor of 2 to reflect the additional filtered capability
Pilgrim	0.00%	$0	Successful torus venting accident progression source terms were reduced by a factor of 2 to reflect the additional filtered capability
Vermont Yankee	0.11%	$200	Successful torus venting sequences were binned into the Low-Low release category to conservatively assess the benefit of this SAMA

Not clear if post-core-damage venting to prevent containment overpressurization failure was considered in these analyses

Core Damage Frequency

Source	CDF (/ry)
NUREG-1150 Peach Bottom (includes internal events, fires, and seismic events based on the LLNL hazard curves)	1E-4
SPAR Internal and External Event Models (BWR Mark I Plants) Duane Arnold Monticello Peach Bottom	 1E-5 2E-5 2E-5
SAMA Analyses (Five BWR Mark I and Mark II plants with internal and external event PRAs)	2E-5 to 6E-5
Global Statistical Value	3E-4

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Economic Consequences

Source	cost/event
Regulatory analysis handbook (NUREG/BR-0184, Table 5.6, Peach Bottom, 1990 dollars)	$3B*
SAMA Analyses Peach Bottom Minimum for BWR Mark I and Mark II plants (Hatch) Maximum for BWR Mark I and Mark II plants (Hope Creek)	 $10B* $0.6B* $30B*
Estimated Fukushima offsite costs (3 Units) (Japan Center for Economic Research, June 2011, includes land condemnation for 20 km and compensation for 10 years)	$62B
Deepwater Horizon oil spill	$23B

*Frequency-weighted average of the point estimates for internal events

Designing a Technical Approach

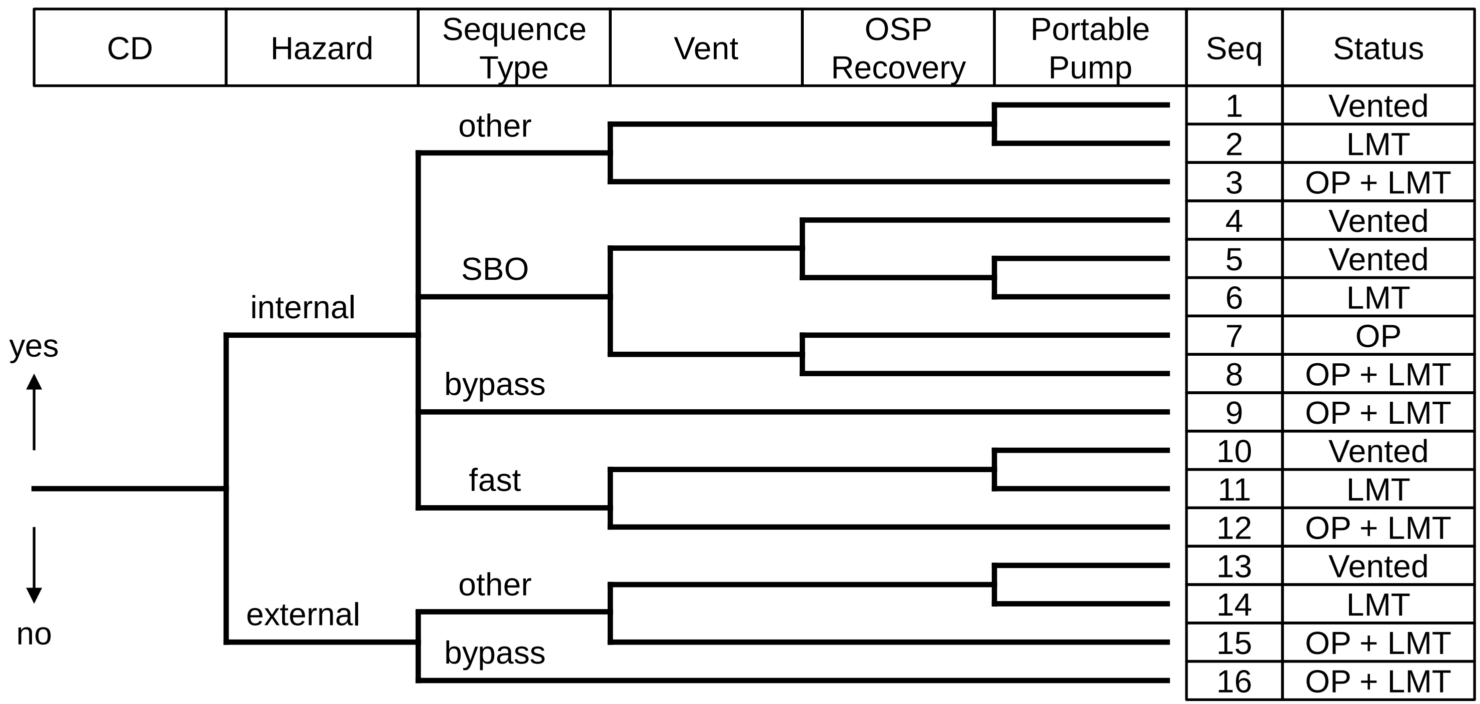
- Focus on BWR Mark I plants
- Risk modeling
  - No change in CDF
  - Need to use simplified Level 2/3 PRA
    - Not feasible to develop complete Level 3 PRA
    - SOARCA MELCOR and MACCS2 for Peach Bottom
- Eight candidate plant modifications
  - Vent actuation: manual or passive — **Affects frequency estimation**
  - Vent location: wetwell or drywell
  - Filter: no or yes

  } **Affects consequence estimation**
- Consideration of post-core-damage core spray or drywell spray to prevent liner melt-through

Assumptions and Groundrules

- Use existing regulatory analysis guidance
  - Risk evaluation developed on a “per-reactor” basis
  - Multi-unit accidents not addressed
  - Spent fuel pool accidents not addressed
- Release sequence consequences are reasonably approximated by determining the consequences of SBO sequences
- Battery life is 16 hours
- Filter decontamination factor of 10
- No credit for recovering offsite power if core-damage was caused by an external hazard (e.g., seismic, high winds)
- If a sequence involves failure to open the vent or containment bypass (e.g., ISLOCA), then use of a portable pump (B.5.b/FLEX) for core spray or drywell spray following core damage is precluded due to a harsh work environment (high dose rates, high temperatures, etc.)

Release Event Tree



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Release Sequence Quantification Data Sources

Parameter	Value		Basis
Core-damage frequency	2E-5/ry		SPAR models
Fraction of total CDF due to external hazards	0.8		SPAR-EE models
Breakdown of sequence types for internal hazards	Other (not SBO, bypass, or fast)	0.83	SPAR models
	SBO	0.12	
	Bypass (ISLOCAs)	0.05	
	Fast (MLOCAs, LLOCAs, ATWS)	0.01	
Breakdown of sequence types for external hazards	Other (not bypass)	0.95	Engineering judgment
	Bypass	0.05	

Release Sequence Quantification Data Sources

Parameter	Value		Basis
Probability that severe accident vent fails to open	Mod 0	1	Current situation (base case)
	Mods 1,3,5,7 – other or SBO	0.3	SPAR-H (manual vent, longer available time)
	Mods 1,3,5,7 - fast	0.5	SPAR-H (manual vent, shorter available time)
	Mods 2,4,6,8	0.001	Engineering judgment (passive vent)
Conditional probability that offsite power is not recovered by the time of lower head failure given not recovered at the time of core damage (internal hazards)	0.38		NUREG/CR-6890
Probability that portable pump for core spray or drywell spray fails	0.3		SPAR-H; consistent with B.5.b study done by INL

Mapping Release Sequence End States to MELCOR/MACCS2 Cases

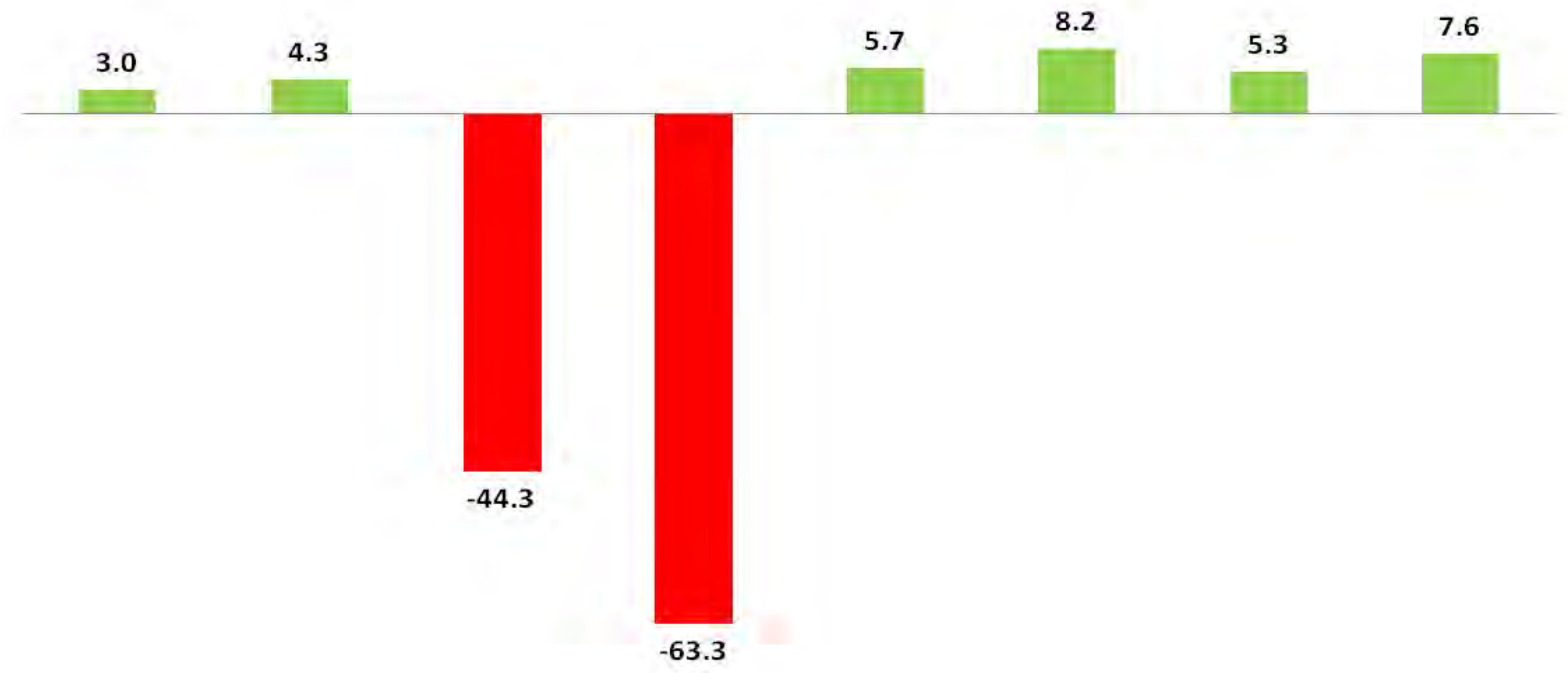
			Release Sequence End State			
		Identifier	vented	LMT	OP	OP + LMT
		Vented	yes	yes	no	no
		Drywell Status	wet	dry	wet	dry
		Sequences	1,4,5,10,13	2,6,11,14	7	3,8,9,12,15,16
Vent Location	**Filter**	**Mod(s)**	**MELCOR/MACCS2 Case**			
Wetwell	No	0 - none 1 - manual 2 – passive	Case 7 or 15 (no filter)	Case 3 (no filter)	Case 6	Case 2
Drywell	No	3 - manual 4 – passive	Case 13 (no filter)	Case 12 (no filter)	Case 14	Case 2
Wetwell	Yes	5 - manual 6 – passive	Case 7 or 15 (filter)	Case 3 (filter)	Case 6	Case 2
Drywell	Yes	7 - manual 8 - passive	Case 13 (filter)	Case 12 (filter)	Case 14	Case 2

Accident Sequence Frequency Contributions

Containment Failure Mode	Manual Vent Mods 1, 3, 5, 7	Passive Vent Mods 2, 4, 6, 8
Overpressurization (OP)	0.4%	0.0%
Liner Melt-Through (LMT)	19.6%	28.0%
Overpressurization and Liner Melt-Through (OP + LMT)	33.1%	5.1%
Total	53.2%	33.1%

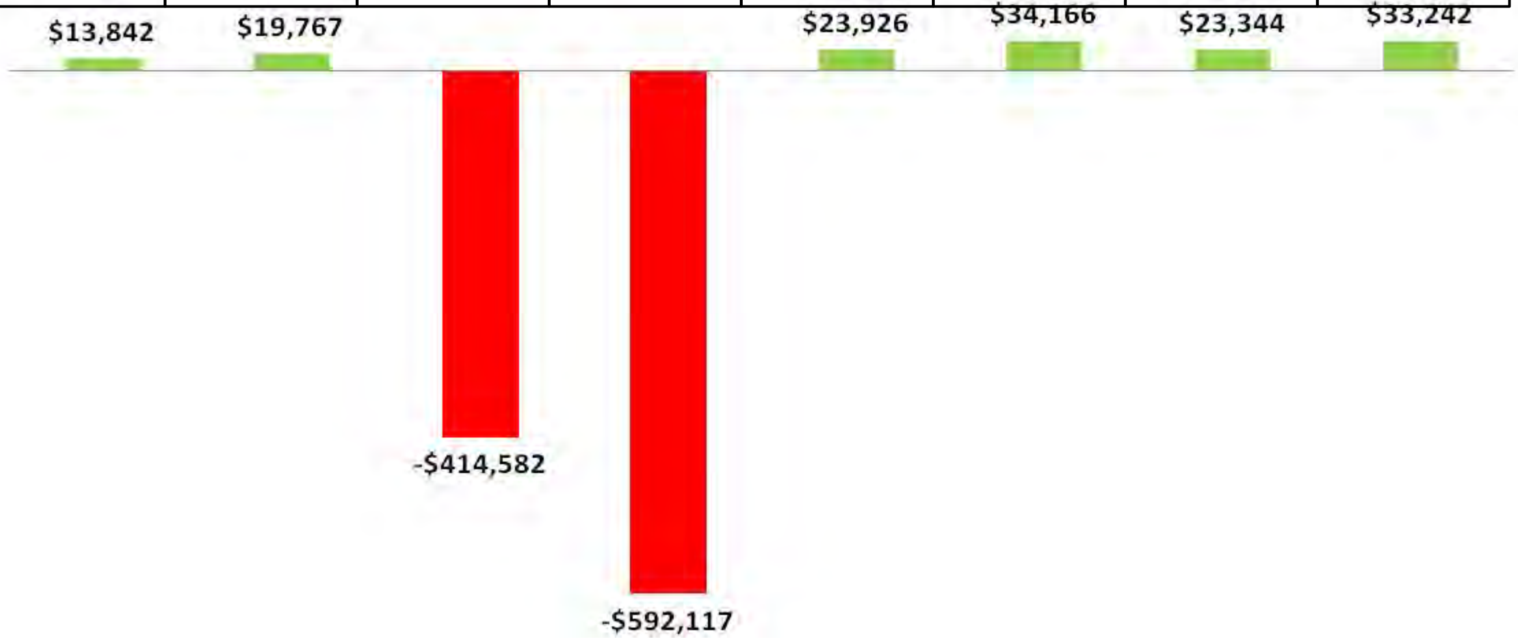
Reduction in Population Dose Risk (Δperson-rem/reactor-year)

Unfiltered				Filtered			
Wetwell		Drywell		Wetwell		Drywell	
Manual	Passive	Manual	Passive	Manual	Passive	Manual	Passive
Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8



Reduction in Offsite Cost Risk (Δ$/reactor-year)

Unfiltered				Filtered			
Wetwell		Drywell		Wetwell		Drywell	
Manual	Passive	Manual	Passive	Manual	Passive	Manual	Passive
Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8



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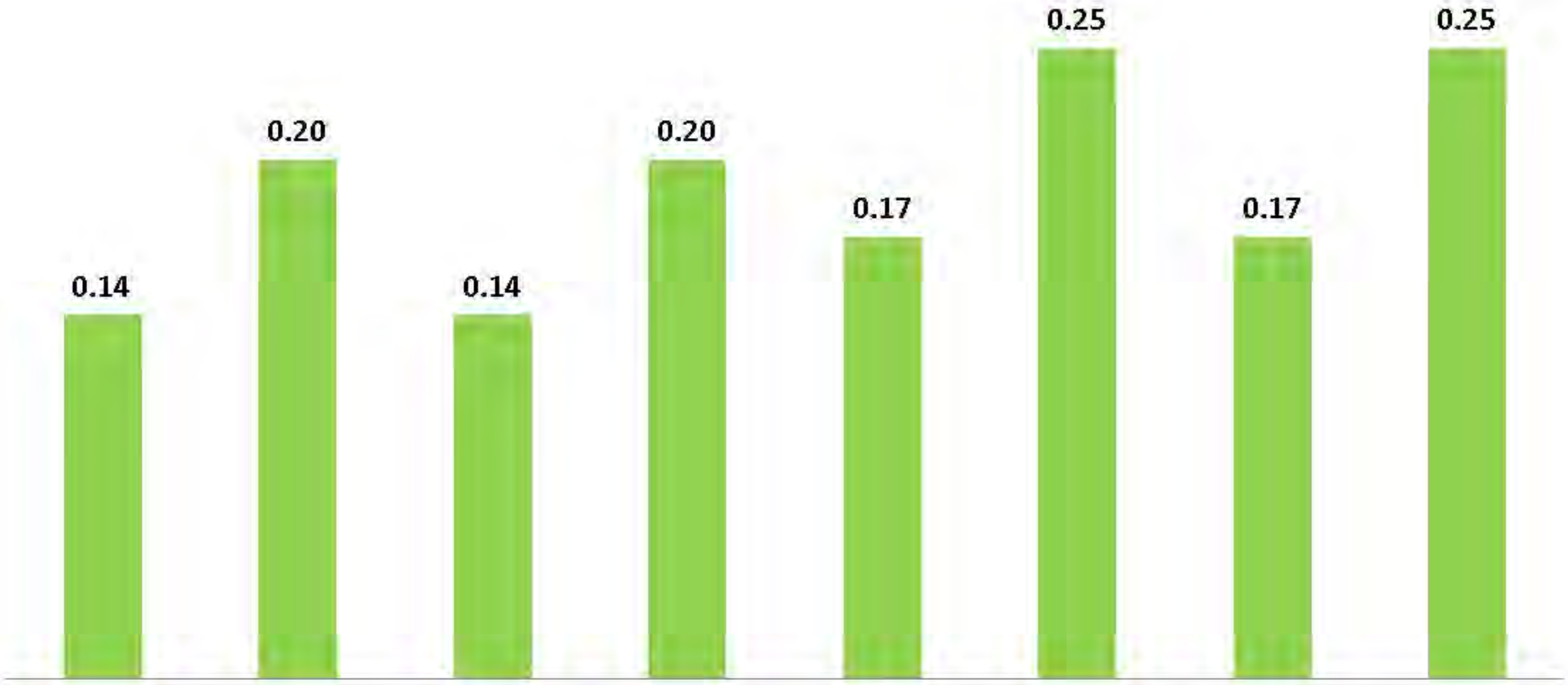
Reduction in Worker Dose Risk (Δperson-rem/reactor-year)

Unfiltered				Filtered			
Wetwell		Drywell		Wetwell		Drywell	
Manual	Passive	Manual	Passive	Manual	Passive	Manual	Passive
Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8



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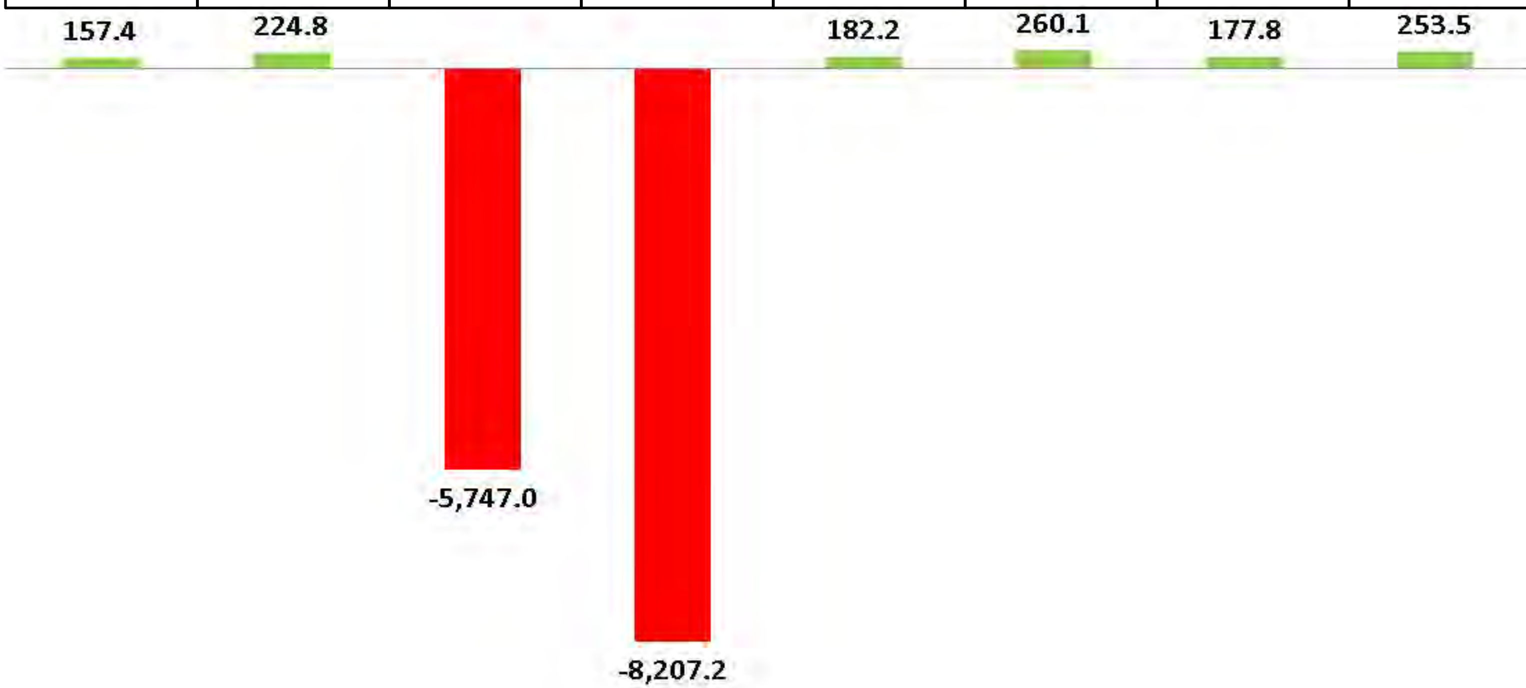
Reduction in Onsite Cost Risk (Δ$/reactor-year)

Unfiltered				Filtered			
Wetwell		Drywell		Wetwell		Drywell	
Manual	Passive	Manual	Passive	Manual	Passive	Manual	Passive
Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8

Reduction in Conditional Contaminated Land Area (Δsquare kilometers)

Unfiltered				Filtered			
Wetwell		Drywell		Wetwell		Drywell	
Manual	Passive	Manual	Passive	Manual	Passive	Manual	Passive
Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8



Uncertainty Analysis

- Approximate Monte Carlo analysis performed to gain an appreciation of the uncertainties involved
  - Sequence frequencies
  - Sequence consequences

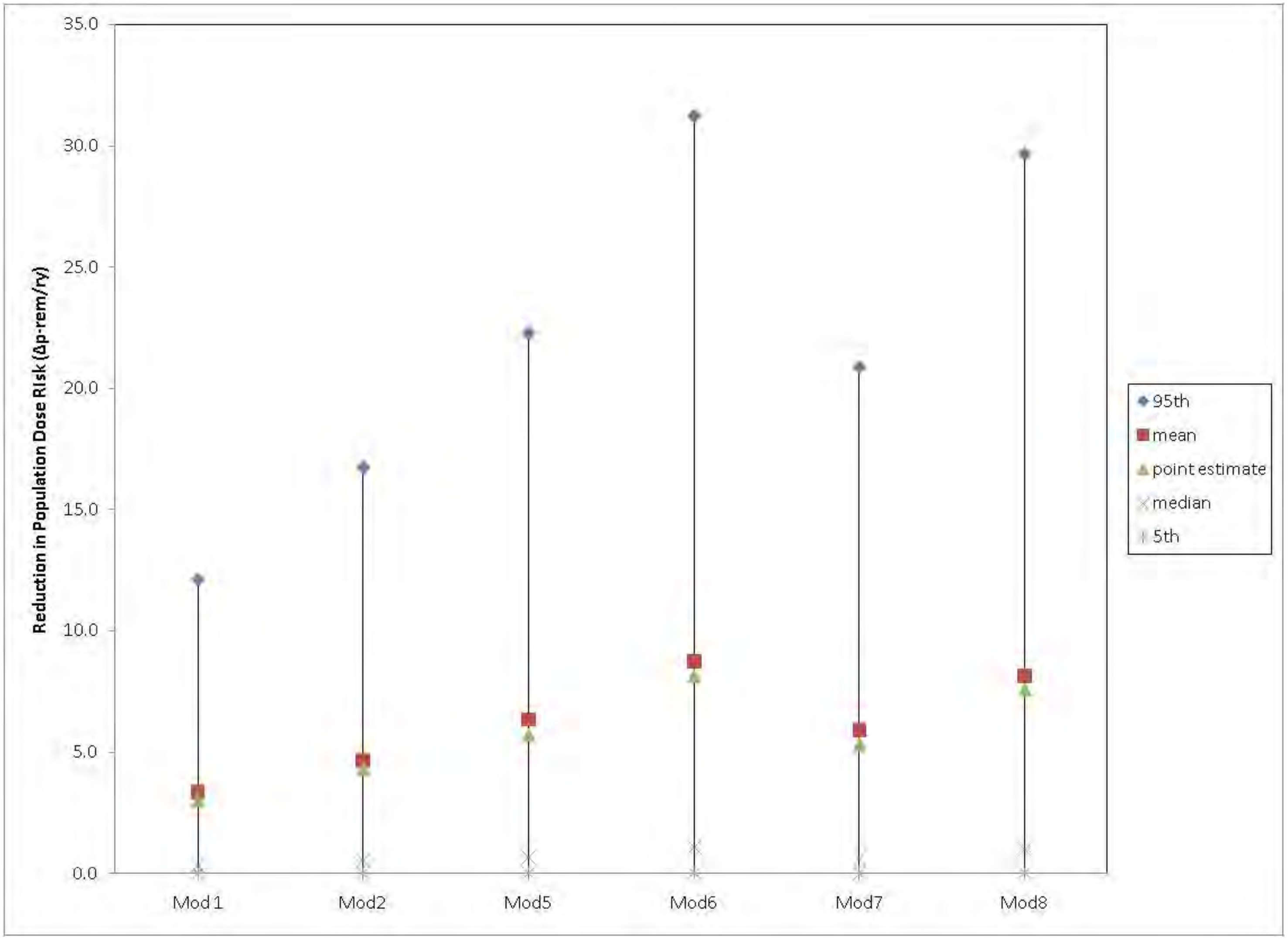
Uncertainty Parameters

Parameter	Mean		Parameters
Core-damage frequency	2E-5/ry		Log-normal; EF = 10
Fraction of total CDF due to external hazards	0.8		Beta; α = 0.5, β = 0.125
Breakdown of sequence types for internal hazards	Other (not SBO, bypass, or fast)	0.83	Dirichlet α1 = 41 α2 = 6 α3 = 2.5 α4 = 0.5
	SBO	0.12	
	Bypass (ISLOCAs)	0.05	
	Fast (MLOCAs, LLOCAs, ATWS)	0.01	
Breakdown of sequence types for external hazards	Other (not bypass)	0.95	Beta; α = 0.5, β = 9.5
	Bypass	0.05	

Uncertainty Parameters

Parameter	Mean		Parameters
Probability that severe accident vent fails to open	Mod 0	1	Not uncertain
	Mods 1,3,5,7 – other or SBO	0.3	Beta; α = 0.5, β = 1.167
	Mods 1,3,5,7 - fast	0.5	Beta; α = 0.5, β = 0.5
	Mods 2,4,6,8	0.001	Beta; α = 0.5, β = 499.5
Conditional probability that offsite power is not recovered by the time of lower head failure given not recovered at the time of core damage (internal hazards)	0.38		Beta; α = 0.5, β = 0.816
Probability that portable pump for core spray or drywell spray fails	0.3		Beta; α = 0.5, β = 1.167
Consequences	Per MELCOR/MACCS2 results and regulatory analysis assumptions		Log-normal; EF = 10 (correlated)

Uncertainty in Population Dose Risk Reduction



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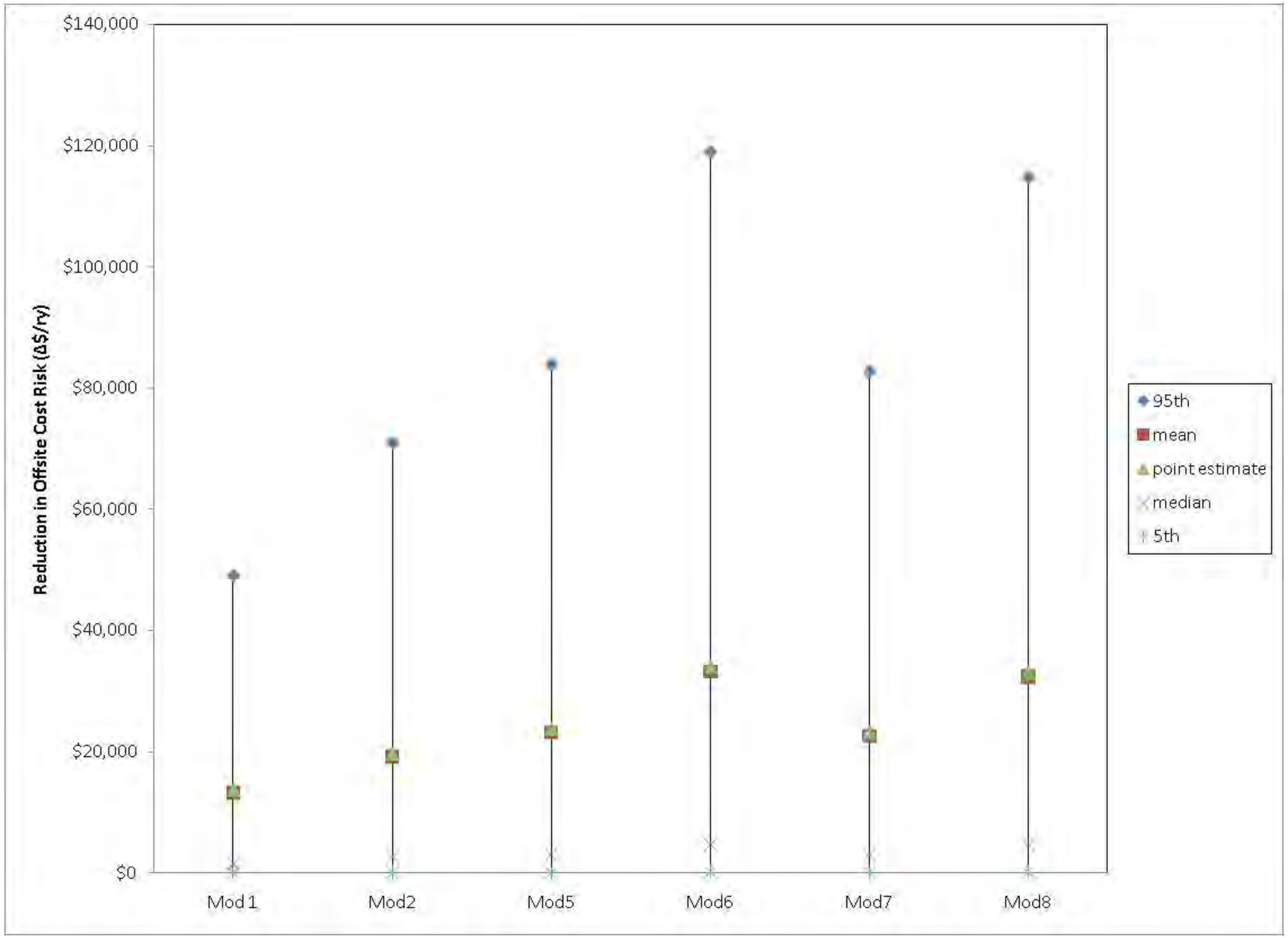
Uncertainty in Offsite Cost Risk Reduction



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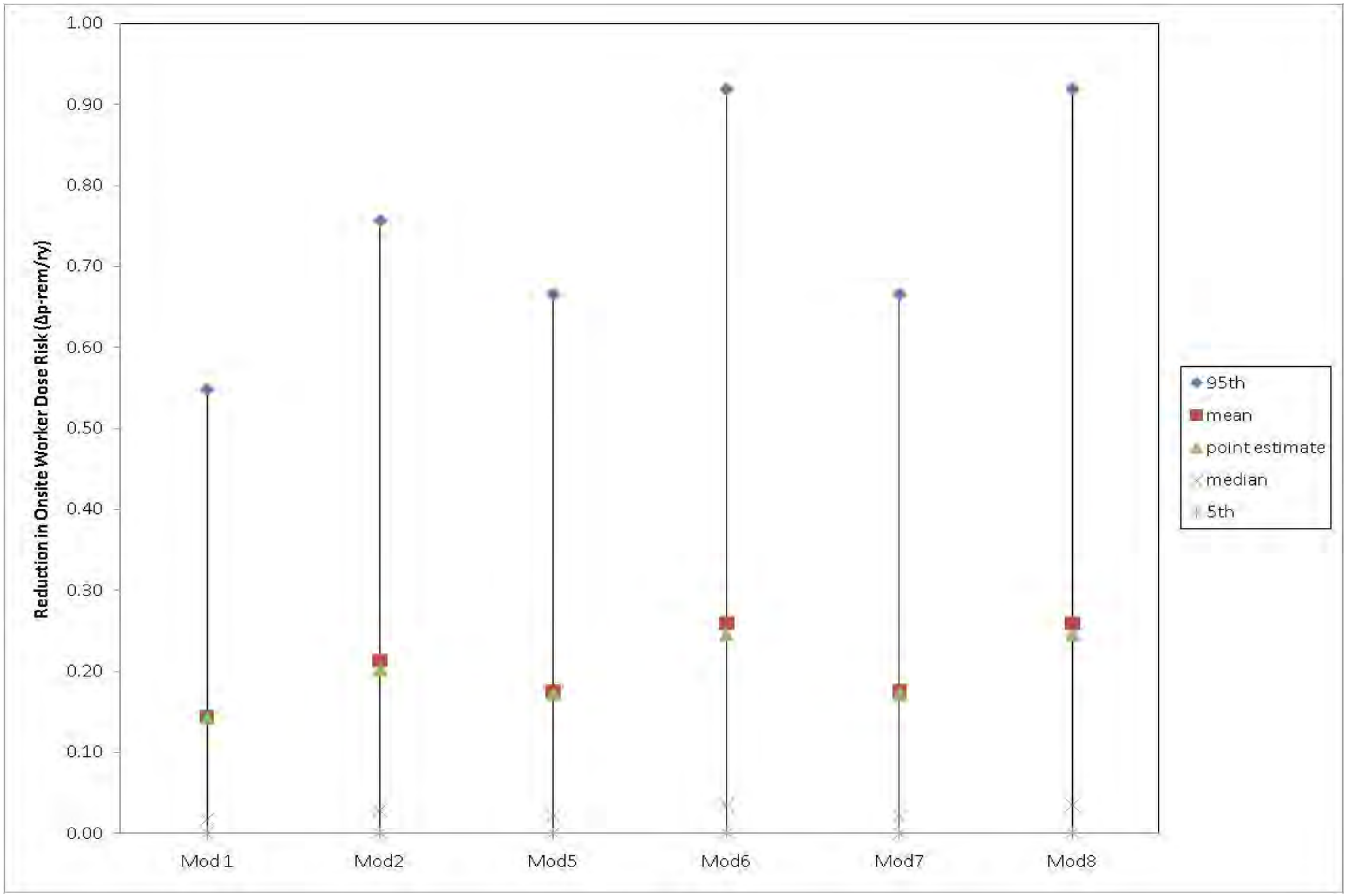
Uncertainty in Onsite Worker Dose Risk Reduction



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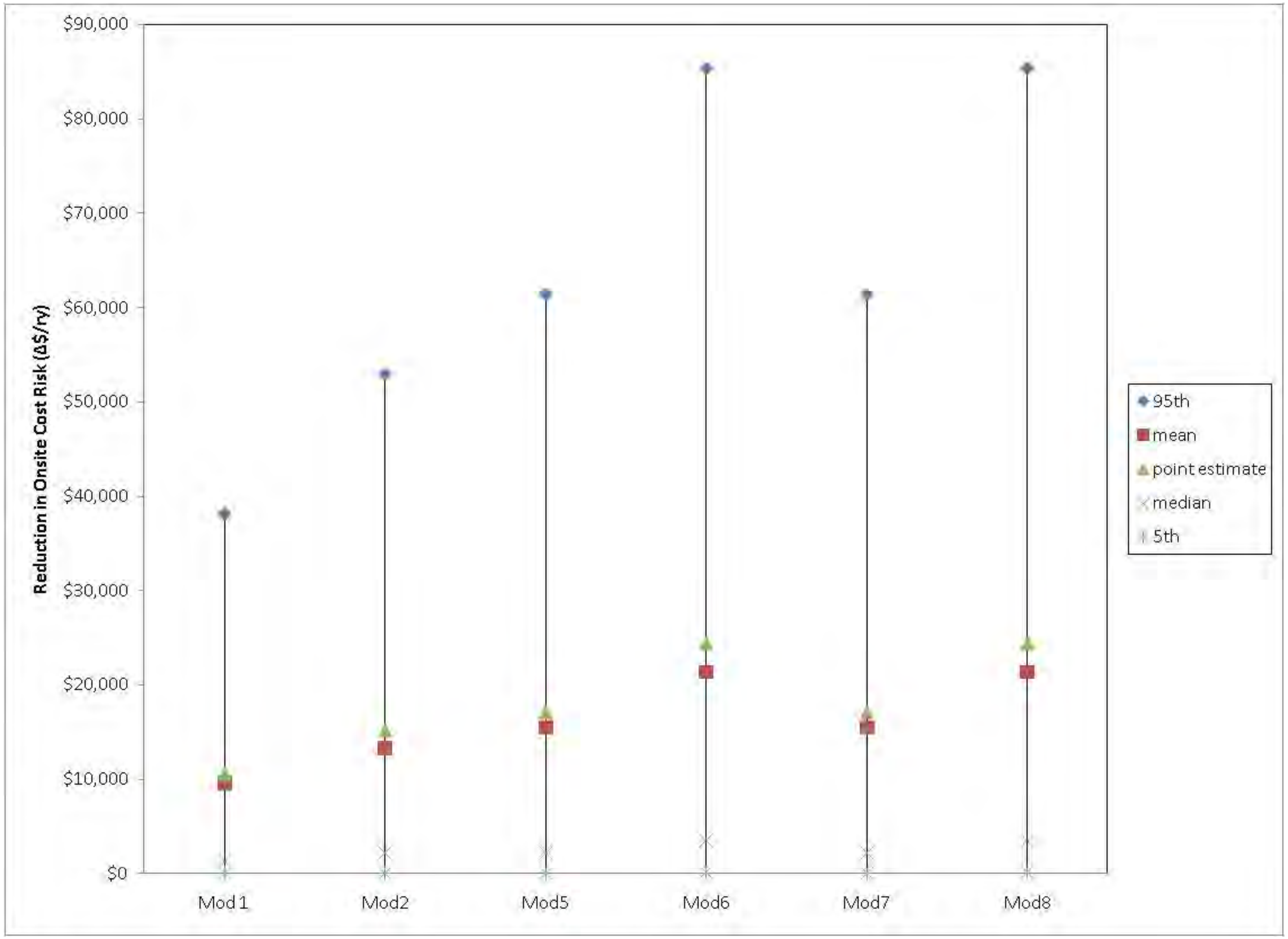
Uncertainty in Onsite Cost Risk Reduction



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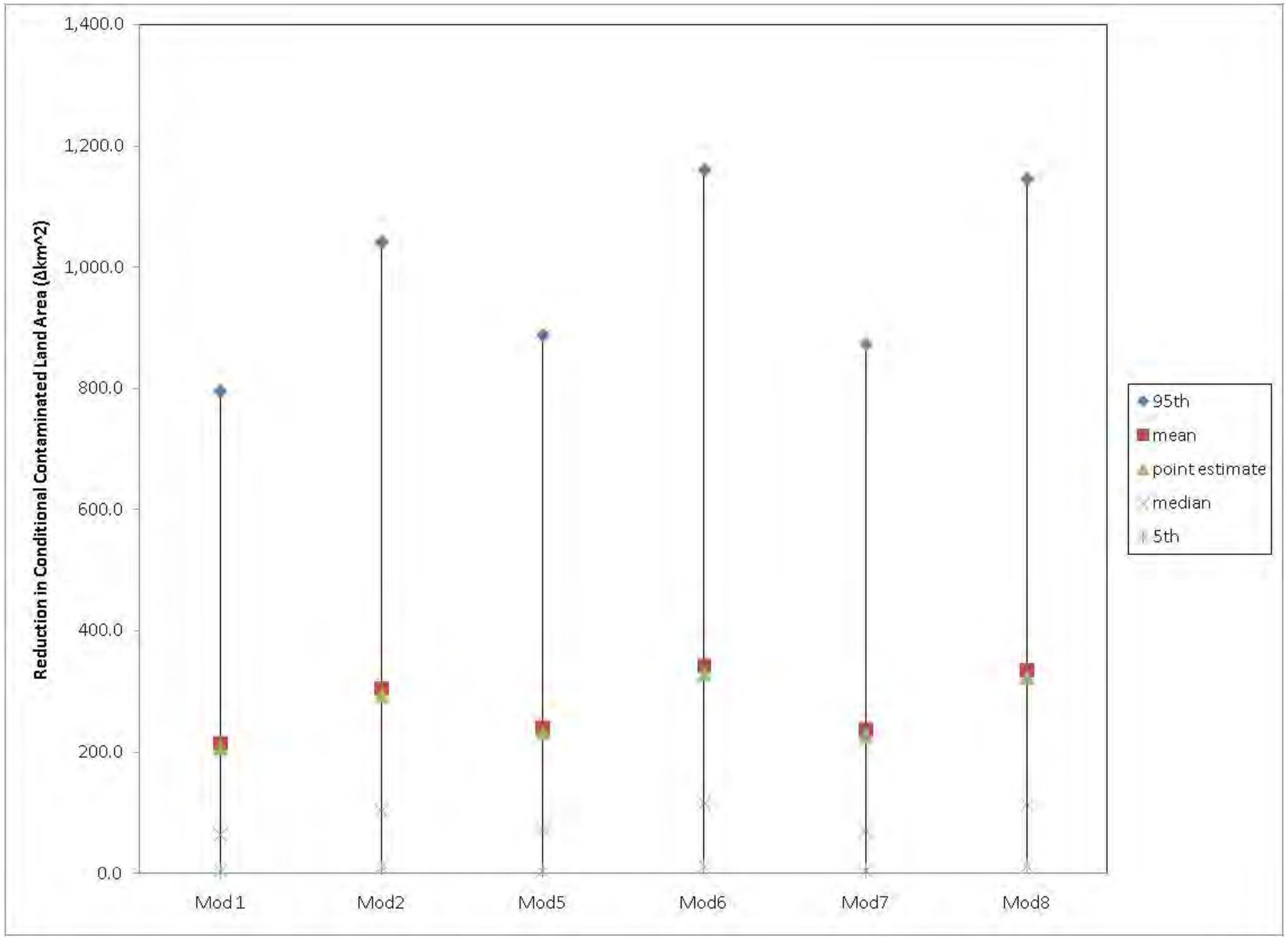
Uncertainty in Conditional Contaminated Land Area



Regulatory Analysis and Backfitting

Aaron Szabo
Office of Nuclear Reactor Regulation
Rulemaking Branch

Outline

- Regulatory Decision-Making Process
- Methodology for Regulatory Analysis
  - Task-specific information
  - Steps for a Regulatory Analysis
- Backfitting
  - Adequate Protection
  - Cost-Justified Substantial Safety Enhancement
- Filtered Vents Regulatory Analysis
  - Assumptions and Sensitivities
  - Quantitative Analysis
    - Current Framework
    - Sensitivity Analysis
  - Qualified Attributes
- Summary

Regulatory Decision-Making Process

- Regulatory Analysis looks at all the costs and all the benefits of the regulatory action to inform decision-makers
  - Quantified and qualified
  - Identify uncertainties with the analysis
- Backfitting determines if we can impose a requirement on licensees (10 CFR 50.109)

Methodology for Regulatory Analysis

- 4 Options
  - 1: No Change (Re-affirm EA-12-050)
  - 2: Severe Accident Capable Vent
  - 3: Filtered Vent
  - 4: Performance-Based Approach
- All attributes dispositioned using current framework
  - NUREG/BR-0058, NUREG/BR-0184, NUREG-1409
  - Any deviations are identified and provided as a sensitivity analysis

Methodology for Regulatory Analysis

- Steps to perform a Regulatory Analysis
  - Identify legitimate alternatives and options
  - Determine if the action is a backfit
  - Evaluate attributes
    - Public Health (Accident)
    - Offsite Property
    - Industry Implementation
    - NRC Implementation
    - Regulatory Efficiency
    - Occupational Health (Accident)
    - Onsite Property
    - Industry Operation
    - NRC Operation
  - Develop recommendations

How Information is Provided

- Recommendations are provided using the "best [point] estimate" calculations
- Benefits and costs are determined by multiplying the probability of the event by the change in consequences
  - (e.g. Probability of event times (Alt. 1 consequence – Alt. 2 consequence))
- Sensitivity analyses are provided for decision-makers

Backfitting

- Adequate Protection
  - Severe Accident Capable Vent
  - Filtered Vent
  - Performance-Based Approach

Backfitting - Cost-Justified Substantial Safety Enhancement

- 2 Part Analysis
  - Substantial Safety Enhancement
  - Cost-justified
- SRM-SECY-93-086, "Backfit Considerations"
  - The safety enhancement criterion should be administered with the degree of flexibility the Commission originally intended
  - The standard is not intended to be interpreted in a manner that would result in disapprovals of worthwhile safety or security improvements having costs that are justified in view of the increased protection that would be provided
  - Allows for both quantitative and qualitative arguments

Backfitting - Cost-Justified Substantial Safety Enhancement

- Substantial Safety Enhancement
  - Attributes included
    - Public Health (accident)
    - Occupational Health (accident)

Backfitting - Cost-Justified Substantial Safety Enhancement

- Cost-Justified
  - Attributes included
    - Public Health (accident)
    - Occupational Health (accident)
    - Industry Implementation and Operation
    - NRC Implementation and Operation
    - Offsite Property and Onsite Property
    - Regulatory Efficiency

Analysis Assumptions (NUREG/BR-0184)

- Onsite Property
  - Option 1 = Upper bound ($2B (1993) or $3.2B (2012))
  - Option 2 = Middle ($1.5B (1993) or $2.4B (2012))
  - Option 3 = TMI ($750M (1981) or $1.9B (2012))
- Occupational Workers (during accident)
  - Does not include decontamination and cleanup
  - Assumes at least 1,000 workers (small dose)
  - Option 1 = Upper bound (14,000 person-rem)
  - Option 2 = Middle (3,300 person-rem)
  - Option 3 = TMI (1,000 person-rem)

Sensitivity Analysis

Parameter	Current Framework	Sensitivity Analysis
Dollar per person-rem	$2,000 (NUREG-1530)	$4,000 (EPA and ICRP No. 103)
Discount Rate	3% and 7% (OMB Circular A-4)	Undiscounted (Current Market)
Initial Event Probability	2E-05 PRA based (SPAR Model)	3E-04 Global Statistical Value (Accidents/Operation)
Monte Carlo PRA	Point Estimate	5^{th} Percentile and 95^{th} Percentile
Replacement Energy Costs	$15.4 million/year (NUREG/BR-0184)	$56.3 million/year to $716,000/year (Updated, regional based with high and low values)
	Other unit(s) at site shutdown	All Mark I and Mark II reactors shutdown (30 units)

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Sensitivity Analysis

- Recommendation will be based on current framework
- Assessed 107 sensitivity cases based on the consequence results for each option, not including the discount values
  - No sensitivity cases for Industry and NRC Implementation and Operation costs

Quantitative Analysis – Option 2, SACV (Current Framework)

- Estimated Costs
  - Industry Costs: $60M
  - NRC Costs: $8M to $12M
  - Total Costs: $68M to $72M

Quantitative Analysis – Option 2, SACV (Current Framework)

- Estimated Benefits (range based on discount factors)
  - Public Health: 112 person-rem averted
    - $4M to $5.7M
  - Occupational Health: 5 person-rem averted
    - $100,000 to $200,000
  - Offsite Property (Cost Offset)
    - $8M to $11M
  - Onsite Property (Cost Offset)
    - $4.4M to $7.5M
  - Total Benefit
    - $16.5M to $24.4M
- Net Value
  - ($55.5M) to ($43.6M)

Quantitative Analysis – Option 3, Filtered Vent (Current Framework)

- Estimated Costs
  - Industry Costs: $465M (based on $15M per unit)
  - NRC Costs: $8M to $12M
  - Total Costs: $473M to $477M

Quantitative Analysis – Option 3, Filtered Vent (Current Framework)

- Estimated Benefits (ranges based on discount factors)
  - Public Health: 212 person-rem averted
    - $6.3M to $9.3M
  - Occupational Health: 7 person-rem averted
    - $300,000 to $400,000
  - Offsite Property (Cost Offset)
    - $14M to $20M
  - Onsite Property (Cost Offset)
    - $104M to $181M
  - Total Benefit
    - $125M to $211M
- Net Value
  - ($352M) to ($262M)

Quantitative Analysis – Option 4, Performance-Based (Current Framework)

- No quantified costs or benefits
- Discussion provided qualitatively
- Amenable to site-specific approaches

Qualitative Arguments

- Will be included in the Regulatory Analysis
- Historically, they have considered safety goal policy qualitative goals, defense-in-depth, uncertainties, consistency with standards (regulatory efficiency), etc.

Summary

- Option 2 (SACV) and Option 3 (filtered vent) do not appear to be cost-beneficial quantitatively in the current framework
  - Sensitivity analysis may provide cases that are cost-beneficial
  - May require qualitative arguments for "substantial safety enhancement"

Qualitative Arguments for Filtered Vents (Option 3)

Tim Collins
Office of Nuclear Reactor Regulation
Division of Safety Systems

Qualitative Arguments

- Defense-in-Depth
- Severe Accident Management Decision Making
  - Operator Response
  - Hydrogen Control
- Consequence Uncertainties
- International Practice

Enhances Defense-in-Depth

- Containment is an essential element of DID
  - Protects against uncertainties in prevention of severe accidents and potential consequences of a large release
- Filtering compensates for the loss of the containment barrier due to venting
- Filtering improves confidence to depressurize containment to address other severe accident challenges

Enhances Defense-in-Depth

- Filtering extends time for emergency planning implementation
  - Adds margin for uncertainty in weather, public response, collateral damage, communications, etc.

Severe Accident Management Decision Making

- Improves operator confidence in a “clean” release for hydrogen control
  - Allows early operator intervention to vent hydrogen and control containment pressure
  - Sustained lower pressure reduces leakage of hydrogen thru penetration seals
  - Decreased leakage reduces threat from hydrogen explosion to reactor building, spent fuel pool, and emergency responders

Severe Accident Management Decision Making

- Facilitates arrest of in-vessel melt progression and ex-vessel challenge to drywell liner
  - Allows early operator intervention to control pressure
    - Sustained lower pressure facilitates injection from low pressure water sources
      - Increases chances of early melt arrest and protection of liner
    - Sustained lower pressure reduces leakage of fission products thru penetration seals
      - Facilitates operator access to reactor building for recovery
    - Facilitates use of all onsite resources

Severe Accident Management Decision Making

- Operator confidence in “clean” release facilitates use of vent as a mitigation tool
  - Supports use of drywell and/or wetwell as vent inlet
    - Alleviates concerns with wetwell floodup strategy
  - Supports passive actuation
    - Minimal consequences of inadvertent actuation

Consequence Uncertainties

- Improves protection against uncertainties associated with potential land contamination
  - Fission product release fractions
  - Weather patterns
  - Farm products/food chain impacts
  - Hydrology
  - Economic impacts

Consequence Uncertainties

- Reduces potential for significant social repercussions
  - Public anxiety
  - Impact on energy supply chain

International Practices

- Consistent with recommendation from Extraordinary Meeting of Members of Convention on Nuclear Safety to upgrade "measures to ensure containment integrity, and filtration strategies and hydrogen management for the containment"
- Consistent with decisions of most European countries, Canada, Taiwan, and Japan

Next Steps

- Continue staff assessment and develop recommendations
- Engage Steering Committee
- Present conclusions and recommendations to ACRS on October 31 and November 1

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Filtered Containment Venting Systems

BACKUP SLIDES

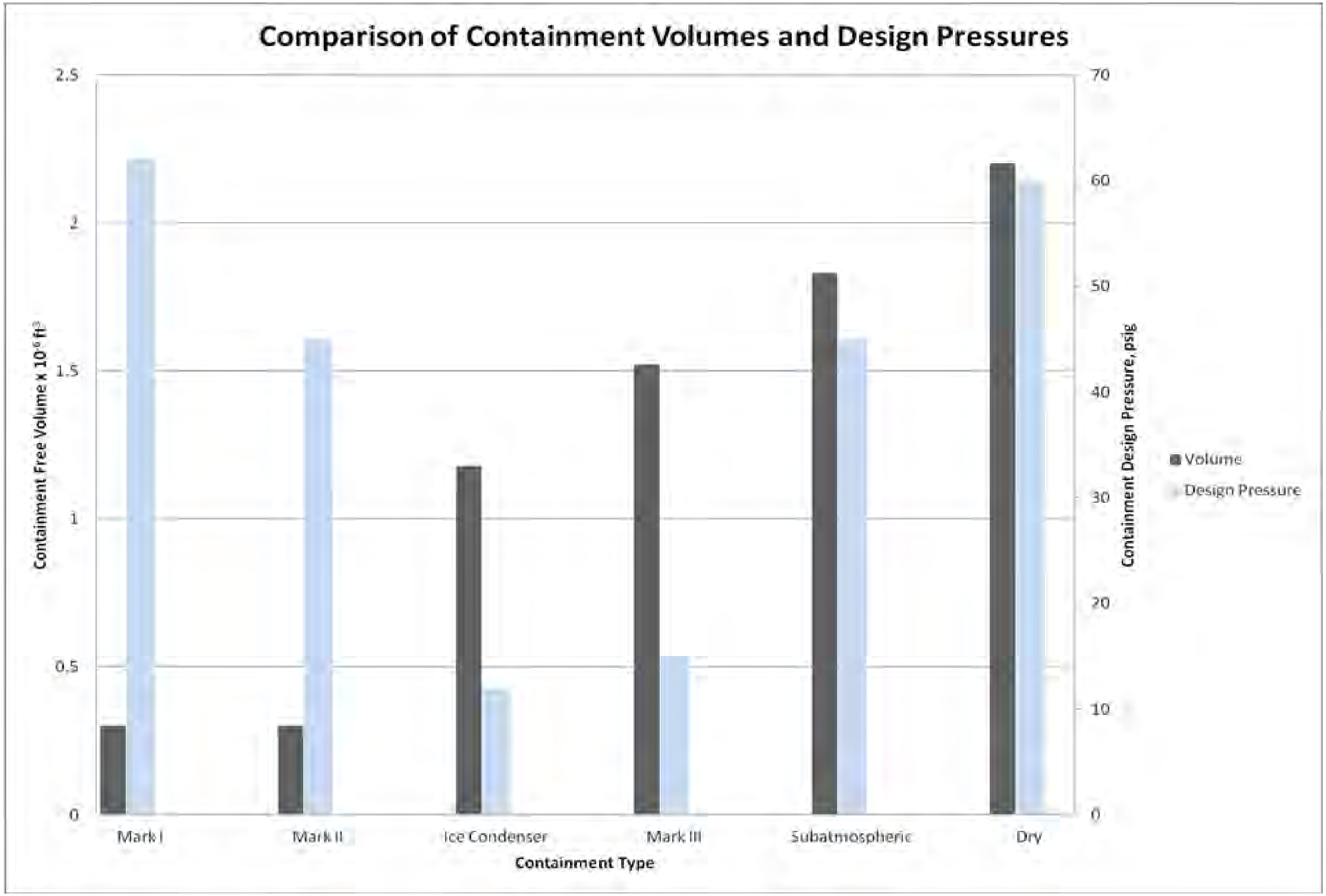
Advisory Committee on Reactor Safeguards

Fukushima Subcommittee

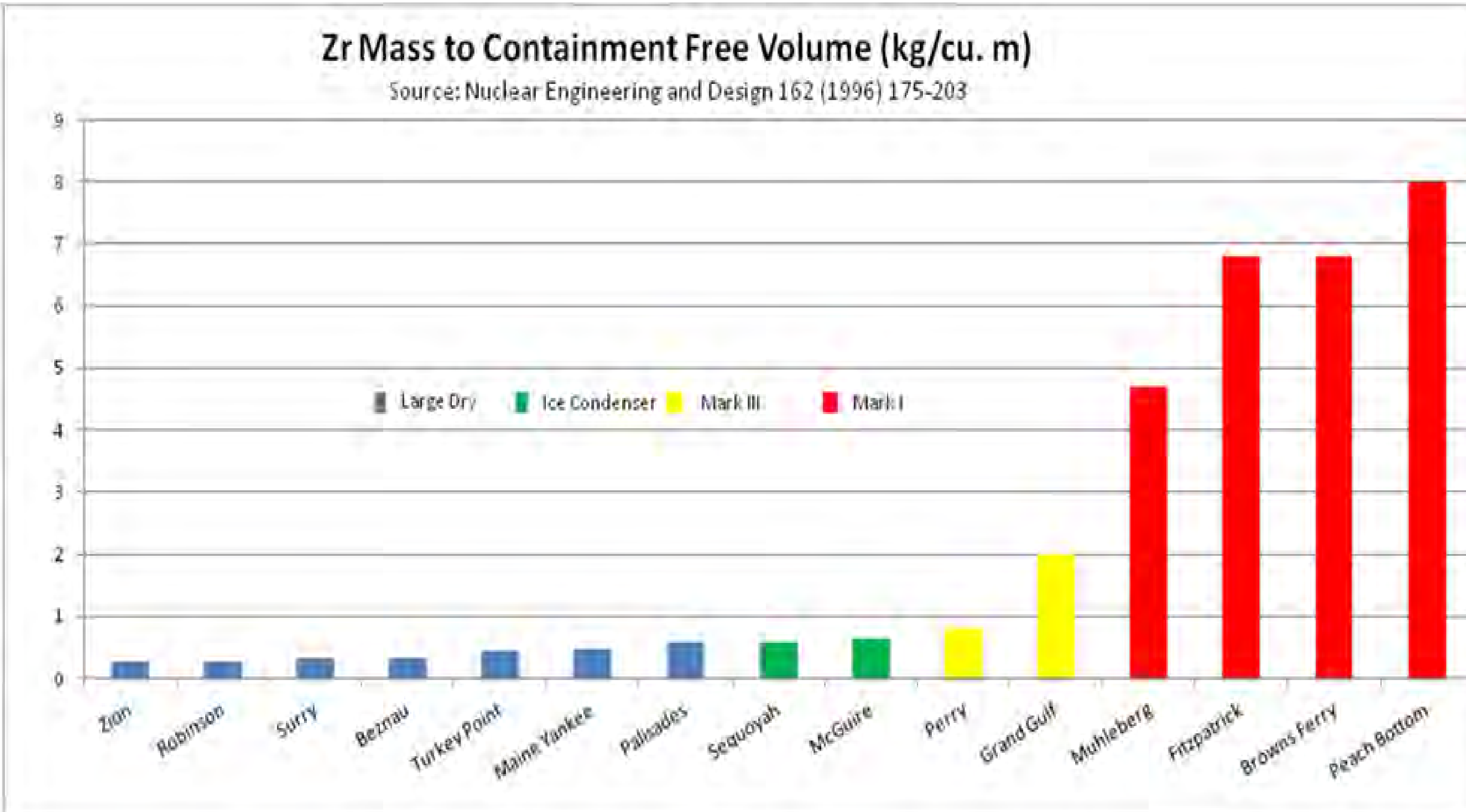
October 3, 2012

Bob Dennig

Backup Slides



Comparison of Containment Volumes and Design Pressures
Containment Free Volume x 10^6 ft^3
Containment Design Pressure, psig
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50
60
70
Mark I
Mark II
Ice Condenser
Mark III
Subatmospheric
Dry
Containment Type
Volume
Design Pressure



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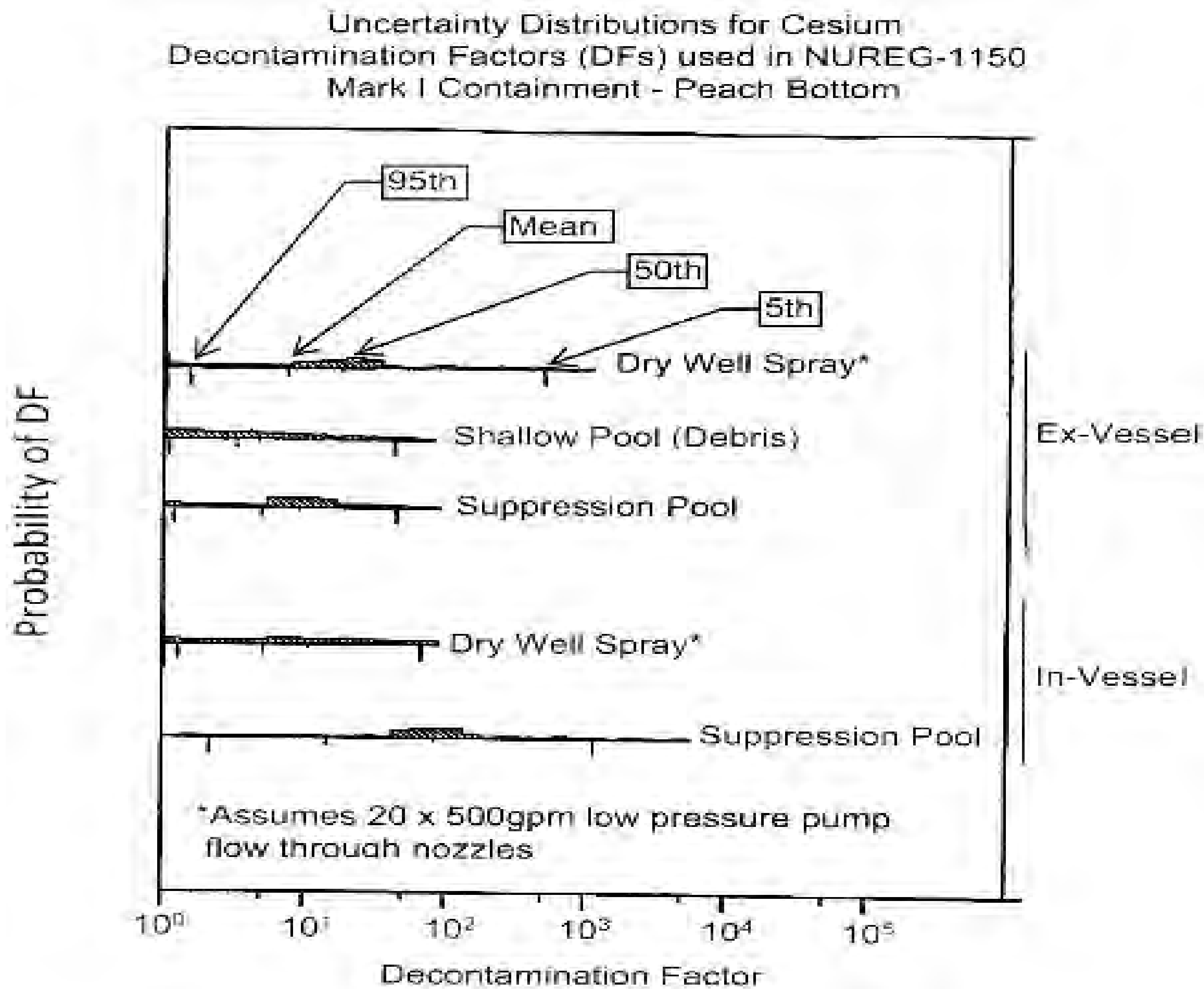

Source: "Assessment of In-Containment Aerosol Removal Mechanisms," BNL Technical Report L-1535, 1992.

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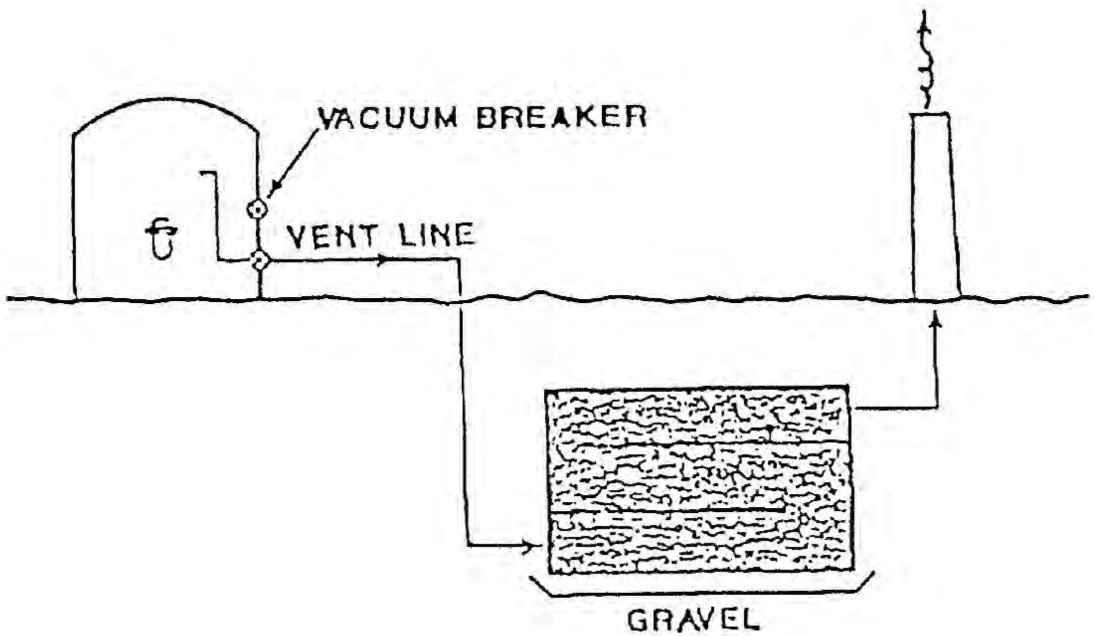
Particle Collection Efficiency in a Venturi Scrubber: Comparison of Experiments with Theory 1986

- Introduction
- Venturi scrubbers are used widely for removing particles from gases because of their many attractive features: they remove submicrometer particles efficiently; they are compact and simple to build, so that initial investment costs are small in comparison to other types of particle collection devices; and they function well in problematic situations such as hot or corrosive atmospheres and when sticky particles must be collected.

20th DOE/NRC Nuclear Air Cleaning Conference – August 1988

20th DOE/NRC NUCLEAR AIR CLEANING CONFERENCE



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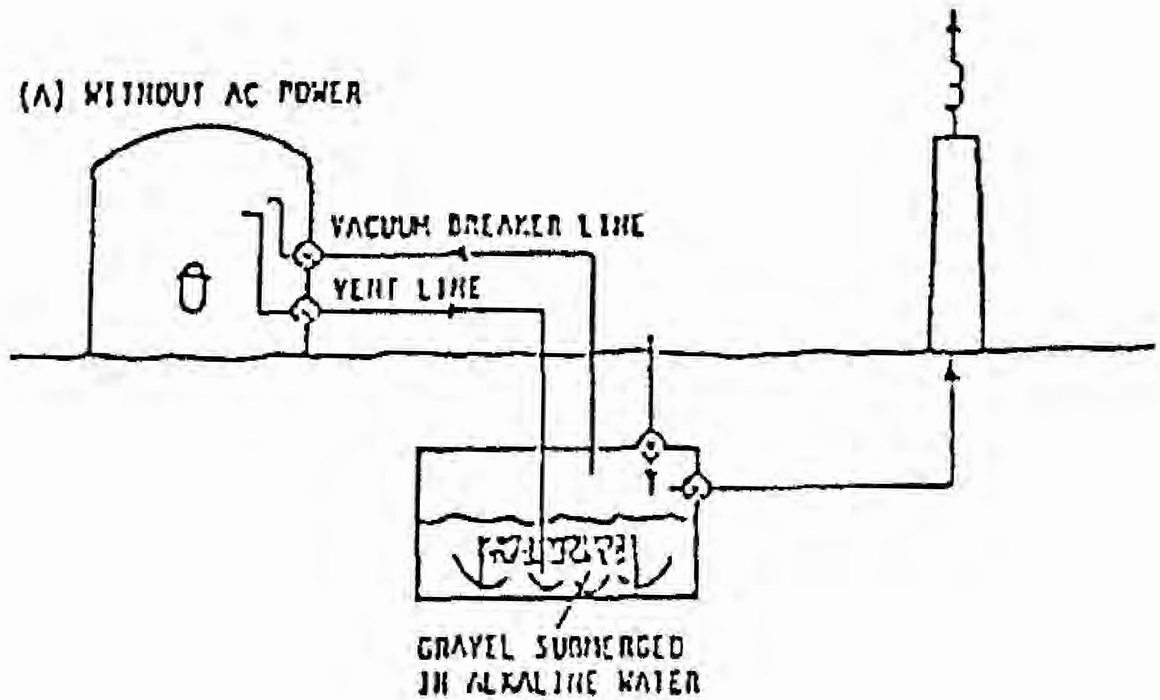
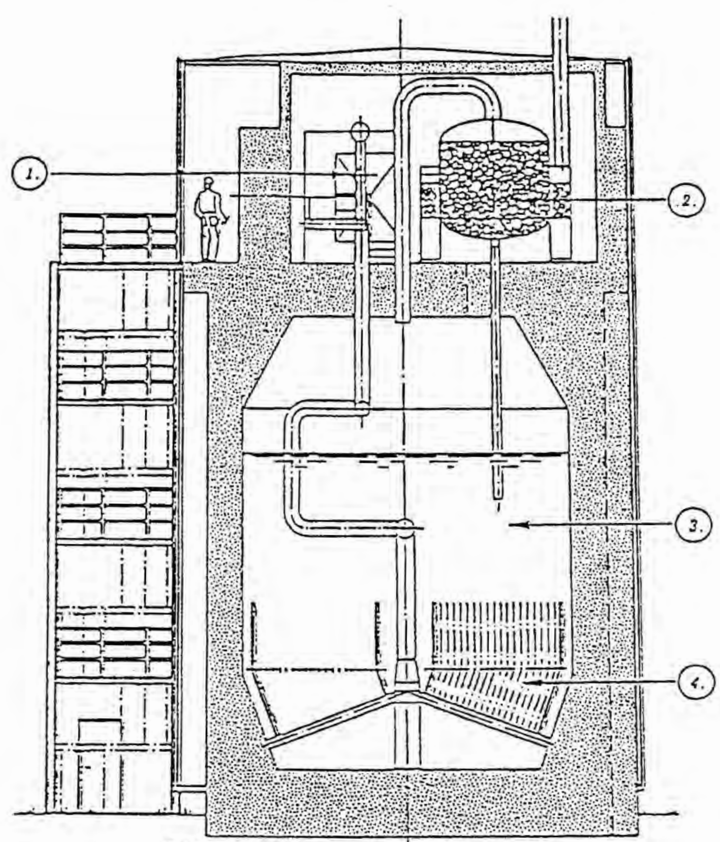
20th DOE/NRC Nuclear Air Cleaning Conference – August 1988



20th DOE/NRC Nuclear Air Cleaning Conference – August 1988

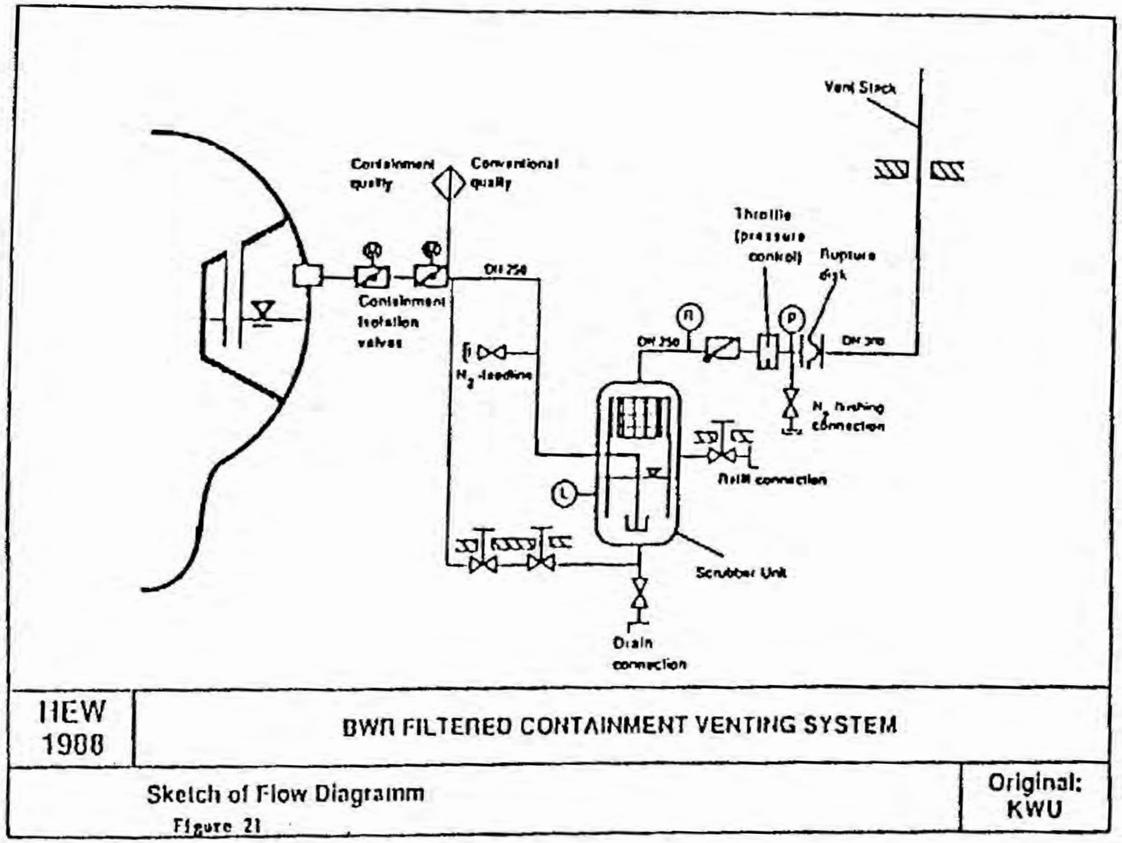


FILTRA-MVSS

1. *Pressure relief system for the reactor containment.*
2. *Moisture separation system.*
3. *Pool.*
4. *Venturi scrubber system.*

Figure 12 The Swedish MVSS Filter Concept

20th DOE/NRC Nuclear Air Cleaning Conference – August 1988



Sweden - FCVS DF Requirement

- No acute fatalities
- Limited area of first year dose from ground contamination (with rain) of greater than 50 mSv (5 Rem)
- Considered met if release of no more than 0.1% core inventory Cs-134, Cs-137, and Iodine of 1,800 MWth reactor, similar for other nuclides important to land contamination (Chernobyl 1%)
- Required demonstrated minimum DF >100; MVSS designed for >500, tested >> 1,000

Canada – FCVS Requirement

“ In 2007, the regulator and the utility discussed the installation of an FCVS similar to those on Swiss plants for severe accident management. The value of an FCVS was assessed by the licensee in a complete Level 2 PSA, including external events, in accordance with CNSC Regulatory Document S-294,. The analysis uses Severe Core Damage Frequency (SCDF), and large release frequency (>1% Cs-137 inventory) as decision metrics that align well with IAEA SSG-3 and SSG-4. The FCVS, costing approximately $14 million Canadian, was found to be cost-beneficial when using the large release frequency metric. The stated purpose of the FCVS is “to prevent failure of containment integrity due to the increase of containment pressure beyond the failure pressure of approximately 220-230 kPa(g), or 31.9-33.4 psig.”

Finland - STUK

- "Containment filtered vent systems have been installed in Finland at the two operating BWRs, Olkiluoto 1 and 2. They were installed in 1990 at both units as a plant modification."
- "The design purpose of the filtered vent is to decrease the containment pressure in a severe accident, if the pressure exceed a specified limit (see question 4). **The system is useful in all severe accident sequences, where energy and fission products are released into the containment"**

Required DFs for FCVS by Country

The following DFs are used

- <u>Aerosols</u>
  - Sweden BWR 100 PWR 500
  - Germany BWR 1000 PWR 1000
  - Switzerland BWR 1000 PWR l000
  - France BWR NA PWR 1000*
  - Finland BWR 1000
- <u>Elemental Iodine</u>
  - Sweden BWR 100 PWR 500
  - Germany BWR None PWR 100
  - Switzerland BWR 100 PWR 100
  - France BWR NA PWR 10*
  - Finland BWR 100

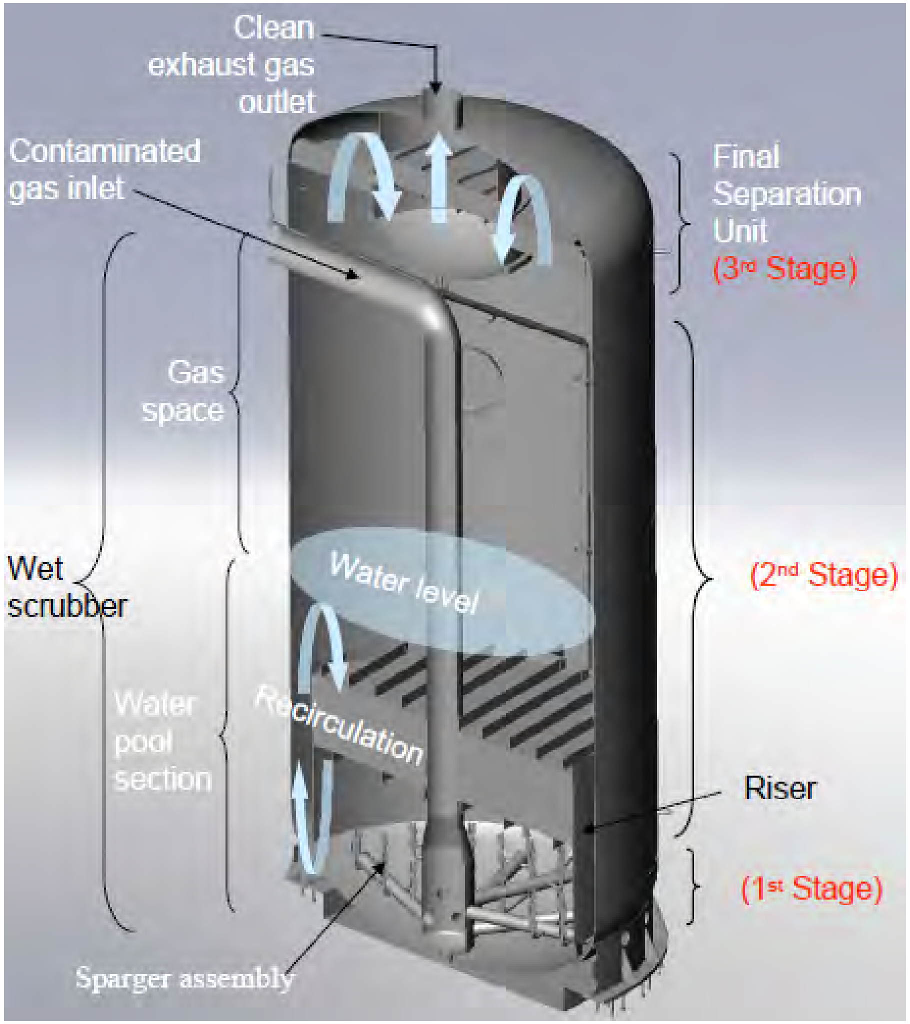
*Upgrade under consideration

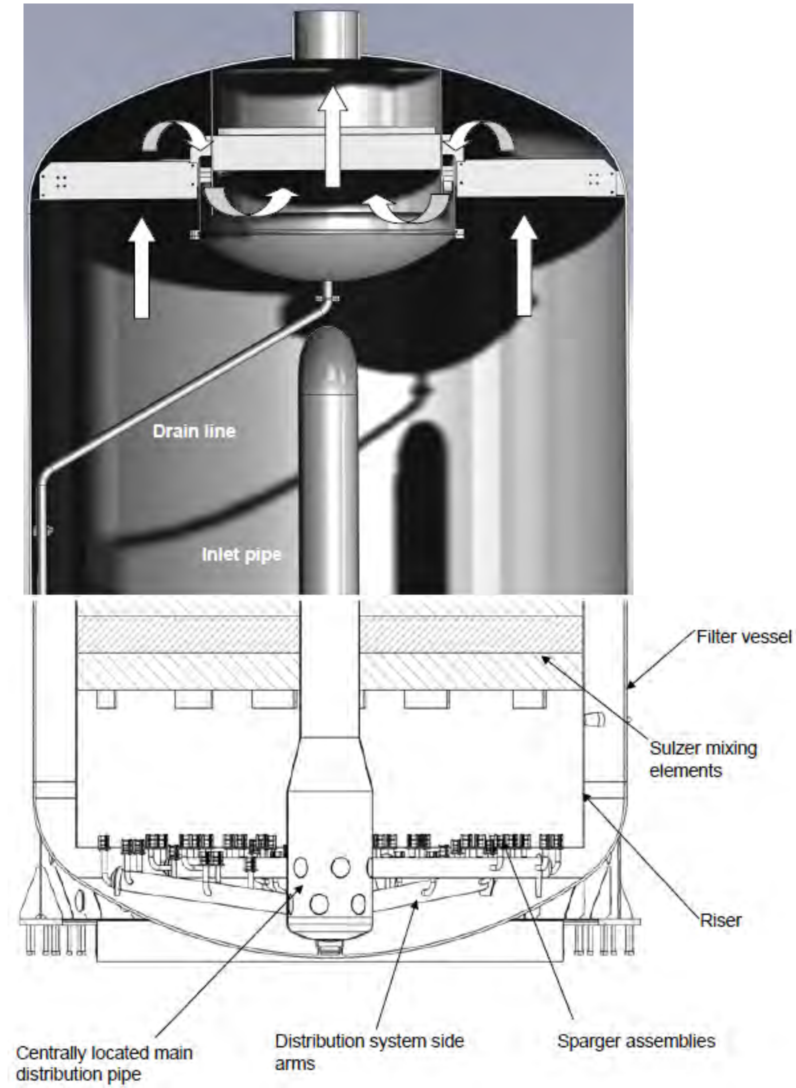
Jerry Bettle

Backup Slides

FCVS in Severe Accident Management

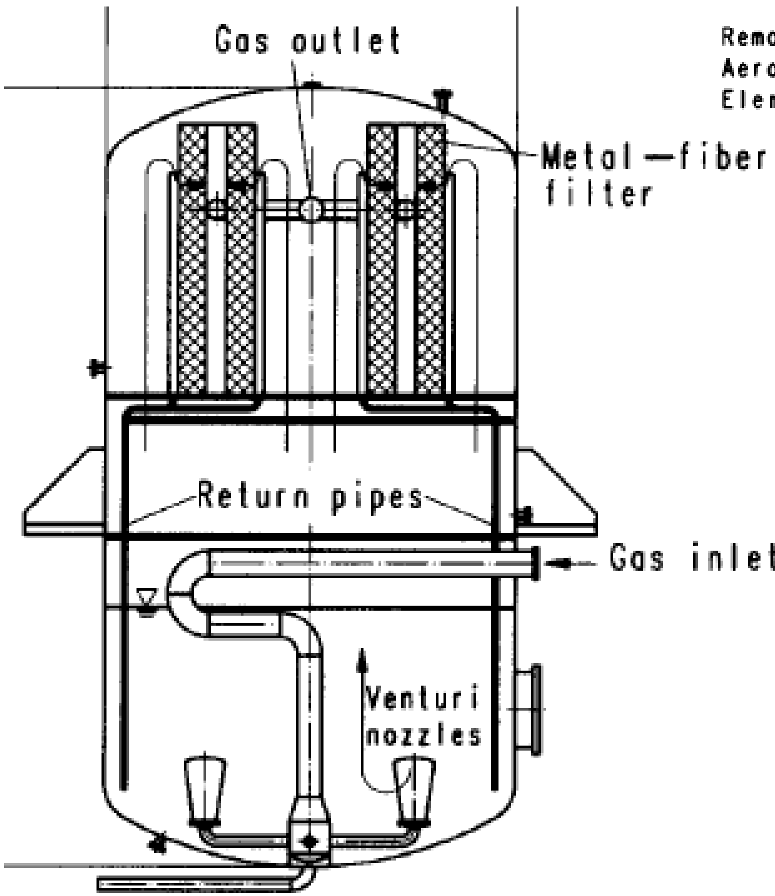
IMI –PSI AMI System – Wet Filter with Nozzles and Impactor/Baffle Plates



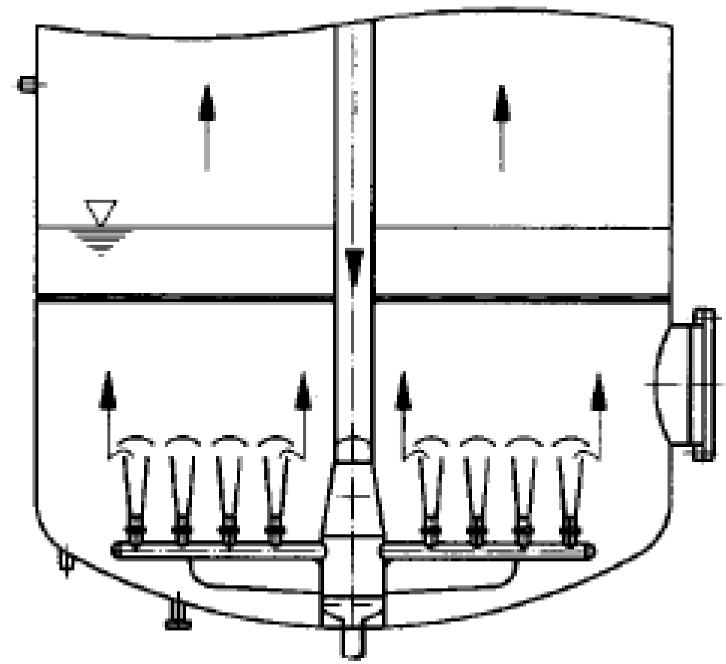


FCVS in Severe Accident Management

Earlier Vintage Wet Filter with venturi nozzles
and NaOH for enhanced iodine retention.



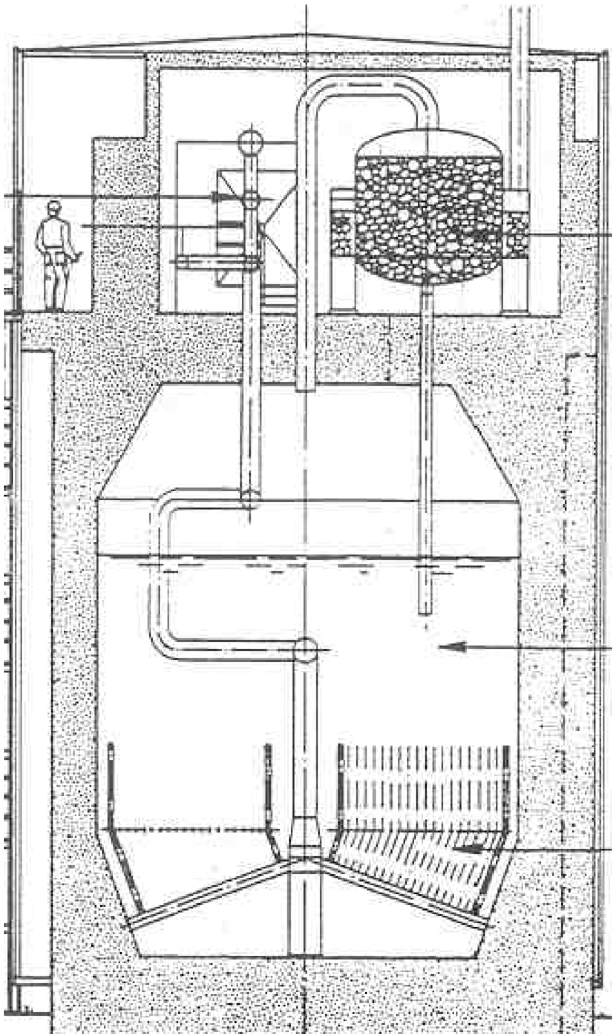
Removal efficiencies	
Aerosols	≥99.99%
Elemental Iodine	≥99.5 %

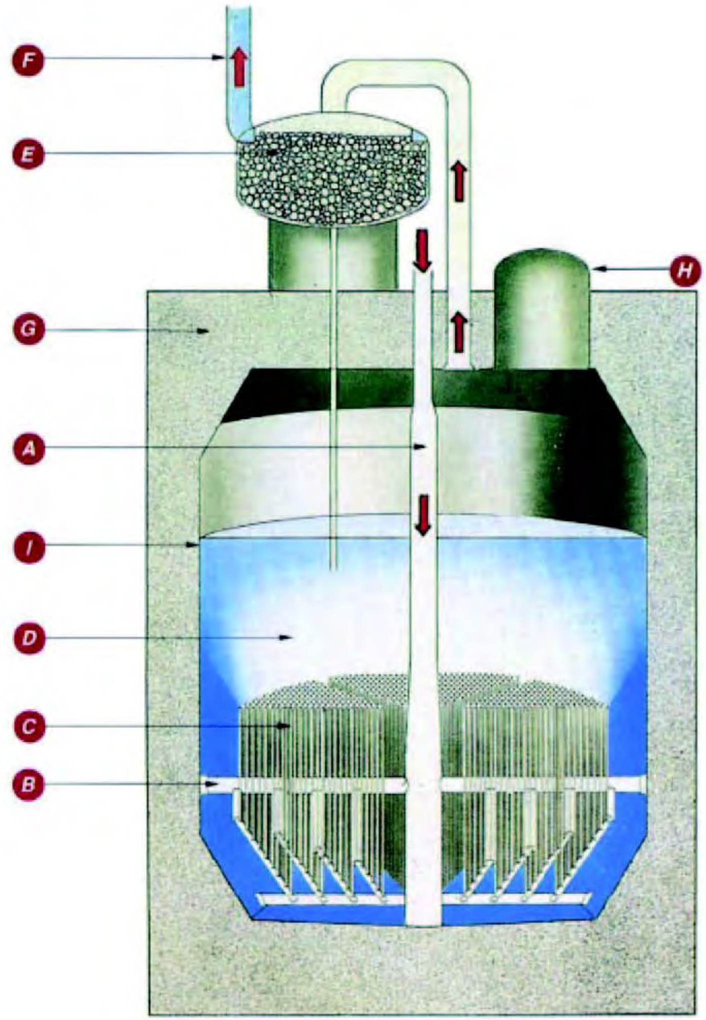


Operation of venturi nozzles
in submerged configuration

FCVS in Severe Accident Management

FILTRA-MVSS Multi-Venturi and Deep Pool





A: Vent line from Rx Cnmt
B: Venturi dist. system
C: Venturis, incl. riser pipe
D: Pool
E: Moisture separator
F: Release to atmosphere
G: Pressure vessel
H: Manhole
I: Liner

FCVS in Severe Accident Management

Injecting Water Into the Drywell to Ensure Vent Benefit

50.54(hh)(2) currently requires capability for injecting water into the DW as well as into the RPV in BWRs, although for a minimum of 12 hours. Order EA-12-049 requires the capability for injecting water into the RPV, but not explicitly for injecting into the drywell. However, at the moment of RPV breach, RPV injection is drywell injection. The EA-12-049 capability requirement extends for an indefinite period, that is until the capability is no longer needed. Order EA-12-050, similar to EA-12-049, was developed for pre-severe accident (pre-core damage) conditions and thus without core breach of the RPV.

FCVS in Severe Accident Management

09/11/2001

↓

Order EA-02-026, Interim Compensatory Measures (ICM) , Section B.5.b.

↓

10 CFR 50.54 (hh)(2) …shall develop and implement guidance and strategies intended to maintain or restore core cooling, containment, … under the circumstances associated with loss of large areas of the plant due to explosions or fire, to include strategies …to mitigate fuel damage…and actions to minimize radiological release.

↓

FCVS in Severe Accident Management

License Conditions and Licensee Commitments to NEI 06-12, B.5.b Phase 2 & 3 Submittal Guideline, Rev 2 dated December 2006

NEI 06-12, Rev 2, Section/Strategy 3.4.9, Provide cooling of the core debris and scrubbing of fission products…an AC-power-independent means to inject at least 300 gpm of water to the drywell for a period of 12 hours. The water injection can be directly to the drywell, or through lines connected to the RPV. This could utilize the Phase 2 portable pump or other existing sources.

FCVS in Severe Accident Management

03/11/2011

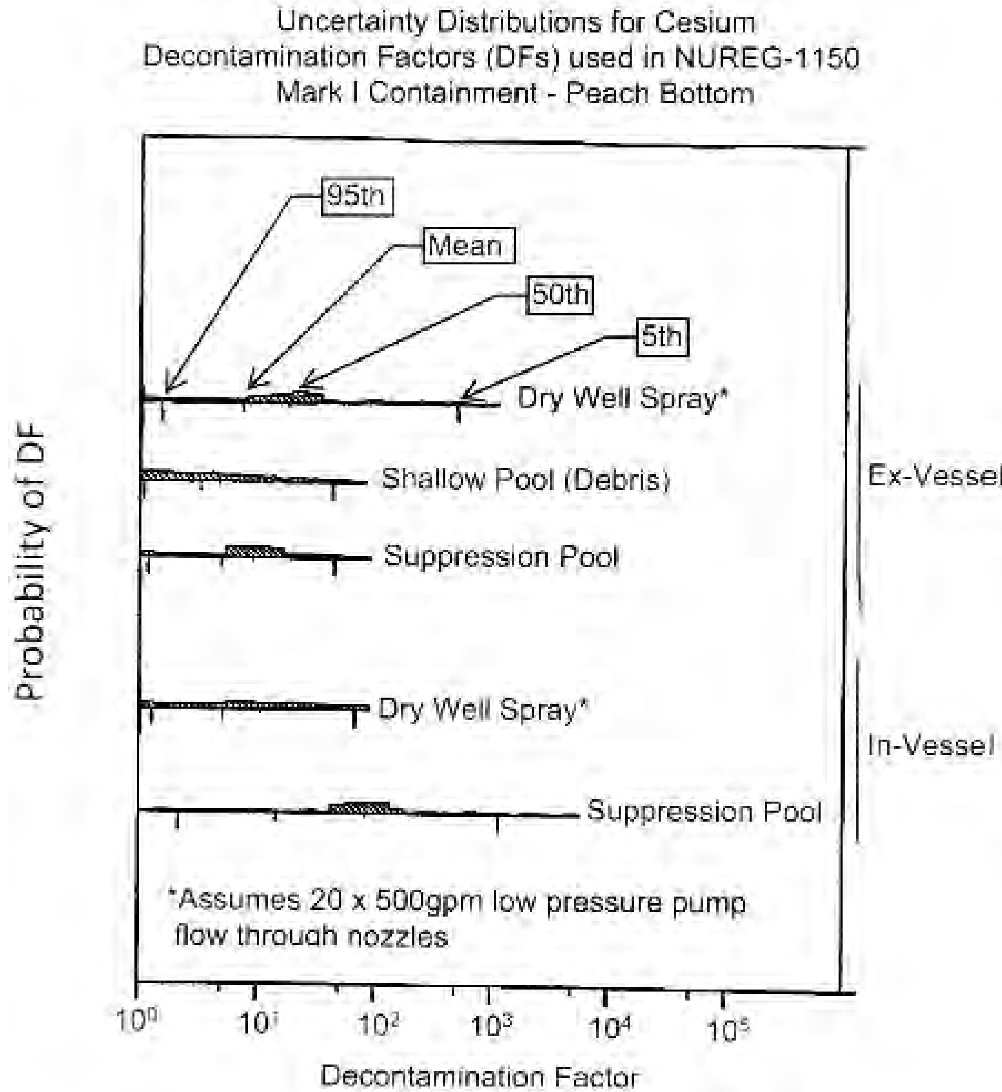
↓

EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events. NEI 06-12, Rev 2 continues to provide an acceptable means of meeting the requirement to develop, implement and maintain guidance and strategies for that subset of beyond-design-basis external events. NEI 12-06, Rev 0, provides for development and implementation of mitigating strategies for beyond-design-basis external events to address those events not covered within the requirements of 10 CFR 50.54(hh)(2).

↓

NEI 12-06, DIVERSE AND FLEXIBLE COPING STRATEGIES (FLEX) IMPLEMENTATION GUIDE, provides for RPV injection capability by portable pump. Equipment required for compliance with 50.54(hh)(2) may be used to support FLEX implementation. FLEX strategies are focused on the prevention of fuel damage and **would be** available to support accident mitigation efforts following fuel damage, but coordination of the FLEX equipment with Severe Accident Management Guidelines (SAMGs) is not addressed.

FCVS in Severe Accident Management



Source: "Assessment of In-Containment Aerosol Removal Mechanisms," BNL Technical Report L-1535, 1992.

FCVS in Severe Accident Management

Table 2.1 Distributions for Suppression Pool Decontamination

Conditions	Decontamination Factor (DF)			
	5th Percentile	Median	Mean	95th Percentile
During In-vessel Release Phase (through T-Quenchers)				
Peach Bottom	2.3	81	14.5	1200
LaSalle & Grand Gulf	1.8	56	10.5	2500
During Ex-vessel Release Phase (through Vent Pipes)				
Peach Bottom	1.2	9.5	5.1	50
LaSalle & Grand Gulf	1.2	6.8	4.	72

SIZING A HARDENED VENT: Five Questions

1. What is the range of **compositions of the gases** that will be vented?
2. What is the range of **quantities of gases** that will be vented?
3. What is the range of **absolute pressures** at which the gases will be vented?
4. What is the range of the **rates** at which the gases will be vented?
5. What is the **minimum area** of a vent that will accommodate the most demanding combination of the above conditions?

A quote from the March 14, 2012, ACRS letter (ML12072A197):

Discussions with stakeholders regarding near-term actions for additional hydrogen control and mitigation measures in plants with Mark I and Mark II containments should be included in the staff's Tier 1 actions.