

Official Transcript of Proceedings
NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguards
Fukushima Subcommittee: Open Session

Docket Number: (n/a)

Location: Rockville, Maryland

Date: Wednesday, September 5, 2012

Work Order No.: NRC-1864

Pages 1-164

NEAL R. GROSS AND CO., INC.
Court Reporters and Transcribers
1323 Rhode Island Avenue, N.W.
Washington, D.C. 20005
(202) 234-4433

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

+ + + + +

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

+ + + + +

FUKUSHIMA SUBCOMMITTEE

+ + + + +

OPEN SESSION

+ + + + +

WEDNESDAY

SEPTEMBER 5, 2012

+ + + + +

ROCKVILLE, MARYLAND

+ + + + +

The Subcommittee met at the Nuclear
Regulatory Commission, Two White Flint North, Room
T2B1, 11545 Rockville Pike, at 1:30 p.m., Chairman
Stephen P. Schultz, Chairman, presiding.

1 COMMITTEE MEMBERS:

2 STEPHEN P. SCHULTZ, Chairman

3 J. SAM ARMIJO, Member

4 DENNIS C. BLEY, Member

5 CHARLES H. BROWN, JR. Member

6 DANA A. POWERS, Member

7 HAROLD B. RAY, Member

8 JOY REMPE, Member

9 MICHAEL T. RYAN, Member

10 WILLIAM J. SHACK, Member

11 JOHN D. SIEBER, Member

12 GORDON R. SKILLMAN, Member

13 JOHN W. STETKAR, Member

14

15 ACRS CONSULTANTS PRESENT:

16 JOHN BARTON

17

18 DESIGNATED FEDERAL OFFICIAL:

19 ANTONIO DIAS

20

21

22

23

24

25

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

Call to Order and Opening Remarks Stephen P. Schultz Chair Fukushima Subcommittee ACRS	5
Evaluation of Strategies for Mitigating Radiological Releases	7
Rick Wachowiak EPRI	7
Jeff Gabor ERIN	41, 57
Questions and Comments	56
Summary of Staff's Efforts	63
Robert Fretz Japan Lessons-Learned Directorate Project NRC	63
Bob Dennig Office of Nuclear Reactor Regulation Containment and Ventilation Branch NRC	
MELCOR Analyses of Filtered Vents	74
Sud Basu RES NRC	74
Richard Lee RES NRC	
Allen Notafrancesco RES NRC	

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

C-O-N-T-E-N-T-S (CONTINUED)

The Swiss Experience on Filtered Vents	131
Denis Grob	131
Salih Guentay	
Questions and Comments	147
Subcommittee Discussion	155
Opportunity for Public Comment	162
Bob Leyse	163

P R O C E E D I N G S

1:30 p.m.

1
2
3 CHAIRMAN SCHULTZ: This meeting will now
4 come to order.

5 This is a meeting of the Advisory
6 Committee on Reactor Safeguards, Subcommittee on
7 Fukushima. I am Stephen Schultz, Chairman of the
8 Subcommittee.

9 Members in attendance today are Sam
10 Armijo, Jack Sieber, Dick Skillman, Harold Ray, Dennis
11 Bley, Dana Powers, Joy Rempe, Charlie Brown, Bill
12 Shack, Mike Ryan, and John Stetkar.

13 The purpose of today's meeting is to
14 receive a briefing and hold discussions on current
15 research efforts associated with the role of filtered
16 vents during severe accidents.

17 This meeting will be open to public
18 attendance, with the exception of a portion that will
19 be closed to protect proprietary information.

20 Pursuant to 5 USC 552b(c)(4) rules, the
21 conduct of and participation in this meeting have been
22 published in The Federal Register as part of the
23 notice for this meeting.

24 The Subcommittee today will hear
25 presentations by and hold discussions with

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 representatives of the NRC staff, the Electric Power
2 Research Institute, the Paul Scherrer Institute, and
3 other interested persons regarding this matter.

4 The Subcommittee will gather information,
5 analyze relevant issues and facts, and formulate
6 proposed positions and actions as appropriate for
7 deliberation by the full Committee. Another
8 Subcommittee on the same briefing is scheduled for
9 early October, followed by a full Committee briefing
10 in November.

11 The staff is developing a notation vote
12 paper that is due to the Commission by the end of
13 November.

14 Antonio Dias is the Designated Federal
15 Official for this meeting.

16 A transcript of the meeting is being kept
17 and will be made available, as stated in The Federal
18 Register notice for this meeting. It is requested
19 that speakers first identify themselves and speak with
20 sufficient clarity and volume, so that they can be
21 readily heard.

22 We have received no written comments or
23 requests for time to make oral statements from members
24 of the public regarding today's meeting. However, I
25 understand there may be individuals on the bridge line

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 or listening into today's proceedings. In addition,
2 before we break into the proprietary session late this
3 afternoon, we will have an opportunity for members of
4 the public to make comments.

5 I did want to emphasize that this is our
6 first meeting with the staff and with industry
7 associated with this particular topic. We have the
8 benefit of briefings today in preparation for the more
9 detailed meeting that we expect the Subcommittee to
10 have in early October, as was previously mentioned.

11 We are going to start the meeting with the
12 presentation by the Electric Power Research Institute.
13 Rick Wachowiak is here for that presentation as well
14 as Jeff Gabor from ERIN.

15 Rick, I will turn the discussion over to
16 you to begin your presentation. Thank you for being
17 here.

18 **MR. WACHOWIAK:** Thank you.

19 So, today what we are going to talk about
20 is our investigations that we did using the MAAP code
21 and MACCS2 to look for strategies for reducing the
22 amount of radioactive material being released
23 following a severe accident.

24 The original impetus for some of this was
25 to look at land contamination, how can we reduce land

1 contamination, and we will get into this in a couple
2 of minutes. But we ended up getting to the point
3 where we can look at what kind of strategies we could
4 have for reducing the radioactive release. And then,
5 what happens to that afterward is similar for the
6 different plants, and we will get into that.

7 What we have in the package today is
8 probably more than we will be able to cover in the
9 allotted time. So, we have tried to structure this so
10 that we get to what we are doing and what our results
11 and insights are upfront. We have material afterward
12 that can be used to address questions and other things
13 like that and, also, for your reference later.

14 All of this is coming out in an EPRI
15 report that tentatively is going to be released in the
16 middle of this month, unless something happens that we
17 have to go back and redo some things. But,
18 essentially, we have completed what we think is our
19 analysis for this.

20 You will notice that in the package the
21 slides, many of them say "Draft" on them. That is
22 only because the report is not published yet. But
23 they are currently the versions of the calculations
24 that we have in our report. And so, it is not like we
25 have given you draft slides. We just haven't pushed

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 the button for the printers to go and publish the
2 report yet.

3 CHAIRMAN SCHULTZ: For the benefit of the
4 Subcommittee, the background here is that Rick and
5 Jeff have had an opportunity to discuss this topic and
6 the details that you have in your package directly
7 with the staff about three weeks ago. Hearing that,
8 we wanted to have the opportunity to bring them to the
9 Subcommittee today to at least get the summary that
10 they are going to present. But that is why the
11 package is so thick.

12 MR. WACHOWIAK: Yes.

13 CHAIRMAN SCHULTZ: They have had
14 discussions already and will have further discussions
15 with the staff.

16 MR. WACHOWIAK: The discussions with the
17 staff took almost an entire day and included more of
18 the results than what we have in here. So, we are
19 trying to focus on letting you understand what the
20 cases are when we get into that, and then the kinds of
21 sensitivity analysis we did to address the
22 uncertainties we have in this area.

23 So, we will start out with the
24 introduction and the insights. We will move to
25 describing the scenarios and how we think strategy for

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 reducing the radioactive materials is viable. As time
2 permits, we will cover as many of the MAAP cases that
3 we have run that cover the different scenarios and the
4 different strategies.

5 But we do want to get into some things on
6 the sensitivity analyses because that was probably
7 where we learned the most about this whole project, is
8 in varying the assumptions and the parameters that go
9 into these things and understanding what that does to
10 our strategies for reducing the release. So that we
11 can communicate that to the owners' groups and they
12 can translate that into actual workable machinery that
13 can be reliable in performing these functions.

14 I would say, "Next slide," but that is me.

15 So, we would start out with our
16 overarching statement, "The best way to avoid a
17 radiological release is to prevent core damage in the
18 first place." So, there are other activities that are
19 going on that are addressing that bullet.

20 MEMBER POWERS: I'm telling you, don't
21 fuel the reactor. That is a much better, a much more
22 reliable way to do it.

23 (Laughter.)

24 MR. WACHOWIAK: We didn't consider that
25 fact.

1 (Laughter.)

2 MEMBER POWERS: The second best way to
3 avoid radiological release.

4 (Laughter.)

5 MR. WACHOWIAK: Release from an operating
6 reactor, not to have core damage in the first place.
7 As I said, there are other activities that you are
8 probably reviewing as the Fukushima Subcommittee that
9 are addressing that piece of it. We are not here to
10 discuss that particular piece. So, we will just start
11 with a core damage event, however it happened.

12 The next thing is that the containment
13 function is there to retain the fission products. We
14 think that the most effective strategy for preventing
15 things from getting out into the environment is to
16 contain it in the place where it was meant to be
17 contained, the containment.

18 If you will, when we get through these
19 things, what we will see --

20 MEMBER POWERS: That is really not true.
21 The intention was to retain it in the RCS. If that
22 fails, then the containment is the backup.

23 MR. WACHOWIAK: All right. I will go with
24 that.

25 MEMBER POWERS: I have got to train you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 guys, see.

2 (Laughter.)

3 MR. WACHOWIAK: The RCS is part of the
4 containment, so not too much outside the -- but that
5 is what we want to do. When we study these things,
6 what we are finding is that many of the same
7 mechanisms and activities that are used in filters are
8 also present in the MARK I and MARK II containments.
9 And so, when we are thinking about, are you filtering
10 releases, if we are using an event in a MARK I or a
11 MARK II, we are filtering the releases. We are just
12 using the vessel that we have designed to do that and
13 is already onsite. So, it kind of is our filter. So,
14 these are filtering strategies.

15 Once again, we are looking at external
16 filters as well in this report. So, you extend the
17 containment to cover the external filter.

18 As I said before, what we want to do is we
19 want to understand how you can reduce radiological
20 releases. We want to understand what is causing the
21 release, how the magnitude changes when you do
22 different things following a severe accident. So that
23 someone can, then, take that information and design
24 equipment or design procedures such that they can be
25 implemented at the plants.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 So, once again, our report doesn't say
2 this is what you should do. It really more covers
3 here is how you can minimize the release.

4 So, what did we find out? First off is
5 that the existing SAMG strategies, the Severe Accident
6 Mitigation Guidelines that are being employed at the
7 plants, they are a good place to start. Most of the
8 things that we looked at here, there are elements of
9 them already in the SAMGs and we just tried to find
10 ways to optimize them, so that they would work better,
11 more reliably, you know, in the context of having this
12 ex-vessel core scenario.

13 One thing we find is that you have to have
14 active core debris cooling. There isn't any path to
15 success in a MARK I or a MARK II if we don't somehow
16 provide debris cooling. We will cover this on, I
17 think it is the next slide or the slide after that.
18 But if we don't provide core cooling, even if we
19 survive the initial action of the core exiting the
20 vessel and the response to that, even if we survive
21 that one, some other failure mechanism will end up
22 coming into play a little later on in the scenario.
23 And so, we have got to get the active core cooling, no
24 matter what we use.

25 We find that spraying the containment

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 atmosphere is beneficial in this, but in the flow
2 regimes that we are looking at here, which are fairly
3 low -- it is not the full 3,000-GPM or 1,000-GPM spray
4 flow that you are used to from previous analysis.
5 This is more like a 500- or 200-GPM flow rate. We
6 find that it is beneficial, but it is not the
7 controlling mechanism for removing the fission
8 products before venting.

9 MEMBER POWERS: But do all the MARK I's
10 have the capability in place to activate the spray
11 with no external action by the operators?

12 MR. WACHOWIAK: What do you mean by
13 "external action"?

14 MEMBER POWERS: It used to be, at least
15 when I looked at it -- and this was a long time ago
16 -- that frequently an operator would have to go
17 outside the control room and put in a spool piece in
18 order to connect water-pumping capability to the
19 drywell sprays.

20 MR. WACHOWIAK: Okay. So, I think from my
21 experience now, the MARK I's have valves there rather
22 than a spool piece. Now there may be some out there
23 that retain that capability.

24 But in these particular scenarios that we
25 are talking about, we are using more like post-

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 accident-recovery-type equipment, FLEX equipment to do
2 this. So, in that context, you would need to use some
3 kind of a spool piece or some kind of predetermined
4 connection to do these.

5 MEMBER POWERS: The other issue on the
6 sprays is, again, when I looked at this -- and this is
7 20 years ago -- that the spray systems that you have
8 in the drywell are not designed for aerosol removal.
9 They are designed to condense steam. And about half
10 of them use spray nozzles that produce droplets fairly
11 coarse. About half of them, for reasons I have no
12 idea -- I mean, I don't know how they pick the spray
13 nozzles -- chose one that was just very good for
14 aerosol removal. But about half of them chose one
15 that it is capable of removing aerosols, but not as
16 efficient as the others.

17 MR. WACHOWIAK: That is right. And one of
18 the concerns that we had in this analysis is that we
19 are using flow rates that are much below the design
20 flow rates of those spray nozzles.

21 MEMBER POWERS: That turns out, for these
22 particular nozzles that at least I have seen, and I
23 think they all use about the same design nozzle, they
24 are relatively insensitive to flow velocity.

25 MR. WACHOWIAK: Okay. So, what we did to

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 look at things like that is we did sensitivities to
2 look at the different drop sizes, and we also looked
3 at what is in the code as a spray effectiveness. It
4 is a multiplier on how well the spray affects the
5 Lambdas for removing aerosols.

6 So, what we find from all of that is that
7 the spray removal of aerosols gives us about a factor-
8 of-two change in the overall containment system
9 decontamination factor. It is more the spray's
10 ability to cool heat sinks and things in the drywell,
11 so that we get more condensation removal of the
12 aerosols than we would otherwise.

13 MEMBER POWERS: That is kind of
14 surprising. But cooling the upper head is a really
15 good idea.

16 MR. WACHOWIAK: So, it is helpful and it
17 is beneficial. We find a benefit toward about a
18 factor of two, is what we see for spray versus just
19 injecting onto the floor for a flooding-type thing.
20 It is probably somewhere in between there.

21 And so, what we would suggest is, when
22 implementing the strategies that we come up with, that
23 we probably should implement it more along the lines
24 of using the flooding cases as the control, knowing
25 that you could probably do better or you are more

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 flexible if you do have any ability to spray.

2 The other thing that we have seen is that
3 the venting, when we are talking about venting in our
4 final strategies, we are talking about a vent that can
5 be controlled, opened and closed at times needed in
6 the scenario. We will get into that particular piece.
7 That helps with addressing uncontrolled releases, and
8 it also helps us manage hydrogen. So, there are
9 additional benefits to doing this.

10 Some of the other things that we have seen
11 in our analysis is that, No. 1, no single strategy
12 alone is effective. I have a slide that covers that
13 in a minute here. But if you just try to say, is
14 there one silver bullet to address everything, we are
15 not there. We have do some combinations of these
16 things in order to be effective.

17 I said the control of the event provides
18 benefit, being able to open it and close it, and we
19 will talk about some of those in a little bit.

20 If we can figure out how to add a low DF
21 filter to some of the strategies -- and I will say
22 what that means in just a second here -- that can be
23 helpful. But the problem is we are not really sure
24 what that means because, once you have used the
25 containment-filtering mechanisms, the sprays, the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 floods, the plate-out, the suppression pool, the
2 nature of the aerosol that is being removed through
3 the vent is quite different from the aerosols that
4 have been studied in the past for this. And you have
5 many of the particle sizes that already broke through
6 those original filtering methods that you are left to
7 deal with. With a low DF filter, the low DF, you
8 know, another factor of 10, a factor of 100, has to be
9 a factor of 10 or 100 for the particles that already
10 weren't filtered by the strategies that you already
11 used. So, it is helpful. We have to be able to
12 define what that actually means in these cases.

13 And we will get to one case in the end
14 here on the MARK II containment. We found -- it is
15 not that we found -- in the context of land
16 contamination, there is an issue with the sump
17 drainlines in some of the MARK II containment designs
18 where there is a potential for a suppression pool
19 bypass that needs to be addressed in order for the
20 strategies that we are presenting here to be
21 effective.

22 It is not an unknown phenomena. It is in
23 all the IPEs that came out for the MARK II plants.
24 But it didn't have any effect on the health effects.
25 So, it wasn't highlighted as an insight before. When

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 we were looking at land contamination, it is a little
2 different figure of merit.

3 MEMBER POWERS: If you are looking at the
4 ex-vessel scenarios for MARK II containments, just
5 cutting the vent pipes gives you a bypass.

6 MR. WACHOWIAK: Yes, and we have looked at
7 that or the plants that have MARK II's have looked at
8 that. The way the vent pipes are arranged and
9 embedded into the concrete, and they are a straight
10 vertical line, we don't really expect that to be the
11 place where you get the bypass. But in these other
12 lines that have the bends in them, we are really just
13 not sure we can credibly say you are not going to get
14 the bypass.

15 MEMBER POWERS: I mean, if you were going
16 to pour all the molten steel that is going to come
17 down from your containment, if it floods those
18 downcomers, it is going to cut a hole in them on the
19 way down. You can send that one to the bank.

20 MR. GABOR: Can I interrupt you here?

21 MR. WACHOWIAK: Go ahead.

22 MR. GABOR: Just one point I guess I
23 wanted to kind of hit on again, and that is, as Rick
24 said, no single strategy provides the benefit; that
25 the only way we found that we could reduce the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 releases was with combinations. And that is important
2 because, when we first went down this path, I think
3 there was a belief that -- and maybe that belief still
4 exists -- that by putting a filter on any containment,
5 you have reduced the risk; you have reduced the
6 release.

7 But specific to the MARK I and the MARK
8 II, you really have to look at the details of accident
9 progression in a MARK I and II to realize that just
10 putting a filter on a vent isn't going to give you the
11 results that you might expect. As Rick pointed out,
12 we have to combine that.

13 I know there has been, initially, a lot of
14 talk about, well, we like just putting a filter on
15 because we can make that passive. We can have a
16 ruptured disc, no operator actions. But, again, we
17 see that that is not the panacea; that is not the
18 silver bullet because you also have to have, as Rick
19 said, active cooling to the debris. Without that, the
20 benefits of any filter disappear.

21 Sorry.

22 MR. WACHOWIAK: Okay. And I think we will
23 cover some of these. Some of that addresses this
24 issue with the downcomer pipes, too, in that, yes, if
25 all you have is the core on the floor and it is

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 progressing without any sort of core cooling, maybe
2 that is going to be the case; you are going to lose
3 the pipe integrity. But, remember, in these cases we
4 have got some kind of active debris cooling which
5 tends to mitigate that particular failure mode.

6 So, we had to decide that we were going to
7 evaluate something. So, we were trying to figure out
8 what cases we should do. If we take the spectrum of
9 all accident challenges, severe accident sort of
10 challenges -- or not severe -- accident challenges, we
11 can divide into two cases: core damage is prevented,
12 which is the vast majority of them, and that is not
13 handled by this project. It is handled by FLEX and
14 other things in beyond-design-basis areas that we are
15 looking at with other committee, or not committees,
16 with other groups within the industry.

17 So, we are focused on the core damage
18 events. And we have two particular types of core
19 damage events, those where the primary containment is
20 the primary barrier to the release and those that are
21 not, like ISLOCA-type scenarios and other things where
22 the release path is outside, is not into the
23 containment and then to the outside. We are focused
24 on the ones that are being mitigated by the
25 containment, and we want to look at how we can

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 maximize the potential benefit from the containment.

2 What we found was that in the existing
3 SAMG strategies there are things that tell us how to
4 do this. Now whether they are optimized for this or
5 not is not 100 percent clear at this point, but there
6 are things that say, you know, you should establish
7 containment spray; here is why you should do flood,
8 and when you should do flood. Here are the times that
9 you would vent the containment. So, the elements are
10 all there, and we tried to draw on those things.

11 And we also looked at a few other things
12 like external cooling of the containment and things
13 like that. But, as I get into the next couple of
14 slides here, we will see that they didn't make the
15 list of being something that we could turn into a
16 viable strategy. They just didn't quite get us there.
17 So, the ones that got us there are on this chart.

18 Another thing to point out is that most of
19 the things that are on here also help to address
20 things in the far blue box, the releases there. We
21 still need to cool the debris and that type of thing
22 in an ISLOCA to prevent prolonged releases, so that
23 that sort of things helps in those cases. But we
24 didn't look at that; we just recognized that they can
25 be beneficial partially in some of those cases.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. GABOR: Yes, another example of that
2 is, if you have containment isolation failure events,
3 clearly, a filtered vent path isn't going to help you
4 in that case, but spraying the containment will
5 provide some benefit. So, like Rick said, we didn't
6 focus a lot of attention on those typically lower-
7 probability events, but we do think the strategies
8 could actually have some impact on them.

9 MR. WACHOWIAK: Right.

10 CHAIRMAN SCHULTZ: Rick, in that central
11 box that you were describing where this is the focus
12 of the study, with regard to capabilities, you started
13 with severe accident management guideline
14 capabilities, and then you also mentioned FLEX. Are
15 both features of the current programs, as well as what
16 is anticipated for the future programs with FLEX, are
17 both of those incorporated into the analysis you are
18 going to describe?

19 MR. WACHOWIAK: So, what we did was we
20 used a reduced flow regime that may or may not be
21 higher than what is being looked at in FLEX. Those
22 kind of things are still yet to be coordinated between
23 the groups.

24 And so, the SAMGs say get water onto the
25 floor. In some cases, it tells you what types of flow

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 rate you are trying to anticipate and things like
2 that. But it is really assuming installed equipment,
3 which tends to be the bigger pumps. And what we
4 looked at tended to be smaller-sized pumps. So, it is
5 more in line with that.

6 But the actions themselves are in line
7 with what is kind of in the SAMGs now. And we will be
8 suggesting some tweaks to what the SAMGs say, so that
9 you can better optimize the performance of the
10 containment-filtering system.

11 So, more in line with FLEX.

12 CHAIRMAN SCHULTZ: Thank you.

13 MR. WACHOWIAK: When we started out saying
14 that we originally were looking at land contamination,
15 we thought that this was going to be a difficult
16 problem to solve in that the amount of land
17 contaminated, given an accident, depends on things
18 like the topology and meteorology of the location
19 where the accident happens.

20 So, rather than trying to do an exhaustive
21 research over areas of the analysis that we really
22 can't control very much, we tried to find a simplified
23 way of gaining insights from Level 3 analyses that had
24 already been performed, and I think here it was the
25 SAMA analyses that we drew from here.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER POWERS: Why did you pick land
2 contamination as a figure of merit?

3 MR. WACHOWIAK: I'm sorry?

4 MEMBER POWERS: Why did you pick land
5 contamination as a figure of merit? What I am
6 thinking of is that we have some boiling water
7 reactors that performed poorly in Japan, and the
8 reaction in California was not the land contamination,
9 but to iodine.

10 MR. WACHOWIAK: I think this particular
11 one came out of the -- I am not sure what the report
12 is, but in the whole Fukushima response spectrum, one
13 of the issues was land contamination. What we were
14 asked for was, how do you address the land
15 contamination?

16 Now I understand that there are other
17 things, other than land contamination, that could be
18 looked at. Over the last few days, we have been
19 discussing whether or not we should go in and take a
20 look at other things like iodine and things in these
21 particular cases. But, right now, what we were asked
22 to do was look at the land contamination, and that is
23 where we focused this particular analysis.

24 MEMBER POWERS: So, land contamination was
25 given to you as a figure of merit? You didn't really

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 select it?

2 MR. WACHOWIAK: It was a given.

3 MR. GABOR: I guess, based on --

4 MEMBER POWERS: I tried to blame you, but
5 you are innocent in this case.

6 (Laughter.)

7 MR. GABOR: Based on the SOARCA results,
8 based on the actual data and the results at Fukushima,
9 we clearly didn't think that focusing on health
10 effects was where we were going with this. And we
11 didn't want to use that as a figure of merit to judge
12 and compare these different strategies. So, we
13 decided to pick cesium. It most directly relates to
14 land contamination, and it was readily available and
15 maxed to be able to output that for a variety of the
16 scenarios that we were looking at.

17 MEMBER POWERS: You could have taken dose
18 at the boundary.

19 MR. GABOR: And again, our thought is our
20 own analysis, the SOARCA analysis showed that
21 individual doses are quite low for these accidents,
22 for various reasons. MARK I's, we end up with a lot
23 of the radionuclides in the suppression pool, for
24 example. And that tends to really skew the results to
25 the low end for cesium and iodine.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER POWERS: Hopefully, that ends up to
2 be the case in II's and III's as well.

3 (Laughter.)

4 MEMBER RYAN: I guess, though, that it an
5 artifact of where the wind was blowing during the
6 accident. The wind was blowing offshore.

7 MR. GABOR: Yes.

8 MEMBER RYAN: If it was blowing onshore,
9 it would be a completely different picture, correct?

10 MR. GABOR: Well, and the plume that they
11 did get to the northwest was, I think they believe,
12 from Unit 2.

13 MEMBER RYAN: And it is in one valley --

14 MR. GABOR: Right.

15 MEMBER RYAN: -- and it is a relatively-
16 contained situation. All those details I think played
17 to the favor of it is not a big deal in terms of land
18 contamination, based on the specifics. But the key
19 phrase there is "based on the specifics" of the
20 meteorology and all the rest. So, is it luck that it
21 wasn't a much bigger deal?

22 You know, another interesting thing I
23 would think about is how much time in terms of time
24 and effort and dose is expended on putting stuff in
25 waste cans from the accident until now, let alone over

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 the next several years. If you want to look at worker
2 dose, and it is going to be a big workforce that gets
3 that dose, I am just wondering if we are saying, oh,
4 that was really good that the environmental dose was
5 relatively small and then that is the end of it,
6 because there are a lot of other dose components to
7 the total dose of the accident that need to be looked
8 at, I think.

9 Do you agree or am I off-base?

10 MR. GABOR: Well, again, I tend to think
11 that using land contamination as we can get out of
12 MACCS2 calculations at least gets us going in that
13 direction.

14 MEMBER RYAN: You can do better than that.
15 You can get land contamination for what was actually
16 there.

17 MR. GABOR: You're right.

18 MEMBER RYAN: You don't need to model
19 anything. You know, measure it.

20 MR. WACHOWIAK: Yes, and one of the things
21 that we think probably needs to be done sometime here
22 is take codes like MACCS2 and things like that and see
23 how well they perform relative to events that actually
24 happened.

25 MEMBER RYAN: That is kind of a

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 calibration --

2 MR. WACHOWIAK: That is not what we were
3 trying to do. We were trying to see what it was we
4 could do with the tools that we had at hand. We
5 looked at several SOARCA analyses -- this was dollar
6 effects -- to see if we could see some kind of trend
7 of, given an input source term and varying that source
8 term, do we vary the results that come out? And we
9 saw that kind of trend with several different analyses
10 that were for -- I think I said SOARCA, but I meant
11 SAMA analyses. We saw that sort of trend.

12 So, we picked our reference plant here,
13 and we got the source term. And then, we ran MACCS
14 using a scaled source term from that plant from a
15 decontamination factor of two, which means half got
16 out, half of that available got out, all the way on up
17 to the higher values of it.

18 What we think is important here is the
19 shape of the trend rather than the absolute values
20 themselves. We see that we get a lot of benefit in
21 the first few decades of decontamination factor. And
22 then, it kind of trails off. So, we are looking at,
23 if we can find things that have a decontamination
24 factor of 1,000 --

25 MEMBER RYAN: That is just simply decay,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 right? I mean, that is radioactive decay. You are
2 not taking credit for anything other than decay then,
3 right?

4 MR. WACHOWIAK: That is not necessarily
5 the case. It is the amount that is available to be
6 dispersed over the area of land that is there.

7 MR. GABOR: Yes. So, each of these DF,
8 the X-axis, represents a different release amount.
9 So, when we look at 1,000, that is a release amount of
10 .1 percent.

11 MR. WACHOWIAK: Right. And we did some
12 sensitivities of this. This particular graph is a
13 variation on the weather. That is just picking the
14 worst-case weather scenario out of all the scenarios
15 that get averaged together in MACCS. And even under
16 the worst-case weather scenario, we see that the trend
17 still follows along the same line.

18 So, we think we are pretty robust at
19 saying, if we can find strategies that get us to a
20 release of .1 percent or a decontamination factor of
21 1,000, that we are on the right track. We are there
22 to prevent the kind of releases that could cause a
23 large areas of land contamination.

24 So, that is now not part of the analysis
25 anymore. We just looked at what it is we can control

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 after that point. This is a summary slide of our
2 different strategies. Remember that every bar that is
3 there represents a series of cases, if not just one
4 case. And we kind of picked the middle or
5 representative version number to pick that in round
6 numbers, you know, tens, twenties, hundreds.

7 MEMBER POWERS: You get up there in DF of
8 1,000; that means you have got no leak in your system
9 bigger than .1 percent. Now the design-basis leak
10 rate for a MARK I is roughly half a percent per day.
11 It is inconceivable to me that the leak rate is going
12 to go down after you have had a severe accident.

13 MR. WACHOWIAK: So, the difference here in
14 some of these cases is that the pressure is different
15 in these cases because we are using vents in some of
16 these cases here. So, the hole is there. It is in
17 the analysis. We put the hole that represents half a
18 percent per day at design pressure into the analysis.
19 As you see in some of these graphs, there is the leak
20 path radiation that is there.

21 What tends to control it more than having
22 that long-term small leak available is where the
23 aerosols and vapors actually are in the containment
24 over the different timeframes that we are doing the
25 release. In most of the cases that we looked at, the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 containment leakage term tends to be an order of
2 magnitude lower than the other release path terms.

3 So, we did a base case. It is called no
4 venting. Here, basically, we let the core melt, come
5 out of vessel, and do what it did. In some cases, it
6 comes out and we have, since there is no water on the
7 floor, we assume a drywell shell interaction melt-
8 through, and it releases about 10 percent of the core.
9 If we don't have a drywell shell melt-through, we will
10 have CCI, core-concrete interaction, and in a few
11 hours we will get an overpressurization and we will
12 release about 10 percent of the inventory of the
13 material.

14 If we don't have significant CCI, it is
15 going to sit there in the containment and heat up the
16 containment structure until it loses all of its
17 structural integrity, and it is going to break. And
18 we are going to release about 10 percent of the
19 material. So, by doing nothing, we end up with this
20 case where we are going to release about 10 percent.

21 Okay. So, let's move on to saying, how
22 about if we spray, flood, or use a reliable hardened
23 vent, some sort of a mechanism there? We find that in
24 many of the cases it gets rid of the first failure
25 mechanism, but a couple of hours later the next

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 failure mechanism comes into play. So, no matter how
2 we rearrange these, if you just pick one of those
3 strategies, it is about the same as doing nothing.
4 Timing is a little bit different, but land doesn't
5 care about the timing of the releases. It is just a
6 release. We see about 10 percent that comes out.

7 We took one extra one and we wanted to
8 highlight it here. If we take the RHV and we add a
9 filter onto that, what we see is that about half of
10 the material gets trapped in the filter and in the
11 suppression pool, but then when the other failure
12 mechanism comes along, it still releases the other
13 half. So, that is a decontamination factor of about
14 20. So, you have reduced by a factor to half.

15 Then, we started taking a look at the
16 combinations of these things, like our guidance
17 currently tells us to do and like we are planning on
18 doing for the FLEX sort of things, in that we take a
19 spray in event or a flood in event, and we see that,
20 if we don't do really anything much different, we turn
21 on sprays when the EOPs tell us to turn on the sprays,
22 when we get to the primary containment pressure limit.
23 You open up the event, like the procedure tells you
24 to, and you leave it open until the water level in the
25 containment gets up high enough, so you have to close

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 the wetwell vent and maybe open up a different venting
2 path to continue to do the spray. So, it is nothing
3 fancy; basically, doing what the procedures tell us to
4 do now. And we see we get somewhere between 200 and
5 500 sort of decontamination factor.

6 When we drill down into what was causing
7 the releases in these cases, what we find is that the
8 suppression pool becomes saturated. So, it is not as
9 effective as a fission product remover that it was
10 before. As the containment pressure comes down, the
11 velocities through the suppression pool drop way off,
12 and it becomes a little bit less effective as a
13 scrubber. With the vent paths just open all the time,
14 we tend to see a longer integrated timeframe when
15 things are getting out.

16 So, our strategies that we looked at next
17 were controlling the vent such that we can prevent
18 those sorts of things. And you can pick things that
19 you are trying to control. Jeff will go through cases
20 where we have something that is kind of like a relief
21 valve where it is simmering between 40 and 60 -- I
22 should convert to gauge -- but, anyway, it is between
23 two setpoints of the containment. And if you couple
24 that with spray, you get pretty good results, well
25 over 1,000 DF.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 If you do other things like saying, okay,
2 I know that, initially, when I open the drywell vent,
3 that is when I get the most material out through the
4 drywell vent, so I want to delay the drywell venting
5 as much as possible. So, you optimize using the
6 wetwell vent, such that you can delay the drywell vent
7 for several days. That provides a good strategy and
8 gets greater than 1,000 DF reliably with doing venting
9 and things at different times. So, we see that we can
10 get there with these cases.

11 Now, remember from the earlier slide that
12 we had, that if we add a filter to these particular
13 cases, we know that there is an improvement on those
14 cases. But, once again, until you can understand the
15 nature of what the stuff is you are filtering, it is
16 hard to pick a value to stick on there. So, it is a
17 little better than those.

18 MEMBER ARMIJO: So, you are saying you
19 couldn't take that little yellow block and just plop
20 it on top of the --

21 MR. WACHOWIAK: Not necessarily. That
22 little yellow block is assuming that everything that
23 would have gone through the wetwell event early on in
24 the accident gets trapped. It is a 100 percent
25 efficient filter. And it is like the theoretical

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 maximum you could do if that is the strategy. Now, if
2 the other ones are the strategy, you can get better
3 performance from the filters, but you have to
4 understand what the material is you are filtering in
5 order to make that assessment.

6 MEMBER POWERS: The differences between
7 the two end blocks are whether you control this
8 venting really?

9 MR. WACHOWIAK: Yes.

10 MEMBER POWERS: And the problem of
11 controlling the venting is that you are allowing
12 pressure to build up in your drywell in the period.
13 That puts a force on your containment head. And that
14 head has a seal in it that is subjected to a
15 radioactive load, as well as a pressure load and a
16 temperature load. What did you do in your analyses to
17 consider failure of that sealing?

18 MR. GABOR: We are going to talk about
19 what we assume for containment failure in, I think,
20 the next slide. So, if you can hold it until then, we
21 will get there.

22 MR. WACHOWIAK: See if that answers your
23 question.

24 MEMBER POWERS: With grave difficulty.

25 (Laughter.)

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. WACHOWIAK: So, in the interest of
2 keeping moving here, you know, I don't want to take up
3 everybody's time for today. We want to get through as
4 much as we can on this and answer your questions.

5 But we have gotten through the basic
6 insights of things. Now the overall conclusions, the
7 next part is to drive down into what the actual
8 scenarios are.

9 MEMBER BLEY: Rick, when you looked at
10 that last case --

11 MR. WACHOWIAK: Yes, cases.

12 MEMBER BLEY: -- cases --

13 MR. WACHOWIAK: By the way, that
14 represents several.

15 MEMBER BLEY: -- you looked at physically
16 the optimal ways you could control it, I assume. Did
17 you think at all about whether that could be turned
18 operational with good reliability?

19 MR. WACHOWIAK: Yes. So, in one of the
20 cases where I was just talking about the simmering
21 between the two setpoints, we looked at it one way
22 where some sort of automatic valve maybe could do that
23 function. And we passed along to the BWR Owners'
24 Group, if you want to implement that strategy, you may
25 need to look at a valve or some device that can do

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 that.

2 We also did another sensitivity that said,
3 well, let's constrain to operator timeframes. So that
4 I think we picked five minutes. So that change in
5 state of the containment or of any of the equipment
6 can happen within any five-minute period. So, once
7 they open the vent, they can't close it again until
8 five minutes later. And once they close it, they
9 can't open -- so, you make the code do anything you
10 want it to do.

11 So, we tried to simulate that operator
12 sort of thing. And the effectiveness goes down when
13 you include the operator. But if you include a simple
14 action to say the last time you used the wetwell vent
15 before you switched to the drywell vent you change
16 your strategy, and instead of stopping at the lower
17 setpoint, you take it all the way down, to prevent the
18 next release from being so big, then we can still get
19 back to the same thing.

20 So, what we are thinking we could do is we
21 take these strategies and then we go to the severe
22 accident management committee groups and we go to the
23 FLEX groups and say, "Okay, let's design some
24 equipment that can do these kinds of things." Then,
25 you go to your plant-specific analysis and you figure

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 out the optimal way for your plant configuration that
2 you can do that.

3 But we have done sensitivities on these
4 things. We think is it pretty robust, and there is
5 not just one razor-edge thing that we can control that
6 gets us here. It is a wide range of parameters that
7 get us to the same response.

8 MEMBER BLEY: Okay. I guess the thing
9 that is hanging in my head is we are thinking
10 everything else is pretty good, and if it is up to an
11 operator, there is not much else going on at this
12 point. You know, these kinds of scenarios might
13 happen in really severe situations --

14 MR. WACHOWIAK: Yes.

15 MEMBER BLEY: -- that might really
16 diminish the ability of operators to do what you plan
17 ahead, which could make things worse instead of the
18 gain you see here.

19 MR. WACHOWIAK: So, that is why we are --

20 MEMBER BLEY: Eventually, somebody has got
21 to think about that.

22 MR. WACHOWIAK: Yes, and so, that is why
23 we are thinking, if we are going to do this, this is
24 why we have to meld it in with the severe accident
25 management committees --

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER BLEY: Yes.

2 MR. WACHOWIAK: -- to make sure that the
3 guidance is robust as well.

4 Okay. Start out with something simple.
5 Here is a MARK I containment.

6 MR. GABOR: Everybody knows what that
7 looks like. Go to the next slide.

8 MEMBER POWERS: Yes, but the one thing you
9 left off there is the vacuum breaker.

10 MR. GABOR: Right. We have those in the
11 model. So, like, for example, when we open up the
12 drywell, you will see when we utilize the drywell vent
13 later in the accident, then the release path
14 potentially would be either through the reactor vessel
15 out into the drywell through the vent or up through
16 the vacuum breaker.

17 MEMBER POWERS: Yes, the vacuum breaker is
18 fairly important in these scenarios because you are
19 kicking all the nitrogen out of here, filling it up
20 with steam, and then you are going to spray it down.
21 You have got to worry about external pressure here.
22 So, you cannot discount that vacuum breaker. And
23 then, you have to worry about what happens if the
24 vacuum break fails.

25 MR. WACHOWIAK: And we just recently had

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 that discussion with a BWR Owners' Group Vent
2 Committee. There was that concern.

3 One of the things that we find, especially
4 with the lower flow rates that we are using here, if
5 you have got the core on the floor in the containment,
6 we are producing enough steam --

7 MEMBER POWERS: Can you have CO2 --

8 MR. WACHOWIAK: -- we are producing enough
9 steam from that to balance anything that we can do
10 with the 500-GPM sprays.

11 MEMBER POWERS: That is very likely true.

12 MR. WACHOWIAK: So, you know, yes, that is
13 a concern, but it is a manageable concern.

14 MEMBER POWERS: But you do still have to
15 worry about that vacuum breaker activating and then
16 not receding.

17 MR. WACHOWIAK: Right.

18 MEMBER POWERS: And that will give you a
19 big release into your reactor building.

20 MR. GABOR: Okay. The next slide just
21 kind of gives you an idea of what some of the boundary
22 conditions are and the types of scenarios. These are
23 not unlike what you have probably seen with SOARCA
24 scenarios.

25 We focused-in on station blackout. We

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 assumed for our base case that RCIC operated for four
2 hours, fairly standard. We did do sensitivity on the
3 RCIC life part of it to see if that would alter our
4 results. It did not. And I included that in the
5 package. We can talk to it, if I talk fast enough.

6 The 36-GPM seal leakage, again, pretty
7 standard in a Level 2 PRA to assume in a MARK I or
8 BWR, doesn't really affect the results in a large way,
9 but does provide a leak path, potentially a source of
10 water to the containment floor early on.

11 We looked at both high- and low-pressure
12 accidents. Our base case was a low pressure. I like
13 the work that was done in SOARCA for looking at the
14 seizure of a single SRV. So, we based our base-case
15 analysis on that assumption, but we did look at the
16 sensitivity if the vessel had remained at high
17 pressure.

18 In a typical MAAP calculation, vessel
19 breach is normally due to melting of the penetration
20 weld in the lower head, failure of a CRD penetration,
21 or instrument tubes. So, that is typically in a MAAP
22 calculation what is controlling vessel breach.

23 For cases where we didn't have an active
24 system to cover the floor of the containment with
25 water, we went with the typical Theophanous approach

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 looking at the shell failures. We had a delay of
2 about 15 minutes after vessel breach before that would
3 occur. Again, for cases where we had active injection
4 or spray, we didn't assume that that failure mechanism
5 occurred, but it did in the base cases.

6 A couple of other pieces. We always, per
7 the SAMGs, we always open the wetwell vent first, per
8 guidelines, per the procedures. Also, per the
9 procedures, since we are in many of these cases
10 bringing external water sources into the containment,
11 the procedures tell us that, upon exceeding certain
12 levels in the torus, they are to isolate the wetwell
13 vent. So, we did that. And, of course, the
14 ramification is that the next time we need to vent, we
15 are going to have to open the drywell vent, which,
16 again, is all part of the current SAMGs.

17 Rick mentioned we found a lot of benefit
18 in not just opening a ruptured disc and letting the
19 containment depressurize. So, we focused in on a lot
20 of different ways to control. One of these ways that
21 Rick mentioned was the simmering valve or the kind of
22 SRV equivalent, where it sat there between 60 and 40
23 psig, just opening and closing.

24 Also, per procedures, if we get too much
25 water in containment, the operators are told to

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 terminate. And that is pretty high up. That is
2 approaching the top of active fuel. But we do get
3 there in 72 -- most of our calculations were run for
4 72 hours, and you can get there. Even with 500 GPM,
5 you can get there.

6 MEMBER POWERS: But what is more
7 interesting to me is the early water levels that you
8 can get before you fill up the suppression. You have
9 to fill the suppression pool to get to these
10 elevations.

11 MR. GABOR: Uh-hum.

12 MEMBER POWERS: And the amount of water
13 you can get on the floor depends on where the lower
14 lip on the downcomer is.

15 MR. GABOR: Right.

16 MEMBER POWERS: And that is highly
17 variable from plant to plant. Some of them, the lower
18 lip is right down on the floor.

19 MR. GABOR: Some it is low. Typically, it
20 is a foot to 18 inches, but --

21 MEMBER POWERS: Maybe even 2 feet.

22 MR. GABOR: -- you are right, there are
23 some that are pretty close.

24 MEMBER POWERS: But there is one where
25 that sucker is only about -- you can get 2 inches of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 water, I think, and that's it.

2 MR. WACHOWIAK: That is right. And that
3 is why we are saying we did this with a reference
4 plant, and we came up with insights. But that is one
5 of the things you have to check with your plant-
6 specific analysis. Is this going to work for you?

7 MEMBER POWERS: Well, that is a fairly
8 important one to call out because, yes, we have a
9 tendency to think all these MARK I's are exactly
10 alike, and they just aren't.

11 MR. WACHOWIAK: Right. Yes. You have to
12 look at those kinds of things.

13 MR. GABOR: Okay. And then, finally,
14 drywell failure. So, like I say, our viable types of
15 strategies that we came up with almost always or
16 always do include some active system to keep the
17 debris cool and some combination of venting a wetwell
18 and then switching over to the drywell vent.

19 For base-case scenarios where we don't
20 have a vent and we don't provide cooling to the core
21 debris, way back 20-some years ago, during the ID core
22 program, Chicago Bridge and Iron did a fairly-decent
23 assessment on the response of the MARK I containment
24 to not only pressure, but temperatures in the
25 containment.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 What they identified, and I think very
2 consistent with the work I saw that came out of
3 SOARCA, was that, until you get to around 500
4 Fahrenheit in the drywell, the pressure capacity is
5 pretty much a standard-type ultimate pressure
6 calculation, anywhere from 120 to 140 psia, but
7 between 500 and about 900 Fahrenheit in the drywell.
8 That dramatically drops off to essentially zero
9 failure or zero ultimate pressure capacity.

10 And then, the locations that were
11 identified by CB&I, and I think also by Sandia, in
12 SOARCA, were primarily the drywell head, which you
13 brought up. So, the idea is, given those conditions,
14 pressure and temperature, that the drywell head would
15 become a pretty dominant leak pathway out.

16 The other is the bellows area down here.
17 That is not as susceptible or it is not going to see
18 high temperatures. Again, for the majority of the
19 scenarios that were viable strategies, this really
20 didn't enter into our work.

21 MEMBER POWERS: Well, the problem with the
22 torus, the problem with the bellows region is it can
23 corrode and you can't see it.

24 MR. GABOR: We did assume that, with our
25 strategies of venting per the procedures, which the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 peak pressure is something like, well, the primary
2 containment pressure limit, very near the design
3 pressure. So, we did assume that the only leakage we
4 had that pressure was the .5-percent-per-day type of
5 leakage.

6 MEMBER POWERS: And the difficulty, I
7 mean, CB&I's calculation is what does steel do. Okay?
8 And, okay, fair enough. The thing that came out of
9 the Limerick PRA for the MARK I's, even though
10 Limerick is not, but the insight that came out of it
11 was, first of all, that molten pattern up there is
12 different for every single one of these plants, and
13 just the thermal expansion of some types of bolts
14 kills you up there well before you get up to that 500
15 F. I mean, at 350, you are dead up there, and it is
16 easy to get up to 350 up there as soon as you lose the
17 drywell coolers. That is only half a megawatt, but it
18 is an important half a megawatt.

19 MR. WACHOWIAK: So, in most of the cases
20 where we had a viable strategy, what we called a
21 viable strategy, even 350 was at the upper end. It
22 tended to stay down below.

23 MEMBER POWERS: The one I have become more
24 interested in now is the Japanese did some studies on
25 the elastomeric seal up there. What they found, they

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 did a nice set of tests. They did temperature alone.
2 And then, they did temperature and steam. And then,
3 they did temperature, steam, and radiation. And that
4 sucker died really quickly when it had all of three of
5 them. It held together up to 250-300 degrees
6 Fahrenheit with temperature and steam. But, as soon
7 as you put the radiation on it in combination with
8 those things, you have got a synergism, and it just
9 died.

10 Now that is died with respect to its
11 elastomeric properties. That is what polymer people
12 measure. What I don't know is, does it die with
13 respect to its ability to retain fission products in
14 there? I mean, what it is doing is embrittle. Does
15 that mean that we get, with you screwing around with
16 the pressures in here rather than just letting it
17 vent, does that mean it is going to break out and we
18 are going to have a head venting up there? I mean, I
19 just don't know.

20 MR. WACHOWIAK: Right. And so, that is a
21 good question. One of the things that we do notice is
22 that, once we have moved off of the wetwell vent,
23 cycling the vent becomes less important. So, you
24 wouldn't necessarily have to do it all the time for
25 the whole scenario.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER POWERS: Yes. Mainly, it just
2 affects your tradeoffs --

3 MR. WACHOWIAK: That's right.

4 MEMBER POWERS: -- in these things. Does
5 it change the story that you have got to keep it cool
6 up there? Well, you are going to keep it cool if you
7 turn on the upper spray because that will put water on
8 it. And that is just a great thing. I mean, sprays
9 are just great things, no matter what you do, because
10 they give you everything. They clean the atmosphere.
11 They put water on your core debris. They probably
12 make good coffee for you in the morning.

13 (Laughter.)

14 I mean, as far as I can tell, there is no
15 downside to sprays.

16 MR. GABOR: I guess what I would like to
17 do -- and I don't want to go over our allotted time,
18 because, as you all know, we could talk, I could talk
19 forever, I think -- let's jump to the sensitivity
20 analysis slide, Rick.

21 I wanted to make a point that, through our
22 own investigation -- and the five, I guess, bars that
23 Rick showed on the one slide represented literally
24 hundreds and hundreds of simulations that we have
25 carried out -- based on our own investigation, based

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 on some feedback that we got from the staff when we
2 presented this to them on the 8th of August, we have
3 tried to include what we think is a significant group
4 of sensitivity calculations to try to just see how
5 robust our conclusions are.

6 This list just gives you an idea of some
7 of the things that we investigated.

8 MEMBER POWERS: You guys are just
9 incredibly conservative.

10 MR. GABOR: Conservative?

11 MEMBER POWERS: Yes, your nominal value
12 per spray drop constitutes a 10-psi pressure drop
13 across the worst spray nozzle I have ever seen in one
14 of these plants. And the problem is big droplets are
15 not as efficient at removing aerosols as little
16 droplets. And your nominal value, your sensitivity
17 value is a 1.5-inch droplet, which is bigger than the
18 droplet you can get just dripping off a structure.
19 And I don't know you get a 1.5-inch drop.

20 MR. GABOR: Like a garden hose, really
21 that kind of spray.

22 MEMBER POWERS: Yes. I mean, it is just
23 a spray that didn't ignite, that's all.

24 MR. GABOR: That didn't work, yes. And as
25 Rick pointed out, when we plot out the individual

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 lambdas for the aerosol removal, we find interesting
2 things in there. We find that by just merely keeping
3 the containment pool, you know, you continue with
4 condensation on the walls and on the structures, that
5 removes a fair amount of the aerosols.

6 As we point out, the other thing we see
7 is, by cycling the vent, every time that vent is
8 closed, we have got gravitational settling playing in.
9 And this is taking place over hours and hours of time.
10 So, the overall removal process is probably less
11 sensitive, what we found, it is a lot less sensitive
12 to the details of the spray than we expected. That
13 doesn't mean that we don't think sprays are great,
14 just like you said, but in an integrated scenario kind
15 of calculation, it turns out not to be as important.

16 MEMBER POWERS: The small size of the MARK
17 I containment plays into the hands of those natural
18 mechanisms very well because gravitational settling
19 suddenly becomes a very rapid actor in there; plus,
20 all that structure. I mean, if you go into a MARK I
21 containment, you get claustrophobia like instantly and
22 you can't move because there are so many surfaces and
23 structures in there that play into the hands of
24 natural removal very, very well.

25 MR. GABOR: Yes.

1 MEMBER POWERS: Not to count on those
2 things because, like you say, you still have to get
3 water in there some way.

4 MR. GABOR: You have got to cool the
5 debris.

6 So, we looked at RCIC timing. I even
7 threw in a case where what happens if we recover this
8 in-vessel.

9 I don't know if you can jump back to the
10 first timing, but the one on the MARK I, the next one.
11 Oh, sorry, go up one to the table.

12 So, you see the general timing. In this
13 case, we assume at four hours we lost RCIC due to a
14 lose of DC power, I think a pretty conservative
15 assumption.

16 For our simulations where we have flooding
17 and spraying of the containment, we assume that that
18 was initiated one hour, within one hour of losing
19 injection, losing RCIC. But what we find, if you look
20 at the BWR Owners' Group SAMGs and their EOPS, is
21 that, clearly, they are going to instruct the
22 guidances there to initiate that prior to vessel
23 breach. Just exactly how close to vessel breach that
24 is probably doesn't matter as long as the water is
25 there before the vessel fails. Again, this is drywell

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 spray, so it has no influence, really, on the core,
2 what is going on inside the reactor vessel.

3 So, we get core recovery in five hours,
4 onset of core damage about an hour later, relocation
5 in a lower head, followed by vessel breach around 12
6 hours.

7 MEMBER POWERS: Are you running this core
8 all -- I mean, when you say core material relocation
9 to the lower plenum, you moved the whole core down
10 there?

11 MR. GABOR: It is interesting, we do. We
12 tend to over a pretty short time window. And that is
13 one of the differences we see that we want to explore
14 more between MAAP and MELCOR. I think Randy Ganz
15 mentioned this in previous presentations, that in the
16 MAAP simulations, our core heat-up phase seems to be
17 relatively short and pretty completely.

18 So, when we say shortly after the time of
19 vessel breach, when we look at our results for almost
20 all of these scenarios, we had relocated 100 percent
21 of the core out of the reactor vessel. We think that
22 is probably conservative in the way that the MAAP
23 model is set up.

24 (Laughter.)

25 Again, these are cases with no mitigation

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 in-vessel.

2 MEMBER POWERS: Well, I am wondering, I
3 bring it up because I am wondering if it is
4 conservative for these purposes. I mean, what we know
5 is those cores that have not gone on to power uprate,
6 that we have this huge gradient of power across, so
7 that the outer ring, which constitutes 25 percent of
8 the core, has incredibly low power relative to the
9 center.

10 Now suppose that, instead of dumping it
11 all into the vessel lower plenum and then plopping it
12 into the drywell, that you have 25 percent of it that
13 now has an opening and things are circulating up
14 there, and it is cooking and doing something, but
15 giving you release into your containment in a
16 continuing fashion. Does that change any of the
17 conclusions you have? It is not obvious to me that it
18 does or it doesn't. I just don't know.

19 MR. WACHOWIAK: It doesn't seem to change
20 the conclusions, but it changes the details. What we
21 find in these scenarios, even in the ones where MAAP
22 has dumped the entire core into the lower plenum, it
23 still leaves fission products behind on surfaces --

24 MEMBER POWERS: That is true, yes.

25 MR. WACHOWIAK: -- inside the reactor

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 vessel.

2 In the cases where the reactor vessel
3 doesn't get any sort of steam cooling and cool off
4 those things --

5 MEMBER POWERS: Yes.

6 MR. WACHOWIAK: -- we see a continuous
7 supply for up to another six hours or so in the
8 containment of aerosol that makes some difference. If
9 you keep these other things in there, it is going to
10 act similarly when you add it to the --

11 MEMBER POWERS: Pliez did a calculation,
12 again 20 years ago, and she got a revaporization,
13 release went on for 50 hours.

14 MR. WACHOWIAK: Yes, I am trying to think
15 of --

16 MR. GABOR: And these calculations, again,
17 with either spraying containment or flooding
18 containment, we see that that gets controlled because
19 the atmosphere is much cooler. Clearly, if we didn't
20 have the sprays or didn't flood, you are exactly
21 right, we could potentially see a very long, drawn-out
22 revaporization. In a MARK I, in these base-case
23 scenarios, that is usually the majority of the
24 release.

25 MEMBER POWERS: It seems to me that, in

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 making your case/recommendation, you need to bring
2 that up, that there are some derivative benefits here
3 that may not be anticipated that could have real
4 impact not on land contamination, but the folks out
5 there.

6 MR. WACHOWIAK: Yes. So, I think the
7 answer to your question is it may change the details.
8 I don't think that it changes the outcome of the
9 strategy.

10 MR. GABOR: So, we included all the
11 details of the sensitivity.

12 Our time is up. So, I will stop and do
13 whatever, answer any questions or do whatever you
14 would like us to do.

15 MEMBER POWERS: Not that we have had any
16 up until now.

17 (Laughter.)

18 MR. GABOR: Yes.

19 CONSULTANT BARTON: Where do the plants
20 with isolation condensers fit into this?

21 MR. WACHOWIAK: They don't. I guess that
22 is kind of a little short answer there. But what we
23 would have to look and see, is the isolation condenser
24 going to act the same way as RCIC does? If it acts
25 the same way as RCIC does, then it is probably going

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 to be about the same sort of thing, except the
2 isolation condenser is not heating up the suppression
3 pool.

4 So, we start with a suppression pool that
5 has much more subcooling margin, but that particular
6 heat-up there, I don't believe it is going to change
7 the details enough to change what the strategy is. I
8 just think it may help it a little bit because one of
9 the factors affecting the containment, the suppression
10 pool temperature, it loses its subcooling less
11 quickly.

12 The other thing is we probably start with
13 a containment pressure that might be 5 psig lower when
14 the vessel fails if we haven't dumped the energy from
15 running RCIC into the suppression pool and it is
16 dumped into the isolation condenser pool.

17 So, the other things that are happening
18 are so much bigger than those particular pieces, I
19 don't think it is going to change it that much.

20 MR. GABOR: The only last point, I guess,
21 that we didn't cover the MARK II. Put the drawing up.

22 MARK II's are unlike the MARK I. I think
23 we already talked about how there are aspects of
24 severe accident modeling in a MARK II that does give
25 it a different outcome or progression. And one of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 them is identified here.

2 Left and right, all we are showing here
3 are two of the five sites that have MARK II plants.
4 There is a single site that looks like the one on the
5 right, where what I call the pedestal region below the
6 drywell is actually filled solid with concrete. So,
7 any debris that would get down there, if not flooded
8 or cooled with sprays or injection, could have some
9 pretty prolonged core-concrete interaction, where the
10 one on the left, which is the majority of the
11 remaining MARK IIs, any debris that gets down, either
12 through the pedestal or through the drywell, is likely
13 going to find its way into water, which is normally
14 considered to be a good outcome.

15 But, as Rick pointed out, the one thing
16 that we did identify, which is identified in a lot of
17 Level 2 PRAs, is the potential to create this pool
18 bypass in a MARK II. And the one that we focused on
19 was the drainline. You can see a picture of it here.

20 But it depends on the plant. They are all
21 unique, but they all tend to have some form of
22 equipment or a sump drain under the reactor vessel, if
23 not one, maybe two. And it is typically a 4-inch
24 pipe. It might be bolted up to the floor on a flange,
25 a 9-inch flange, or something. But it does

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 potentially present a way that, if not cooled, debris
2 could melt that and create a pathway out.

3 You mentioned the downcomers. We do think
4 that any material that moves out into the drywell, the
5 typical downcomer lip is about a foot above. We think
6 that is probably going to melt away due to the debris.

7 But, as Rick pointed out, the downcomer
8 pipes themselves are anchored in a couple locations
9 embedded in the floor. There are a lot of them. We
10 haven't done the specific heat-up calcs, but the
11 assumptions have been that there is enough surface
12 area, and that pipe would remain cool enough, that it
13 wouldn't fail below the floor. So, that is a
14 consideration you brought up.

15 But, for our cases, we basically looked at
16 the plant as-is and the plant, and you will see in the
17 plots it says "bypass" or "no bypass", and you can see
18 the outcome, depending on what you assume on the
19 bypass. And again, we think there are mechanisms to
20 cool and protect at least the sump, the sump
21 drainline, that has already been employed at other
22 plants. I think Palisades had a modification made to
23 their cavity to do a similar thing. So, there are
24 ways to protect that, prevent the pool bypass.

25 And then, it does tend to respond more

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 like a MARK II. It is a little more robust, a little
2 more volume there. Being able to get the debris
3 directly in the suppression pool is usually an
4 advantage in terms of long-term cooling of the core.

5 MEMBER BLEY: Of course, you wouldn't be
6 generating as much uncondensables, right? So, pre-
7 closing the vent might get you into some trouble here,
8 might it not, from reverse pressure?

9 MR. GABOR: The pressurization that we
10 normally see is due to decay heat, steaming of the
11 water through decay heat. So, again, with our flow
12 rates and using the sprays as we are, we are not
13 seeing, if you are talking about the negative pressure
14 potential, we are just not seeing that in the
15 simulations that we have run. Maybe with much higher
16 flow rates, we might get there.

17 MR. WACHOWIAK: So, one of the things that
18 we have discussed with the Owners' Group was that
19 maybe in the case where you are using the low-flow
20 spray for quite some period of time, and then you have
21 got stuff back, you probably ought to consider bumping
22 up from the 500- to 5,000-GPM flow rate for these
23 types of considerations. So, if you go into a higher
24 flow rate, you probably should look into that. But,
25 at the lower flow rates, I am having a hard time

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 getting to a point where the steam supply isn't
2 supplying enough to keep the containment from going
3 to a negative pressure.

4 MR. GABOR: So, I guess, just to summarize
5 our presentation, we think that we do see that the
6 existing SAMGs, the BWR Group's SAMGs provide a lot of
7 the benefits and a lot of the right strategies for
8 reducing land contamination, for mitigating the
9 releases. As you have heard, that involves
10 spraying/flooding containment and utilizing the
11 reliable hardened event, which the MARK I's have.

12 And the additional insights: again, no
13 single strategy alone is effective. Putting just a
14 filter on a MARK I containment will not do the job.
15 And you have to think through how the MARK I behaves
16 in an accident situation. Things like liner failure
17 and the temperature impact on the drywell head that we
18 talked about, all those have to be part of your
19 thought process because, without considering those,
20 you could put a filter on and get no benefit out of
21 it.

22 Again, we find a lot of benefit in the
23 controlling schemes. As we mentioned, the MARK II has
24 some unique features that kind of set it aside from
25 the MARK I.

1 MR. WACHOWIAK: And you have to consider,
2 even with the controlling schemes, you have to
3 consider the whole thing because, like you say, there
4 may be some case where you are doing a controlling
5 scheme and there is a failure mode that you didn't
6 think of that you introduced at that point. So, we
7 need to look at, overall, how is the entire system
8 performing in order to make sure that we get a
9 strategy that reliably gives you a decontamination
10 factor that is acceptable.

11 MEMBER POWERS: That is the word. It
12 would really be nice if you projected slide 19. I
13 just like to look at it.

14 (Laughter.)

15 MR. GABOR: We put that in just for you.

16 (Laughter.)

17 MEMBER POWERS: Just to indulge me a
18 little bit.

19 MR. GABOR: We did.

20 MR. WACHOWIAK: He will be autographing
21 that slide for everyone afterwards.

22 (Laughter.)

23 Unless there are any other questions for
24 us, we will let the next team come up here.

25 CHAIRMAN SCHULTZ: I think in the interest

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 of time, Rick, we will move on to Bob Fretz'
2 presentation.

3 Bob, do you want to move up to the table?

4 And while you do that, I want to thank
5 you, Rick, and you, Jeff, for the presentation that
6 you have made here. We look forward to the report
7 that is going to be published and further discussions
8 as well. Thank you.

9 MR. WACHOWIAK: Thank you.

10 CHAIRMAN SCHULTZ: With that, Bob, I will
11 turn the podium over to you for your discussions on
12 the overall program here.

13 This is Bob Fretz.

14 MR. FRETZ: Okay. Thank you.

15 I will see if I can get to my
16 presentation.

17 Good afternoon.

18 My name is Bob Fretz. I am with the Japan
19 Lessons Learned Project Directorate. I am here to
20 talk about some of the actions that the staff has been
21 taking with respect to studying this issue.

22 With me is Bob Dennig from the Containment
23 and Ventilation Branch in the Office of Nuclear
24 Regulation.

25 Go down to the next slide.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 I was really going to talk about a little
2 bit of background information as well as the staff
3 actions and our project plan, and really leading up to
4 the presentation by the Office of Research. With your
5 permission, in the interest of really saving some time
6 and getting us back on the agenda, I can really maybe
7 skip the background information. I think most of the
8 Committee is familiar with some of the insights. I
9 think you are probably more interested in hearing from
10 the Office of Research as well as from the folks from
11 Paul Scherrer Institute.

12 MR. DENNIG: Unless you really like
13 citations from SECY numbers.

14 (Laughter.)

15 CHAIRMAN SCHULTZ: Move right ahead.

16 MR. FRETZ: Again, the staff was
17 essentially tasked with taking a look at this issue by
18 the Commission. Really, following the issuance of the
19 orders for the reliable hardened event in March of
20 this year, the staff has been very busy taking a look
21 at a number of aspects of this issue. We have taken
22 a look at our past regulatory actions.

23 Of course, we have taken a look at the
24 actions of Fukushima to see what sort of insights we
25 could gain from that experience. We did consult with

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 a number of our counterparts, with some of the foreign
2 regulators, with respect to filtering technology.

3 We have been working very, very closely
4 with the Office of Research with respect to a number
5 of cases that will essentially be used for our
6 regulatory analysis. Again, the Office of Research is
7 also assisting us with taking a look at a number of
8 PRA risk insights.

9 And again, we have been studying very hard
10 many of the same issues that you heard prior to us
11 with respect to use of filter containment venting with
12 respect to implementation of severe accident
13 management strategies. Again, we are looking at many,
14 many of the same things that you saw earlier today.

15 MR. DENNIG: Everybody is pretty much
16 onboard with the "get the water in there", get it into
17 the core, get it under the vessel, and eventually
18 needing active systems to bring things to a successful
19 end. The notion is that we are looking at the filter
20 containment venting system as a way to buy some time,
21 if you will, or something you don't have to worry
22 about while you are trying to do those actions, is one
23 way to think about it. But nobody is disagreeing that
24 you have to eventually cool things and cover things.

25 MR. FRETZ: In addition, in support of our

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 technical analysis, we have held a number of meetings
2 with the public as well as the industry in really
3 pursuing our research on this.

4 MEMBER POWERS: Well, in the spirit of
5 buying yourself some time, so that you can assure that
6 you have water in the drywell, are you looking at
7 trying to mitigate threats of hydrogen combustion
8 events in the reactor building?

9 MR. DENNIG: In the reactor building?

10 MEMBER POWERS: Yes. We seem to have had
11 a couple of those.

12 MR. DENNIG: Yes, right, some come to
13 mind.

14 (Laughter.)

15 The hydrogen question, I think we fed back
16 to the Committee that, at least for the present time
17 while we are talking about the venting, since it
18 obviously has an effect on what is in the containment
19 and what gets out when and how, that once we had
20 figured out what we were doing with the hydrogen
21 management aspects of depressurizing the vessel and
22 keeping it from using the reactor building as a sieve,
23 we would again turn to that issue and see what would
24 make sense to do next, in addition to any benefit we
25 would see from the venting. So, that is a long way to

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 say "sort of".

2 MEMBER POWERS: I interpreted it as a long
3 way of saying "no".

4 (Laughter.)

5 MR. DENNIG: I think that is a bit harsh.
6 The intention is to look at this and then see what --
7 because there have been fixes put in on some of the
8 plants overseas, and some simple things. Analyses
9 have been done of the reactor building in terms of
10 hydrogen and fission product retention.

11 MEMBER POWERS: It is a little off the
12 topic here. What I know is, or think I know, is that
13 neither MELCOR nor MACCS have a very firm experimental
14 base for modeling core degradation in BWR accidents,
15 certainly not the kind of experimental database that
16 we have for PRA, for PWR core degradation. So, how
17 accidents progress, those codes have been written by
18 reasonable individuals doing the best job they can,
19 but they aren't bolstered by having a lot of
20 experiments to substantiate that. And we learned from
21 the PWRs that we needed lots of experiments; our
22 intuition was poor on these extreme phenomena.

23 And so, details of how things melt down,
24 and what not -- the one thing I know occurs in severe
25 accidents when you don't have cooling is you generate

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 hydrogen. And the one thing I learned, to my chagrin,
2 in the Fukushima accidents is that we have ways of
3 leaking hydrogen into the reactor building, and it
4 will not just deflagrate; it will detonate. And I
5 said, wow, when we wrote the hydrogen rule, we really
6 missed that one, because we thought inerting the
7 drywell was enough to get us out of the woods on that.

8 And the problem is there is safety-related
9 equipment in those reactor buildings. If you get
10 detonation events of the kind we saw, you are going to
11 lose that equipment.

12 And I don't need MELCOR or MACCS to tell
13 me I have got a hydrogen problem in the reactor
14 building. Whereas, these other things, like vented
15 filter, I am going to have to get a lot of information
16 from Fukushima before I know what exactly happened in
17 there.

18 Here, I don't need -- I mean, the movies
19 outside told me everything I need to know. I missed
20 the idea that I can leak hydrogen into the reactor
21 building in these severe accidents, and I didn't think
22 about mitigating it in the reactor building.

23 It seems to me that that is the one lesson
24 I get out of Fukushima that I don't need the computer
25 codes for. I don't need the dissection of the core

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 and things like we did with TMI to tell me what was
2 going on. It is obvious on the face of it that I have
3 got a hydrogen problem.

4 I have spoken, I have preached --

5 MR. DENNIG: Yes. No, your point is well-
6 taken, noted, and that is very helpful. It is an
7 issue that we have to look at, and we will look at
8 that next. We will be sure that we go at it in a way
9 that is satisfies everybody's curiosity and needs.

10 MR. FRETZ: Real quickly, again, these are
11 examples, some of the foreign regulators and licensees
12 that we consulted along the way and some of the sites
13 that we visited in order to gain greater insights of
14 how venting and how filter venting was used in those
15 countries.

16 Like I said earlier, we have held a number
17 of public meetings. In May, we sort of teed-off the
18 issue with the public and the industry and,
19 essentially, presented them this issue and providing
20 an overview of the various issues, and we gained a
21 number of insights from the industry as well as from
22 the public from those meetings.

23 Now, in addition, we have held meetings to
24 gain greater insights with respect to filtering
25 technology. Last July 12th, we held a public meeting

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 with the representatives from AREVA, and we learned a
2 bit more about their filtering technology as well as
3 the research and development that they have conducted
4 with respect to their ability to filter contaminants.

5 In addition, yesterday we had a meeting
6 with a representative from the Paul Scherrer Institute
7 and IMI Nuclear. Again, they will be talking with you
8 later on this afternoon. So, you will hear more about
9 that this afternoon.

10 In addition, as you mentioned earlier
11 during EPRI's presentation, they did meet with us on
12 August 8th. Again, we do look forward to
13 hearing/seeing more of their details for their report
14 that they indicated that they should have to us by the
15 middle of this month. So, again, we look forward to
16 those additional details regarding their strategies.

17 Again, while we have had some interactions
18 with the ACRS, the May 22nd meeting was essentially a
19 review of what we learned when we went overseas.

20 MEMBER SKILLMAN: Bob, would you go back
21 to seven, the previous slide, please?

22 MR. FRETZ: Yes.

23 MEMBER SKILLMAN: For those stations where
24 there is a vent, did you look at the analysis or how
25 they used the analytical tool and how they took credit

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 for the vent?

2 MR. DENNIG: I think that in the sense of
3 did we go over things in the way you were going to go
4 over the MELCOR and the MACCS analysis or the way we
5 are looking at what EPRI is doing, we didn't go into
6 that level of detail. But we certainly do have the
7 information of what was used and how it was done and
8 how it was interpreted and what the major inputs were.
9 But nobody has scrutinized the calculations in some
10 kind of a review sense.

11 MEMBER SKILLMAN: Okay. Thank you.

12 MR. DENNIG: And all those plants have
13 vents, filtered vents.

14 MR. FRETZ: Again, some of the upcoming
15 actions that the staff plans to make: on the 13th of
16 this month, next week, we will be holding a public
17 meeting with essentially the Office of Research
18 teaming up with us, where, again, they are going to
19 talk about their analysis that they have done through
20 MELCOR, essentially, much of the same material you are
21 going to hear today on that. We are going to hold a
22 public meeting. In addition, we have offered time for
23 members of the public to be able to present any kind
24 of information that they would like. So, again, it is
25 going to be an all-day public meeting. We have

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 invited a number of key stakeholders, and we are
2 looking forward to hearing from them next week.

3 Again, we have tentatively planned an
4 October meeting, but that has really not been firmed-
5 up.

6 In addition, of course, we will have a
7 number of interactions with the Japan Lessons-Learned
8 Steering Committee in order to gain their alignment
9 and review of the Commission paper.

10 In addition, and, of course, very
11 importantly, is our interactions with this Committee.
12 And so, we are slated, at least currently right now,
13 to meet with this Subcommittee on the 3rd of October
14 to present a little bit more information related to
15 our analysis done by the Office of Research.

16 Finally, we will meet with the full
17 Committee on the 1st of November.

18 Again, our goal is and our charge is to
19 submit a Commission paper by the end of November. We
20 plan to get that to the EDO's office by September
21 20th. Certainly, that is our current goal.

22 And I believe that is it that we have here
23 for our formal presentation. I think we are probably
24 generally close to being on schedule --

25 CHAIRMAN SCHULTZ: We are on schedule.

1 MR. FRETZ: -- to take our break, I guess.

2 CHAIRMAN SCHULTZ: I would like to go
3 ahead and call for a break. It is on the agenda. We
4 are going to break until 3:15. I encourage everyone
5 to be back to start with the presentation, and we will
6 work to have that presentation ready to start at 3:15.

7 Just to review, what will also happen
8 later, as I mentioned, we are going to have the public
9 presentation associated with the Paul Scherrer
10 Institute discussions first. Then, we will have an
11 opportunity for public comment and, also, for comments
12 by members of the Subcommittee, before we go into the
13 proprietary session. And we won't call the session
14 back into a public session after the proprietary
15 session.

16 Thank you.

17 We will, then, recess.

18 (Whereupon, the foregoing matter went off
19 the record at 2:58 p.m. and went back on the record at
20 3:16 p.m.)

21 CHAIRMAN SCHULTZ: I will call the meeting
22 back into session now.

23 And the next portion of the program is to
24 have a presentation by Research associated with their
25 work on this topic. I would like to introduce Sud

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 Basu, who is going to be introducing the topic for us.
2 Thank you.

3 DR. BASU: Thank you, Mr. Chairman, ACRS
4 members.

5 Again, my name is Sud Basu. I am with the
6 Office of Research at NRC.

7 And we are providing technical support to
8 NRR/JLD in addressing the determined ventilation.

9 I am going to give you one-half story
10 about the whole truth today; the other half will come
11 about a month from now, when the other Subcommittee
12 meeting is scheduled.

13 The partners in my crime are Dr. Richard
14 Lee, sitting at the table; Allen Notafrancesco, both
15 in the Office of Research. We also have Dr. Ed Fuller
16 in the audience from the Office of Research.

17 The MELCOR analysis that I am going to
18 talk about shortly, MELCOR calculations were done at
19 the Sandia National Laboratories. We have Jeff
20 Cardoni from Sandia represented here today. He is in
21 the audience. So, I am mentioning his name just in
22 case you have questions, you know who to address your
23 questions to.

24 MEMBER POWERS: In that regard, I should
25 acknowledge that I sometimes visit Sandia National

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 Laboratories and get employed there. And so, I will
2 try to refrain from commenting extensively about their
3 work.

4 (Laughter.)

5 CHAIRMAN SCHULTZ: Thank you.

6 MEMBER POWERS: Not that I know anything
7 about it. I mean, I don't know anything about it.
8 They certainly don't tell me anything about it.

9 DR. BASU: Okay. So, the presentation
10 outline is I am going to touch briefly on the
11 objectives and the scope; spend a good deal of time in
12 MELCOR calculations, discussion of results; also,
13 insights from MELCOR analysis. Time permitting, I am
14 going to talk a little bit about the decontamination
15 factor. And then, I will end with a list of follow-on
16 activities. These are activities that you are going
17 to hear again in the October Subcommittee meeting.

18 So, by way of objectives or what we are
19 doing, as I mentioned earlier, providing technical
20 support to NRR/JLD in addressing the containment
21 venting issue, in particular, in regard to informing
22 a decision on whether filter vents should be required.
23 This work, the Commission asked us, instructed us to
24 carry on in parallel, concurrent with the development
25 of the technical basis for reliable hardened events.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 So, this is work that was actually classified as an
2 additional issue in the NTF recommendations for
3 addressing later on, but the Commission directed us to
4 actually do it now. And this is what really we are
5 doing, we have done in part.

6 So, the scope of my presentation today is
7 going to be focused on MELCOR calculations only, and
8 within MELCOR calculations, as you will see, we will
9 talk about various prevention/mitigation actions,
10 venting with and without filter, and, of course, the
11 calculations you heard from the previous speaker from
12 EPRI, that their calculations were informed by SOARCA
13 and Fukushima. So are our calculations informed by
14 SOARCA and Fukushima.

15 So, if you are going to find a lot of
16 similarities between their calculations and our
17 calculations, don't be surprised. We didn't compare
18 notes with each other until about a month ago, when
19 they came and gave us the presentation, but in terms
20 of the number of ways that you can address this issue,
21 I think there is a synergy between how EPRI looked at
22 it and how we looked at it thus far.

23 The scope, overall, the broader scope,
24 actually -- and I am not going to talk about a lot of
25 that -- includes the MACCS consequence calculations

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 using the output from MELCOR. It also includes taking
2 a look at the PRA on event sequences and then the risk
3 assessment; and, of course, the products of
4 consequences coming out of MELCOR/MACCS and the
5 frequency estimates that are coming out of the PRA
6 activities.

7 Again, I am not going to talk about PRA
8 activities this meeting, nor am I going to talk about
9 the MACCS calculations at this meeting. They will
10 come in the next meeting, along with the regulatory
11 analysis.

12 MEMBER SHACK: What range of consequences
13 are you going to be computing with MACCS?

14 DR. BASU: What kind of consequences? The
15 population dose, the LCF risk, land contamination,
16 site boundary dose, all of those.

17 CHAIRMAN SCHULTZ: It sounds like the full
18 range of consequences.

19 (Laughter.)

20 DR. BASU: Pretty much what MACCS is
21 capable of doing, and what we do, basically, do the
22 whole range. And you are going to see those in the
23 next time around.

24 Again, in terms of MELCOR calculations,
25 the accident scenarios that we are going to focus on

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 in the remainder of my presentation are informed by
2 SOARCA and Fukushima. The focus is on the long-term
3 station blackout. We did run the case of short-term
4 station blackout as well and a couple of other
5 sequences. We did run, as many as you heard from the
6 previous presentation, hundreds of calculations. We
7 did run about 30-plus calculations. So, I should be
8 able to show you some of our calculations, something
9 of that, again, a sensitivity analysis that we
10 conducted.

11 MEMBER POWERS: Dr. Basu, let me ask a
12 question out of more curiosity than anything else. In
13 the Fukushima accident scenarios, at least for a
14 couple of the units, there was a prolonged period in
15 which sea water was injected and some speculation that
16 sea water, sufficient sea water, was evaporated, that
17 sodium chloride may have precipitated out in the
18 vessel, maybe not for Unit 1, but certainly for 2 and
19 3. Has that been confirmed, and is that taken into
20 account in the analyses that come out of Fukushima?

21 DR. BASU: Okay. The answer to the second
22 one, it is not taken into account in this analysis we
23 did. Is it confirmed? I do not know the answer.

24 MR. LEE: There is no change in terms of
25 MELCOR calculations. This is similar to the version

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 that SOARCA used. For example, if you want to look at
2 the ex-vessel, does a lot of salt end up in the ex-
3 vessel, remember, we said that in the end case all the
4 fission products and encapsulated, those type of
5 phenomenons are not calculated. So, it is a tradition
6 of straightforward severe accident analysis.

7 MEMBER POWERS: At least on the back of
8 the envelope, if you had a large bed of salt, either
9 in-vessel or ex-vessel, the core melt progression
10 would be substantially different.

11 DR. BASU: I believe so. I should
12 mention, and I should have mentioned before, that what
13 we are presenting to you is simply not scoping
14 calculations. The objective is to look at various
15 prevention/mitigation measures and assess their
16 relative merits and benefits. We are not looking into
17 the absolute numbers and precise accident progression
18 scenario.

19 Yes, the accident progression will be
20 different in a case like what you just described.
21 Whether in terms of the relative merit and benefit of
22 various mitigation measures, even for that accident
23 scenario, whether that will be substantially different
24 from the ones that we are presenting, I kind of doubt
25 it will be.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. NOTAFRANCESCO: Could I add? We try
2 to focus on providing a foundation for the regulatory
3 analysis, which gets into the cost/benefit. So, we
4 didn't go too far in that area. Okay?

5 DR. BASU: So, again, as I said, if you
6 are going to see a lot of similarities between the
7 previous presentation and this presentation, do not be
8 surprised. We looked at a number of
9 prevention/mitigation measures/actions, such as RCIC,
10 core spray, drywell spray, venting. Then, we got
11 filter.

12 We also looked at sensitivities of RCIC
13 timing, for example, the spray flow rate, spray
14 actuation timing, as well as what I call here passive-
15 versus-active venting. That is like active venting
16 would be you vent once and keep the vent open. I'm
17 sorry. Passive is you vent once and you keep it open.
18 Active venting is you cycle the vent, as you heard in
19 the previous presentation. So, we did look into the
20 sensitivities sort of in our scoping analysis and,
21 then, we made a number of calculations.

22 MEMBER REMPE: Sud?

23 DR. BASU: Yes?

24 MEMBER REMPE: What about reactor building
25 nodalization? Would that affect some of your results

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 with respect to aerosol deposition or hydrogen
2 combustion? And why is that not included as a
3 sensitivity?

4 DR. BASU: Good question. Well, I don't
5 know if this will come across as an excuse, but let me
6 tell you, we started this work sort of mid-May
7 timeframe. And you can run a large number of
8 sensitivities with a large number of parameters and
9 come up with, again, a very large set of output to
10 analyze and to come to some sort of conclusions.

11 The reactor building wasn't one of those
12 that we kind of targeted that we would look into to
13 start with. Because, if you will remember, we were
14 looking at the relative merit of mitigation features.

15 By the way, we did look into specifically
16 the hydrogen combustion issue with regard to the
17 MELCOR/MACCS calculation. And I agree with Dr. Powers
18 that, around MELCOR/MACCS, it tells me about the
19 hydrogen issue that was observed in Fukushima
20 particularly.

21 MR. LEE: Under the DOE/NRC Fukushima
22 forensic analysis using MELCOR, they did look at the
23 buildings, transport into that part. For, I think it
24 was Unit 2, for example, maybe 1 or 2 percent of the
25 fission parts leaked because of the head flange

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 leakage into the reactor building. So, at the time
2 that the reactor building blew up, the assumption is
3 that that 1 or 2 percent got transported out.

4 MEMBER REMPE: Okay, but I am just
5 wondering if you had smaller compartments, you might
6 have ignition earlier or you might have more
7 deposition. And I just am wondering how big that
8 effect could or couldn't be. And you are assessing
9 the merits of adding venting and filtration versus
10 sprays and things like that, and it seems like
11 something that is a given is that you could do a few
12 calcs and say, "Yes, this isn't that important" or you
13 might do a few calculations and say, "Well, maybe some
14 of these measures aren't so important if we just
15 refined our model."

16 MR. LEE: But, right now, our
17 concentration really is not to have hydrogen leaking
18 into the reactor building.

19 MEMBER REMPE: Right. I know.

20 MR. LEE: The strategy is not to have
21 it --

22 MEMBER REMPE: Okay.

23 MR. LEE: -- and to prevent these types of
24 combustion events to occur.

25 MEMBER REMPE: Okay.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. LEE: And then, Dana asked about
2 Fukushima. What else we did about informing is that,
3 during the DOE analysis, they also developed and
4 refined models for the torus room, for example.
5 Instead of using one model, they had developed 16
6 models. But they didn't have the opportunity to do
7 the analysis and incorporate it into the DOE study,
8 but that model exists.

9 So, we use that model to look at how would
10 the signatures change when we do the MELCOR
11 calculation versus the Fukushima. And you will see
12 that when you treat the heat transfer in the torus
13 room differently, then you will see the pressurized
14 signature match very well. So, that type of things we
15 looked at. What is the further validation that you
16 can do? But the MELCOR code gave you a better
17 validation. If I do certain model changes, we found
18 that it does; it did.

19 MEMBER REMPE: So, more refined models
20 will not help, is what you are saying?

21 MR. LEE: It did.

22 MEMBER REMPE: It did help?

23 MR. LEE: It helps you to match the
24 observation data from Fukushima pretty well.

25 MR. NOTAFRANCESCO: The issue is, when you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 have a four-hour RCIC, you are not sensitive to pool
2 nodalization. But if you go out in the long-term --

3 MEMBER REMPE: Right.

4 MR. NOTAFRANCESCO: -- you will get
5 stratification effects. So, we needed to divide the
6 wetwell pool to capture 10-20 psi that wasn't probably
7 captured in the SOARCA because it didn't go out so
8 many hours.

9 MR. LEE: So, we did explore some of those
10 sensitivities to see what improvement do you do. But
11 the starting days for this calculation, the deck is
12 from the SOARCA deck.

13 DR. BASU: To answer your question
14 quickly, there are a couple of slides I have. One
15 slides shows the active building nodalization, the one
16 that we used, and we didn't run any sensitivities on
17 that.

18 But there is the other slide that shows
19 the different pathways for the fission products, and
20 I am talking about fission products pathways only, not
21 the hydrogen. And you will see, in that slide you
22 will see that most of the fission product is through
23 the wetwell vent part and all that, and only about 10
24 percent of the inventory, 10 percent of the release,
25 is through those other paths that you are talking

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 about.

2 So, if I do some different nodalization,
3 I think I am going to make some difference in that 10
4 percent, not --

5 MEMBER REMPE: It would be significant?
6 That is what I am asking.

7 DR. BASU: Yes.

8 MEMBER REMPE: Okay.

9 DR. BASU: Right?

10 MR. LEE: I think we need to pretty
11 quickly move --

12 DR. BASU: Okay. So, very quickly, the
13 other model that we used is the Peach Bottom SOARCA
14 model. Unless you have any question, I really don't
15 want to go through it. You have heard about the Peach
16 Bottom SOARCA model at times before.

17 A couple of changes we made, and Richard
18 mentioned one change, which is a finer nodalization of
19 the wetwell volume. And the other one is we changed
20 the solidus-liquidus temperature that was used in the
21 SOARCA Peach Bottom analysis.

22 Now, if you remember the SOARCA Peach
23 Bottom, solidus-liquidus temperature was based on the
24 concrete solidus-liquidus temperature, if you can
25 think in terms of a concrete solidus-liquidus

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 temperature. The pair that was used, the value was
2 1400 for solidus and 1700 for liquidus.

3 We are talking about core melt onto the
4 drywell floor trying to spread. So, it is the
5 solidus-liquidus of the core melt that we should be
6 concerned with. So, what we did is in this
7 calculation we used the solidus-liquidus of the core
8 melt. Specifically, we used 1700 for solidus and 2800
9 for liquidus temperature. So, that is one change we
10 made. Otherwise, the MELCOR version that was used in
11 the SOARCA Peach Bottom, including the sensitivity
12 analysis, is what we used.

13 MEMBER ARMIJO: What is the result of
14 increasing the solidus-liquidus temperatures? Is it
15 less spreading?

16 DR. BASU: Well, slower spreading.

17 MEMBER ARMIJO: Slower spreading?

18 DR. BASU: So, in the Peach Bottom SOARCA,
19 you saw spreading to the liner in about six to seven
20 minutes. We are seeing it in about a couple of hours.
21 We are still seeing spreading. We are still seeing
22 liner melt-through --

23 MEMBER ARMIJO: But it is kind of oozing
24 as opposed to flowing?

25 DR. BASU: Yes. That is correct, yes.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 Okay. That is your reactor building
2 nodalization. We can change it. We can run some
3 sensitivity, but I don't think that is going to --

4 In this slide, I should mention the
5 various pathways. Again, that goes back to your
6 questions of fission product leakage.

7 MEMBER ARMIJO: Sud, just to follow up,
8 those are very high temperatures, the solidus-
9 liquidus, and that is mostly, I guess, UO2? What
10 about all that metal that has flowed down there which
11 would be entirely liquid?

12 DR. BASU: Well, 1700 in terms of solidus
13 is really not that high. You can have some concrete
14 there and some other metals, like stainless steel and
15 all that. Twenty-eight hundred, you might argue that
16 it is too high, but in terms of the melt spreading
17 calculations which are in MELCOR now, it really
18 doesn't matter whether that 2800 was there. If I put
19 that as 2400, for example, it didn't matter because of
20 the logic that is employed in current melt spreading
21 calculations in MELCOR. You are going to see maybe in
22 a couple of minutes here a difference.

23 MEMBER ARMIJO: Okay.

24 DR. BASU: Okay? So, what I am showing
25 you is an example, metrics of MELCOR calculations, and

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 I am going to show you some plots based on these
2 metrics. The important thing to note here is that we
3 had Case 2 which is nothing, no mitigation, no
4 venting, no core spray or containment spray, some RCIC
5 running. In our case, for all these cases that you
6 are seeing in this table, the RCIC ran for about 18
7 hours with a 16-hour emission time.

8 Now you have seen some sensitivities in
9 the previous analyses at four-hour Xe, eight-hour Xe,
10 twelve-hour Xe. We also ran sensitivities at four
11 hours and eight hours. I will show you some results
12 later on.

13 Case 3 is we have RCIC with vent. So,
14 this is like, you know, a single mitigation, if you
15 will, a single mitigation action.

16 Case 6 is RCIC with core spray, again
17 single mitigation action.

18 Let me jump to Case 14, which is RCIC with
19 drywell spray, again single mitigation action.

20 Then, you come to 7, which is core spray
21 and vent. So, you have a combination.

22 And the same thing with Case 15, the
23 drywell spray and the venting.

24 The results in the table are pretty
25 consistent in terms of what is happening by way of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 accident progression. The core in all cases is
2 uncovered at about 23 hours, I mean about five hours
3 after the RCIC flow terminating.

4 Core debris is relegating to lower plenum
5 at about another three hours, up to core uncovering.
6 And the lower head is fairly up to about 36-37 hours.
7 There are a couple of exceptions. Well, let me just
8 point out, anytime you have venting, we are finding
9 that the vessel lower head is a couple of hours
10 earlier. We don't know exactly why it is doing it.

11 (Laughter.)

12 We are looking into it. But, given the
13 phenomenological uncertainties in the modeling that we
14 are looking into within, talking about MELCOR, a
15 couple of hours of failure time difference, I don't
16 want to make a big issue out of it.

17 The drywell pressure exceeding the 60-psig
18 design limit, you know, pretty consistently around 23
19 hours or so. Now, in those cases where we don't have
20 venting, we get into head flange leakage, and that
21 happens a couple of hours after the drywell pressure
22 exceeds the 60-psig limit.

23 In those cases where we don't have any
24 water in the flow or any spray action, you see that
25 you get the liner melt. Not surprisingly, you have

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 the liner melt.

2 Now, unlike the EPRI calculations which
3 ran for 72 hours, our calculations we ran 48 hours.
4 MELCOR is not nearly as fast a code as is MACCS. So,
5 they can run a whole bunch more calculations than we
6 can do.

7 Okay. So, some selective results of
8 MELCOR calculations, and I am going to show them in a
9 plot form shortly. Again, debris mass ejected is
10 relatively consistent across the board, as is in-
11 vessel hydrogen generation. For ex-vessel hydrogen,
12 we are seeing some increased hydrogen production in
13 Case 3, the RCIC and vent. This is the case, recall,
14 that we don't have any spray action. It is just
15 venting with RCIC, and after RCIC terminates, you have
16 core on the floor. So, there is a sizable amount of
17 non-condensable production from core-concrete
18 interaction. So, it is not surprising that in Case 2
19 and Case 3 you are going to see more hydrogen, ex-
20 vessel hydrogen production than in other cases.

21 Just some estimates of cesium release
22 fraction at 48 hours, as also out and release
23 fractions.

24 Let me go to the plots here.

25 MEMBER REMPE: Before you go to the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 plots --

2 DR. BASU: Sure.

3 MEMBER REMPE: -- although maybe the
4 question will rise up in the plots, too. But it seems
5 like venting seems to increase in-vessel hydrogen
6 generation on this table, for like, if you look at the
7 difference between Case 2 and 3?

8 DR. BASU: Yes. Yes. Well, you know, if
9 you say, all right, between 525 kilogram mole and 600
10 kilogram mole there is a difference, yes, I agree
11 there is a difference, but, again, within the realm of
12 phenomenological uncertainties.

13 MEMBER BLEY: But it is always in that
14 direction, though.

15 DR. BASU: Yes.

16 MEMBER BLEY: It is doing something.

17 (Laughter.)

18 And on the other page it was consistent.

19 DR. BASU: And that is what we are looking
20 into now, why for the venting case. I don't have an
21 answer to that. I don't have an answer to it. We are
22 looking into it.

23 Earlier failure will actually explain more
24 ex-vessel --

25 MEMBER REMPE: Ex-vessel, but not in-

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 vessel.

2 DR. BASU: It will not explain the more
3 amount of in-vessel production, that is correct.

4 Okay. I am just showing you a whole bunch
5 of plots here. I don't know whether these plots are
6 going to beg question.

7 But, basically, what it is showing is that
8 the debris mass exiting the vessel kind of bounded
9 really, 250 to 300 metric tons, nothing unusual or
10 inconsistent than what we saw in other cases that we
11 ran in MELCOR, for example, SOARCA, Fukushima, et
12 cetera.

13 Now this plot actually gives you, it is a
14 composite plot of all the cases that we ran. The
15 point that we are making here, and I probably already
16 mentioned, that in Case 2 and 3 where we don't have
17 any spray or water on the floor, we are seeing liner
18 melt-through, and that is what you are seeing. Two is
19 the red color right there and 3 is the green color.
20 You are seeing liner melt-through in those two cases.

21 The cases where you don't have an event
22 happening, you are seeing the head flange leakage, as
23 in Cases 2 and 6 and, also, 14, for that matter. And
24 then, when you have the venting in the cases of 3, 7,
25 and 5, or 15, you don't have any head flange leakage

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 because you open the vent. So, you basically
2 prevented the overpressure fairly well from the event.

3 Okay. So, this is in-vessel hydrogen
4 production. We already had a question on that for
5 cases with venting. We will take that as an IOU; we
6 will get back to you.

7 For core-concrete interaction, let me show
8 you the value generation, nothing unusual there. And
9 this is the other non-condensable production from
10 core-concrete interaction, mainly seal. There is a
11 little bit of CO₂. I didn't plug the CO₂. CO₂
12 relative to CO is very, very small.

13 Okay. Here is the cesium release fraction
14 to the environment. As you can see, for Case 2, which
15 is no venting and no spread, nothing. We are going to
16 see a head flange failure, eventually leading to later
17 on, not in 48 hours, leading to perhaps more a
18 catastrophic event. But you can already see that that
19 one, because of the liner melt-through, I mean to say
20 not head flange leakage but liner melt-through, there
21 is no water on the floors except liner melt-through
22 because a liner melt-through you see a much larger
23 fractional release of cesium, and the same thing goes
24 for iodine.

25 Now for Case 3, which is also dry, you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 know, there is venting. So, that venting action
2 actually in some ways reduces the release inventory to
3 about a third, I would say, relative to Case 2.

4 There are other cases, Case 6, 7, 14, and
5 15, all of which have reactions of some type. You can
6 see that we get some scrubbing benefit from this
7 reaction, resulting in much smaller release.

8 So, again, these are kind of very much
9 consistent with what results we have seen in the
10 previous presentation.

11 MEMBER POWERS: Just a couple of
12 questions, again out of curiosity. You have no
13 concrete interactions going on for -- what? -- 10
14 hours or something like that here? Do you collapse
15 the pedestal?

16 DR. BASU: Do you know that is about
17 middle or so deep, right? That is what you are
18 referring to?

19 MEMBER POWERS: The pedestal is -- what?
20 -- 1.4-meters-thick concrete. And if you erode that,
21 the vessel collapses and will typically pull the
22 penetration out.

23 DR. BASU: I don't have a plot here, but
24 in some of the calculations we looked at, the CCI, the
25 best-mapped erosion, if you will, for us is 72 hours,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 and it would be the CCI rate. We didn't see the whole
2 thing, you know. So, whether or not the erosion depth
3 was large enough to cause a collapse, that still --

4 MEMBER POWERS: I don't think, I mean --

5 DR. BASU: I don't think so, but I will
6 have to check.

7 MEMBER POWERS: I don't know, but does the
8 code do a structural calculation on that pedestal?
9 Because you don't have to erode it to cause it to
10 collapse. I mean, just eventually it is going to
11 thermally degrade the concrete to the point the steel
12 has no strength at these kinds of temperatures, so
13 that it will collapse and the vessel will pull
14 penetrations out. And you will leak directly into the
15 building at the point.

16 DR. BASU: Yes, yes. I mean, if it
17 collapses, that is correct.

18 MEMBER POWERS: The other point of
19 curiosity here, you are plotting fractional release of
20 cesium, and a quake calculation suggests to me that
21 that is a few thousand curies. Is that enough to
22 violate the site boundary criterion, 25 rem TEDE?

23 DR. BASU: Okay. So --

24 MEMBER POWERS: It is not clear to me that
25 it is for cesium alone.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 DR. BASU: Oh, whether this is going to
2 violate --

3 MEMBER POWERS: Yes. I mean, when you get
4 down to a 10th of the percentile of the inventory of
5 cesium, for cesium alone, I don't think you can
6 violate 10 CFR Part 100 with that.

7 DR. BASU: Please stay tuned for the
8 next --

9 MEMBER POWERS: Ah, the consequence
10 calculation, yes, that's right.

11 DR. BASU: That is where we are going to
12 talk about whether that is going to happen.

13 MEMBER POWERS: Yes. Okay.

14 MEMBER STETKAR: So, one more curiosity on
15 this one.

16 DR. BASU: Yes.

17 MEMBER STETKAR: I am way outside of my
18 knowledge level. But your observation, if I look at
19 1 versus 2 -- oh, I'm sorry -- 2 versus 3, 6 versus 7,
20 both of those show lower cesium releases if I vent.
21 I kind of understand why that is.

22 On the other hand, 14 and 15 show about a
23 factor of three times larger, if I look at your table,
24 cesium release fraction if I vent. Is there a
25 physical reason for that?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 DR. BASU: Good catch. I thought I was
2 going to get away --

3 (Laughter.)

4 Okay. So, what is happening -- I don't
5 know if this explains -- what is happening is in Case
6 14 and Case 15 we are actually doing the drywell spray
7 at 24 hours.

8 MEMBER STETKAR: Yes. Okay.

9 DR. BASU: Now, if you look at the table,
10 your vent is opening before that.

11 MEMBER STETKAR: Oh, okay.

12 DR. BASU: So, you are not getting the
13 benefit of --

14 MEMBER STETKAR: Of the spray?

15 DR. BASU: -- reaction for a certain
16 amount of time.

17 MR. LEE: In other words, you have to look
18 at the details in order to understand the releases
19 because the vent operation may open where you don't
20 get the benefit from the spray. That is what we have
21 seen. So, just looking at the table itself doesn't
22 make sense. We thought the trends should be lower,
23 but it is not necessarily --

24 MEMBER STETKAR: Okay. Okay. Thanks.

25 DR. BASU: Sure.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 Okay. And this is the other plot that I
2 was referring to. You can see this is particularly
3 for Case 14. This is the drywell at 24 hours. And
4 you can see the partitioning of the initial core
5 inventory by different flow paths.

6 For another case, it will be different
7 than what you see here. But, by and large, you see
8 that most of the fission products are either in the
9 lower RPV or in the wetwell vent pipes. Only about 10
10 percent total elsewhere.

11 So, I just showed these as an example. We
12 have actually these plots for all the case runs that
13 we have done. Again, you have to look at these things
14 all in combination to come up with the analysis and
15 the conclusion.

16 MR. LEE: And those vent pipes, if I am
17 not wrong, they show on this diagram over here with a
18 small arrow that you cannot see.

19 DR. BASU: Okay. What I am showing you on
20 the next few slides are actually the sensitivity cases
21 of different types. Okay. So, this one is the effect
22 of spray actuation time, and this goes back to your
23 question, Dr. Stetkar. I think I mentioned that the
24 case that you were looking at that I showed was the
25 24-hour.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER STETKAR: But, Sud, if you go back
2 to slide 15 -- I am still trying to digest -- the one
3 I had the question here.

4 DR. BASU: Yes.

5 MEMBER STETKAR: If you look at the jump
6 in that cesium release, 25-26 hours there for Case
7 15 --

8 DR. BASU: Correct.

9 MEMBER STETKAR: -- the scenario is RCIC
10 fails at whatever it is, 18 hours.

11 DR. BASU: RCIC fails at about 18 hours.

12 MEMBER STETKAR: I open up the vent at 24,
13 and sometime later I spray, right?

14 DR. BASU: That is correct.

15 MEMBER STETKAR: Or don't spray?

16 DR. BASU: Well, you spray in both Cases
17 14 and 15. You either open the vent in one case --

18 MEMBER STETKAR: Oh, I'm sorry. I'm
19 sorry. Never mind. Never mind. I have got it. I
20 was mixing up times. Never mind.

21 DR. BASU: I can come back.

22 MEMBER STETKAR: No, I have got it.

23 DR. BASU: Okay. So, this is the spray
24 actuation time sensitivity. You know, this way,
25 depending on when you are actually doing spray, there

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 is some difference in the fractional release, but I
2 don't know if it is really worth talking much about
3 it. Because if you look at the release fractions
4 range, it is basically between .5 percent to .9
5 percent, or it is .05 percent to .09 percent. So, I
6 don't know.

7 MEMBER POWERS: We didn't think any spray
8 calculation is that accurate.

9 (Laughter.)

10 DR. BASU: There you go. So, when I look
11 at the spray actuation timing, I can't really make any
12 conclusion that the actuation timing has any
13 sensitivity to what the release fractions would be.

14 MEMBER ARMIJO: Not even a general
15 statement that spraying early is beneficial?

16 MEMBER BLEY: Well, look, the middle one
17 is the longest time.

18 DR. BASU: So, I would say spray is
19 beneficial. I don't know whether spray early is
20 beneficial or spray later is. Spray is beneficial for
21 pressure control.

22 MEMBER ARMIJO: The priority should be on
23 pressure control.

24 DR. BASU: Yes. I don't think there is
25 any conflict about that.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER POWERS: At these times out here,
2 your priority should be to protect that head flange.

3 DR. BASU: So, again, I can't make a
4 definitive conclusion on this, and I am not sure
5 whether it is really warranted.

6 We looked at the spray flow rate just like
7 EPRI did, spray flow rate sensitivity. Our base case
8 was 300-GPM spray. We also looked at 100 GPM, 500,
9 1,000 GPM. These are still, by and large, very low
10 spray flow rates relative to the design flow rates
11 that you can achieve in those drywell sprays.

12 So, again, I don't really expect to see a
13 whole lot of sensitivity here. The one thing that
14 kind of jumps out maybe is that can you go to very low
15 spray flow rates, such as 100 GPM, kind of sprinkling,
16 dripping kind of thing; you do get, order-of-
17 magnitude-wise, you get about almost an order of
18 magnitude higher.

19 MEMBER POWERS: It depends a lot on what
20 nozzle you have.

21 DR. BASU: Absolutely. Again, yes.

22 MEMBER POWERS: I mean, I presume these
23 calculations were all done with the same kind of
24 nozzle.

25 MR. LEE: The same, I think for the low-

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 flow rate here, it is that the containment cannot
2 depressurize at basically head flange. That is why
3 you have this lost cesium release.

4 MEMBER POWERS: Yes, I mean, there is one
5 kind of nozzle you get down to 100 GPM and it won't
6 ignite. That is, it will just drip out like a --

7 MEMBER BLEY: It is not a spray.

8 MEMBER POWERS: It is not a spray.

9 DR. BASU: Yes. Well, you know, design-
10 wise --

11 MEMBER POWERS: It makes those 3-
12 centimeter droplets.

13 (Laughter.)

14 DR. BASU: No, no. Of course, in the
15 MELCOR sprays you realize that we didn't look into the
16 design of spray headers and all that. We basically
17 said we are going to get 100 GPM or 300 GPM or 500
18 GPM.

19 But, for me, what is more interesting to
20 look at is, when you go from 300 to 500 to 1,000, you
21 are not really seeing a whole lot of difference in
22 terms of release fraction or sensitivity of spray flow
23 rate to release fractions. Now we didn't, obviously,
24 go to 5,000 GPM or 10,000 GPM.

25 (Laughter.)

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER POWERS: It is kind of impressive
2 when you do.

3 MEMBER ARMIJO: Does your model change the
4 size of the droplets depending on the spray flow rate?

5 DR. BASU: Well, we didn't do any droplet
6 sensitivity. We didn't. Now, when you operate a
7 spray with different flow rates, I suspect your
8 droplet size distribution is going to change.

9 MEMBER ARMIJO: Yes.

10 DR. BASU: And that is captured in
11 whatever the spray model that we have in MELCOR. I
12 didn't do any particular sensitivity with the droplet
13 size.

14 MEMBER POWERS: What you would see is,
15 with one kind of nozzle that is often used in the MARK
16 I's, it changes fairly dramatically with flow rate.
17 In another kind of nozzle that is also used very
18 frequently, and I think it has become dominant -- but,
19 I mean, it has been 20 years since I looked at this --
20 it is relative insensitive. There is no intention to
21 do this. I mean, it is just the way it turned out to
22 be.

23 It is all in that region, which is pretty
24 good for our souls. And so, it gets a bit coarser as
25 you drop down in pressure drop, which is the same as

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 changing the flow, the GPM downwards, but it is not
2 very much for one kind of nozzle. And it is pretty
3 significant for another kind of nozzle. So, it just
4 depends on what nozzle you have.

5 DR. BASU: And I wouldn't doubt that now.
6 What I would be curious, though, that if I take these
7 different nozzle designs and just use the very low-
8 flow regime, whether the difference would be that
9 pronounced or not. I mean, I can see in the high GPM
10 that --

11 MEMBER POWERS: The sprays are just
12 wonderful. If you don't like what you have got, go an
13 hour longer.

14 DR. BASU: Oh, yes.

15 MEMBER POWERS: It is a nice and reverse
16 phenomena. So, if you don't like what you have got at
17 one point, just go a little while longer and you will
18 be even cleaner, you know.

19 DR. BASU: Okay. So, that is the flow-
20 rate sensitivity. We did RCIC duration, as I
21 mentioned, 4-hour, 8-hour, 16 hours. And basically,
22 the visible difference you see is basically delaying
23 core uncover, as it should be with the RCIC operation.
24 Of course, there are some nominal changes in the
25 accident progression, et cetera, but the real big

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 change is the delay of core uncovering with RCIC
2 duration.

3 Okay. So, I think this is the one where
4 our results simply defer on the EPRI results. What we
5 are seeing is the event cycling. The two cases that
6 I talk in here, Case 4, which is vent cycling without
7 any spray action, by the way, and then what was
8 denoted here as Case 18 events, cycle venting. That
9 is the 8-hour drywell spray and vent cycle.

10 And then, there are other cases that I
11 plotted. What, again, sort of jumps out is that the
12 vent cycling is giving you sort of larger release
13 fractions than venting once and keeping the vent open.
14 Now I have my own explanation that may or may not be
15 the right explanation, but I will offer that for your
16 deliberation today.

17 I think with vent cycling what is
18 happening is, when you are closing the vent, you are
19 still generating fission product that is still in the
20 system. At the same time, you are basically raising
21 the drywell pressure with the vent closed. So, when
22 you open it next time, you are actually driving that
23 fission product that is accumulated in the system
24 already to the vent pipes and out in the environment.

25 So, I don't see any particular reason why

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 vent cycling would necessarily give you a lower
2 release, unless there is settling in the system
3 deposition played out, and you are not then
4 revaporizing and resuspending those fission products
5 in the system. So, that is my kind of very simplistic
6 way of looking at vent cycling not being any more
7 beneficial than venting once and keeping it open.

8 We are looking into these differences,
9 though, further. I would say that this would be
10 another IOU that we will come back and see whether we
11 come to any different conclusion or different
12 explanation of this difference in what we are seeing
13 versus what EPRI --

14 MEMBER REMPE: So, Case 4 is really a Case
15 3 with cycling? Is that true?

16 DR. BASU: That's true.

17 MEMBER REMPE: And Case 3 is one where you
18 have a lot of core-concrete interaction occurring?

19 DR. BASU: So it is in Case 4, remember.

20 MEMBER REMPE: That is true. So, you have
21 cycled when you have had a lot of core-concrete
22 interaction occurring in this case?

23 DR. BASU: Yes, that is correct.

24 MEMBER REMPE: Can you explain to me,
25 also, what Case 18 is? Is it like Case 15 and/or 14?

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 DR. BASU: Case 18 is drywell spray
2 actuated at eight hours. So, it is like Case 14
3 except that you still have a 24-hour drywell actuation
4 time; you have actually eight hours.

5 MEMBER REMPE: Okay.

6 DR. BASU: So, this is one difference that
7 we kind of noted.

8 MEMBER ARMIJO: Isn't it a big difference
9 between the EPRI results and your results?

10 DR. BASU: It is a difference. Now, in
11 the overall scheme of things, when you look at, I
12 mean, if you are looking at a target decontamination,
13 and if your result of cycle venting and other actions
14 you are saying that I have reached that target
15 decontamination, and I am okay with it, so there I
16 guess is what we are seeing, what EPRI has presented
17 to you. We will have to come to some understanding of
18 what is the real story.

19 MEMBER BLEY: Did you follow cycling
20 strategies akin to what EPRI did? Or what did you do
21 when you did vent cycling?

22 DR. BASU: Okay. The cycling strategies,
23 basically, the vent opens at 60 psig and closes at 45
24 psig.

25 MR. LEE: And you let the code calculate

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 it.

2 MEMBER BLEY: Okay. So, it is similar to
3 what they did, if not at the same pressure point?

4 DR. BASU: Very similar, but the core --

5 MEMBER BLEY: But you get more out?

6 MR. LEE: That is what the MELCOR
7 calculating is.

8 DR. BASU: We are getting more out, that
9 is correct.

10 MEMBER BLEY: Now you don't have, Case 18,
11 you don't have the case up here which is exactly like
12 that but without vent cycling, right?

13 DR. BASU: No. We don't have it in this
14 plot.

15 MEMBER BLEY: So, this picture isn't -- I
16 mean, we have 3 and 4.

17 DR. BASU: So, if you look at 3 and 4, for
18 example, in the case of 4, you are getting
19 substantially more.

20 MEMBER BLEY: Do you know why that is
21 happening?

22 MEMBER REMPE: But isn't it, if you get --

23 DR. BASU: Well, I offered my explanation
24 of why it is happening, but --

25 MEMBER BLEY: I didn't quite follow it.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER REMPE: But if you picked a case
2 like Case 2 that didn't have a lot of ex-vessel core-
3 concrete interaction occurring, you might not see such
4 a dramatic increase with the cycle. I am kind of
5 wondering if you didn't pick a case that you have
6 applied it to that is giving you a higher release.

7 DR. BASU: Even Case 2? Case 2 would
8 be --

9 MEMBER REMPE: Yes, if you did Case 2,
10 where there is less cesium release, because you didn't
11 have earlier vessel release where you had a lot of
12 core-concrete interaction occurring -- so, you have
13 invoked cycle venting in a case where you can make
14 your results a bit worse.

15 DR. BASU: Yes. No.

16 MEMBER REMPE: I don't know if that was
17 the intention or not.

18 DR. BASU: No, I see your point. But if
19 we take Case 2, we would not be comparing passive
20 venting versus active venting. We would be comparing
21 no venting versus cycle venting or --

22 MEMBER REMPE: Right, yes.

23 DR. BASU: -- no venting versus --

24 MEMBER REMPE: But, of course, the
25 relocation of the ex-vessel, the earlier failure -- I

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 think we need to really compare sequences that are
2 similar, is what I am trying to get to.

3 DR. BASU: So, one sequence that would be
4 similar -- and this is going back to answering Dennis'
5 question -- is, if we run Case 18 with passive and
6 then compare.

7 I don't think we did exactly that, but a
8 similar one we did. When we compare again, the cycle
9 venting seems to be releasing more. But we will go
10 back and compare that.

11 MR. LEE: So, we do plan to explore that
12 with EPRI sometime next week, look into exactly what
13 they did versus what we did.

14 DR. BASU: I think that was really the
15 high point of disagreement.

16 (Laughter.)

17 MEMBER ARMIJO: But it just says, if you
18 vent once and leave it open, that is your best case?
19 That is what I got out of it, Case 3. You just open
20 the vent and I guess leave it open.

21 DR. BASU: That seems to be giving you
22 more manageable --

23 MEMBER ARMIJO: But that is a minimum
24 release.

25 DR. BASU: Well, no, but realize Case 3,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 that, of course, assumes that you are not going to
2 take any other mitigative action. Case 3 is no spray
3 action. It is venting only. And that will lead to
4 the liner failure. Yes. Eventually, it will lead to
5 liner failure. So, you are going to sort of release
6 a large quantity at that point anyway.

7 And so is Case 4. Case 4 has no spray
8 action, no water. And you can see, from the
9 signature, you can see that after about 38 hours or so
10 it is gradually going up, and that is an indication of
11 liner failure and larger release. I mean, if you are
12 doing some sort of mitigative action, you will not do
13 that most likely.

14 Okay. So, the next one, I am just
15 showing, again, the difference between -- now, if you
16 take Case 4, which is no spray action, of course,
17 cycle venting, as opposed to, then, you put some spray
18 action, you do see the beneficial effect of a
19 combination of spray and venting in that case. So,
20 that trend is in the right direction. And that trend
21 is also in the right direction, as you pointed out.

22 But, again, what we come back to is
23 between passive venting and active venting we really
24 didn't see a particular benefit.

25 MEMBER ARMIJO: You don't see a benefit,

1 yes.

2 DR. BASU: Let me come back to the
3 decontamination issue later on, if we have time.

4 But these are the insights from the MELCOR
5 calculations. And again, if you go through these, you
6 are not going to find anything that is really
7 significantly different from what EPRI noted. The
8 presence of water in the drywell is beneficial in
9 preventing liner failure. Spraying action will
10 actually be beneficial in controlling the drywell
11 pressure. But none of these alone will get you there.
12 So, you need to go to a combination of these actions,
13 the venting, core spray venting, with drywell spray,
14 and active venting versus passive venting. That gets
15 you there. Of course, again, our calculations do not
16 show vent cycling to be more effective than passive
17 venting or once-open venting.

18 CONSULTANT BARTON: I thought you said
19 venting alone would not prevent vessel failure, liner
20 failure, but here you say venting prevents
21 overpressurization failure. But one of your colored
22 charts showed that, if you only vent, you are going to
23 get liner failure.

24 DR. BASU: If you do not have any water on
25 the drywell slope by any means, spray or flooding or

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 anything, that leads to liner failure, even if you
2 have venting. It leads to liner failure.

3 Now venting by itself does prevent the
4 overpressurization failure because that is what you
5 are achieving by venting, where you don't want to
6 reach that level of pressure that will fail. But it
7 does not prevent failure automatically unless you have
8 some deterrent to melt spreading. And that deterrent
9 is your presence of water in some fashion.

10 So, venting through the wetwell.
11 Incidentally, all the cases that we presented are
12 through wetwell venting. We did run a couple of
13 drywell venting cases. As you can imagine, drywell
14 venting without any scrubbing action is going to lead
15 to much larger release fractions unless you have some
16 sort of filter downstream of the drywell vent.

17 So, venting through wetwell provides an
18 opportunity for scrubbing in the suppression pool. It
19 can be appreciable. In the cases that we ran -- and
20 I am going to back to this slide here -- in the
21 venting cases we ran, and this is only a subset of
22 many of the cases, we see basically a decontamination
23 factor in the suppression pool in the range of 100 to
24 300. And that is in the ballpark of what you had seen
25 in the EPRI presentation as well. So, there is no

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 surprise there.

2 So, pool scrubbing. I just said that
3 venting through the drywell does not have the pool
4 scrubbing benefits. So, the release is significantly
5 higher. The spray can provide, obviously, some
6 scrubbing effect, depending on the spray flow rate and
7 other factors that can be nominal, and you are 2 to
8 10.

9 So, let me see. I want to say external
10 filtration effect. In case you haven't already
11 concluded this or arrived at the understanding, MELCOR
12 does not have a model per se for external filter. So,
13 we just specify a DF for the small filter and we apply
14 that DF to reduce the release by that much amount.
15 So, if the DF is two, for example, whatever we get as
16 a release fraction from the MELCOR calculation, it
17 gets reduced further by 50 percent. If it is a DF 10,
18 it gets reduced by 90 percent, and so on and so forth.

19 So, it does have the capability of
20 providing, obviously, additional fission product
21 attenuation that you already get from the pool
22 scrubbing or some other form of scrubbing. So, in
23 that sense, it does have a direct influence on the
24 amount of fission product released to the environment
25 and consequent health effects and land contamination.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 Stay tuned for that in the next meeting.

2 I will just stop there in terms of that
3 particular item.

4 MEMBER ARMIJO: How will you pick the
5 decontamination factor for the filter? You know, what
6 number were you --

7 MR. LEE: Basically, a certain filter has
8 a DF factor of aerosol 1,000 scrubbing. So, we apply
9 that to the aerosol. We apply certain DF factors to
10 scrubbing iodine, and so forth.

11 MEMBER ARMIJO: Based on the test results
12 on that filter?

13 MR. LEE: Based on whatever the design is,
14 because it is a MACCS calculation.

15 MEMBER ARMIJO: And the filters, are they
16 designed to handle certain size of aerosols
17 differently?

18 MR. LEE: That is the thing you will have
19 more discussion coming after us.

20 (Laughter.)

21 MEMBER ARMIJO: Okay.

22 MR. LEE: A range of everything. AREVA
23 filter is different. A sand filter is different. The
24 Westinghouse filters are different. So, those filters
25 are all different.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 DR. BASU: So, if you look at the third
2 bullet I have on this slide, it doesn't give you a
3 number. It says, "Traditional filter technology".
4 The ones that we are more used to in the past have
5 very modest DF. Particularly if you had already
6 scrubbed your fission products once through either
7 pool or through some other means, you alter the size
8 distribution of that fission product. So, the net
9 effect of that small filter, traditional filter, is
10 less than what it would have been if you were to
11 actually filter the original size distribution.

12 Now you are going to hear about the
13 filtration technology in the next presentation that
14 appears to be more promising.

15 MR. LEE: For example, in application, you
16 see that the torus wetwell has a factor of 100 to 300.
17 So, if I am going to additional calculation on the
18 filtration from the pool, the venting part from the
19 wetwell, we consulted with Dana and we said apply a
20 factor of 2 to 10. Based on traditional filter, we
21 know that it cannot screen out that very small
22 fraction that was left. But if there is some other
23 filter, say, that it can do better, then we can apply
24 1,000 or 10,000, whatever you say.

25 MEMBER ARMIJO: Okay.

1 MR. LEE: And then, we can calculate a
2 consequence on our effects, land contamination,
3 anything you like.

4 MEMBER POWERS: The original filter they
5 were looking at was basically just another suppression
6 pool.

7 DR. BASU: Yes.

8 MEMBER POWERS: So, I just looked at what
9 we could have done on suppression pool effectiveness
10 as a function of depth. I looked at going from 3
11 meters to 5 meters and said, okay, if I put an extra
12 2 meters on, how much additional decontamination do I
13 get, because now you are decontaminating an aerosol
14 that has already been heavily decontaminated. And I
15 came up, well, it depends a lot on what the
16 temperature of the water is and what your bubble size
17 is, and things like that. So, somewhere between a
18 factor of two and ten.

19 Now they are talking about things like
20 water-injected Venturis and stuff like that. Well, we
21 have never analyzed those. Quite frankly, you don't
22 really analyze these things; you correlate
23 experimental data, is what you actually do. I mean,
24 we decorate it with a lot of fancy things on aerosol
25 physics, but, in truth, what we are doing is

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 correlating a bunch of experimental data, yes.

2 MR. LEE: Because, basically, the designer
3 will test out if they can put aerosol of this size in
4 and see what comes out. That is what the filter is.
5 Then, the operation ranges, they tell it what that is.

6 MEMBER POWERS: The thing you have to
7 watch is these people that are pushing these things
8 will come in and say, "Well, we get a DF of 10,000."
9 If I put bowling balls through it, I get a DF of a
10 billion.

11 (Laughter.)

12 You have got to find out what it does to
13 each different size bin and then look at the size bins
14 that you have coming into it.

15 MEMBER ARMIJO: Sure, because it is being
16 pretreated.

17 MEMBER POWERS: Well, yes, I mean, it just
18 depends on which one. There are lots and lots of
19 subtleties to these sorts of things that you have to
20 be careful about.

21 The one I really caution about is anytime
22 we are talking about DFs that get up into what I call
23 the heroic range, which is anything over 100, now you
24 get dominated by leak rates out of the system. The
25 idea that you are going to go through an accident,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 like the MARK I BWR has a design basis grade of a half
2 of percent per day. Now the idea that leak rate is
3 going to go down in a severe accident is a little
4 implausible to me.

5 So, anytime somebody comes in and says,
6 "Well, I got a DF of 10,000," I mean, somehow they run
7 and seal the leaks in this system. So, you have to be
8 very careful about these because these are heroic
9 kinds of decontaminations people are talking about.
10 I mean, when they put up they are a 10th of a percent
11 or they are a cesium release fraction, you are talking
12 about decontaminations that are hard to get in the
13 laboratory. Especially, iodine is particularly
14 obnoxious, but even cesium, it is very difficult to
15 get those kinds of decontaminations, even in the
16 laboratory.

17 CHAIRMAN SCHULTZ: It is hard not to
18 presume or interpret that they are overestimated in
19 terms of the capabilities --

20 MEMBER POWERS: Yes.

21 CHAIRMAN SCHULTZ: -- what has happened
22 before.

23 MEMBER POWERS: Yes, I would say that.
24 And you have to just be very careful with these
25 things, not to think that you have sealed everything

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 up.

2 Of course, the other things that the guys
3 who do accident analysis will tell you is accidents
4 don't go in a nice way that they are lined out in the
5 computer codes. I mean, none of them ever go that way
6 when we have checked them in reality. They are all
7 kind of funny in their own respects, and there are
8 lots of thing that you can't anticipate. So, you want
9 to be cautious about things.

10 And finally, the absolute truth is that
11 the accuracy with which things get plotted belies the
12 inherent uncertainty in the physical models that we
13 have. Any one investigation tends to be very highly
14 precise, but when you compare two investigations using
15 different techniques together, you come away not quite
16 so confident in your ability to calculate those.

17 MR. LEE: So, are you saying, Dana, that
18 the hydrogen predictions that we calculated, that if
19 the trends look strange, they really don't concern
20 you? Is that what you are saying?

21 (Laughter.)

22 MEMBER POWERS: Well, trends I tend to
23 believe. Absolute values, with a jaundiced eye.

24 MEMBER SHACK: There does seem to be a
25 discrepancy between the decontamination factors you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 have for pools, which is 100 to 300, and the EPRI
2 value of 10.

3 MR. LEE: But I can tell you this is the
4 code calculation. Basically, we see how much material
5 gets input into the 1 mL part and you see what came
6 out, and we just take the ratio of those two. And you
7 can plot it over time for the entire wetwell
8 calculations. And that pool model is from Dr. Powers.

9 (Laughter.)

10 MEMBER POWERS: If it is out of MELCOR,
11 no, it is not. It is Spark 90.

12 DR. BASU: But, in fairness to Dr. Powers,
13 though, I mean, I am looking at the EPRI chart. I am
14 not sure if I am --

15 MEMBER SHACK: I am looking at the second
16 column, spray, flood, or RHV, 10. By yours, I would
17 guess it would be 100 to 300.

18 DR. BASU: You know, I would like to ask
19 EPRI whether --

20 MEMBER SHACK: EPRI will, no doubt, tell
21 me why I am wrong.

22 DR. BASU: No, no.

23 MR. WACHOWIAK: This is Rick Wachowiak
24 from EPRI.

25 The reason that you are seeing a

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 difference there is you are reading our plot a little
2 bit wrong.

3 (Laughter.)

4 What that 10 is, is that we are
5 recognizing that if we go to any of those cases, we
6 have a different containment failure mode that comes
7 into play. I am not sure that their cases, since they
8 are running the pre-core-melt part for so long, and
9 then the post-core-melt part shorter, I am not sure
10 that they are picking up some of the same secondary
11 failures that we did. So, that is something that we
12 will have to talk about with them next week and
13 reconcile this.

14 But there is a difference in the timing
15 that we have here. Our value of 10 for that is
16 picking up secondary containment failure modes.

17 MEMBER POWERS: If he is running on spray,
18 he is using bowling balls for his spray droplets.

19 DR. BASU: I think that is fair in terms
20 of the timing of the duration, but also in our case
21 most of that 100 and 300 comes from combined action,
22 not just a single action. There are a couple of cases
23 where you have single action, so you have low DF
24 there. But other cases you have both venting and
25 spray of some sort.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 CHAIRMAN SCHULTZ: Are there other
2 questions from the Committee to this presentation?

3 MEMBER BLEY: Steve, are we going to go
4 around the table here?

5 CHAIRMAN SCHULTZ: Not right now. We have
6 a public presentation associated with the filter
7 technology.

8 MEMBER BLEY: Let me say something here
9 because I would really be interested when we see
10 EPRI's report. These things didn't align very well
11 for me, and it might be my knowledge as much as any
12 other problem.

13 When I look at your results, if I go back
14 to tables 8 and 9, which you showed earlier, and if I
15 look at the various graphs you have put up, I can't
16 draw the kind of conclusions you have drawn about, if
17 you do multiple things, you get a lot better effect
18 because everywhere I see things going in different
19 directions.

20 What I am thinking is, if I could see the
21 details behind the EPRI's, I would probably see
22 individual scenarios that have this wide variability.
23 Somehow they have been accumulated into cases -- I'm
24 not sure exactly how because we haven't seen that --
25 that let you see clear results.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 From the MELCOR stuff, I haven't seen a
2 way to put it together to get some of the clear
3 results you had on some of your bullets at the end.
4 So, I think it is probably due to details of
5 particular scenarios that are getting run. I know you
6 are not finished with everything, so you haven't had
7 a chance to organize this in a way we can see things
8 clearly. But, right now, I see things going in very
9 different directions. If you add a vent, it gets
10 worse. If you add one here, it gets better. You add
11 a spray, something else happens. And it is just not
12 a clear picture as yet. I am sure we will get there,
13 and I am looking for that, but for me it is a little
14 vague. I wanted to get something on this in before we
15 go on.

16 CHAIRMAN SCHULTZ: I think it is an
17 important comment. I had the same reaction. But in
18 terms of interpretation of results, my impression was
19 we are getting ahead of ourselves because --

20 MEMBER BLEY: Yes.

21 CHAIRMAN SCHULTZ: -- we don't quite
22 understand the individual cases yet. In order to
23 derive those results/interpretations, we have to be
24 able to, first, understand them, and then understand
25 how we are going to combine them and, then, interpret

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 what the benefit of the filtered vents would be.

2 DR. BASU: And your point is well-taken.
3 I think a couple of IOUs that I noted, when we come
4 back, that ought to help clear up the confusion.

5 MEMBER BLEY: That would be nice.

6 MR. LEE: But we have been doing this
7 analysis for months. We started with cases and we
8 looked at it, and we said let's vary this. So, we
9 have a long time to study it. I am sure in this
10 presentation we cannot go into all those details. So,
11 we did write up all this analysis which will be
12 appended to the SECY paper. And that document
13 probably will be available to the Committee members at
14 a certain time when the whole review is done
15 internally, before we send it to ACRS. And I am sure
16 we can have more detailed discussion.

17 MEMBER ARMIJO: But there has got to be
18 some set of scenarios that you base your decision on.

19 MR. LEE: The analysis we will base on
20 certain scenarios, but we are presenting you a lot of
21 cases. Okay? So, when you come to recognize this, it
22 is not necessary to pick everything.

23 MEMBER ARMIJO: Sure.

24 MR. LEE: Because you start your base
25 case; I want to look at a few things. What does it

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 change? So, that will be much more clear. Right now,
2 we are presenting you more information that, because
3 of the way that we have the opportunity to look at it
4 more than you do, so we came to those type of
5 conclusions that we came to.

6 MR. NOTAFRANCESCO: If I could add, the
7 takeaway you should have here, there are two things.
8 You need reliable sprays and reliable venting. And
9 the other stuff is in the noise.

10 MEMBER STETKAR: Allen, something you just
11 said is something that is fundamentally troubling me.
12 What is reliable venting? Because my takeaway from
13 what I saw from the staff is reliable venting is a
14 passive ruptured disc. And my takeaway from what I
15 heard from EPRI is reliable venting is a controlled,
16 very well-controlled, vent system, which could be
17 automatic or manual or something like that. That is
18 a fundamentally-different notion of what reliable
19 venting ought to be. Or am I misinterpreting that
20 difference?

21 MR. NOTAFRANCESCO: Well, PRA folks will
22 say this manual cycling --

23 MEMBER STETKAR: No, no, no. Give me a
24 perfectly-operable, active vent. Let me worry about
25 what reliable means in terms of it being able to open

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 and close when it ought to open and close a hundred
2 million times.

3 From my interpretation of what I saw here,
4 it is that it is better to have a ruptured disc,
5 period, that shall never reclose, that only opens.

6 MR. DENNIG: No, that is not the
7 intention.

8 This is Bob Dennig.

9 MEMBER STETKAR: Okay. Then, I am getting
10 something fundamentally, a different message.

11 MR. DENNIG: No, that is not the
12 intention. The systems that are normally installed or
13 have been installed have both an active and a passive
14 path. They can be done both ways. You can bypass the
15 pressure disc if you want to go sooner or, if you
16 can't operate the valves, it will go by itself. So,
17 that is kind of like the ideal combination.

18 And we are talking about kind of subsets
19 of that. But the idea is not that it will just open
20 and you can't close it. I think in the analysis they
21 were doing, it is the timing of the opening. And
22 again, there is a human reliability factor in terms of
23 the active operator opening the valve, and so on and
24 so forth, and those sorts of issues.

25 MEMBER STETKAR: Okay.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MR. DENNIG: So, yes, you are seeing just
2 pieces of an entire analysis, and it certainly needs
3 to be laid out in more detail, yes.

4 MR. LEE: So, I think some of this
5 hydrogen production may be also due to a RCIC
6 operation because we have different hours, 8 hours, 16
7 hours, and longer. Those have big effects on the core
8 melt progressions.

9 MR. NOTAFRANCESCO: See, our base case is
10 16 hours, and we are running out only 48 hours, not
11 72, where they are doing 4 hours and 72 hours. So, we
12 may be losing some of the --

13 MR. LEE: All we captured in the table is
14 a total hydrogen generation of this much. Okay. If
15 you go into the sequence, if you look at the different
16 signatures and how the water comes in, maybe there
17 will be of the water more hydrogen. We have to go and
18 look at those details. So, those details are in
19 there, but we cannot factor this out onto a table
20 because it says too much.

21 MR. WACHOWIAK: This is Rick Wachowiak
22 from EPRI.

23 Can you move back to slide No. 20? And
24 maybe we can point one thing out that maybe is getting
25 some people that see an anomaly here. On slide 20,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 the Case 21 and Case 18 with cycled venting are
2 similar cases. Just one has a passive vent, in your
3 vernacular, and one has the active vent.

4 Notice at the end, around 47 hours, Case
5 21 is starting to take off just like the other one.
6 I don't know that, with what we have here in these
7 timeframes shows you that there really is a difference
8 between those two cases. So, at least that anomaly
9 that is causing some confusion may be that it is
10 because the case ended right there and didn't go to
11 completion.

12 So, it is not as confusing to me as it
13 maybe is to others, but, then, again, we have looked
14 at some of the same kinds of anomalies before, and you
15 are right, we did find anomalies and we went and
16 looked at them and tried to consolidate them into
17 strategies that work. So, you see the ones that
18 worked in our presentation.

19 (Laughter.)

20 And that is the case. That is why we
21 tried to show that it was robust and what we were
22 doing wasn't skewing the results.

23 But we were trying to find -- we had
24 anomalies when we did our cases and we investigated
25 them, figured out how to adjust the strategy, so that

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 it doesn't have that sort of anomaly. So, I think it
2 is all in the matter of timing, and we will be able to
3 work out these differences. They are not as
4 surprising to me as they may be to somebody who hasn't
5 looked at another --

6 CHAIRMAN SCHULTZ: Thank you, Rick. That
7 is helpful.

8 DR. BASU: Okay. So, we are done.

9 CHAIRMAN SCHULTZ: We will look forward to
10 the resolution that you might be able to develop in
11 September.

12 Thank you very much for the presentation.
13 We really appreciate it.

14 What has been handed out to you is the
15 non-proprietary presentation associated with the
16 filtered venting system to be made by IMI. There is
17 a lot of information here. Again, a preview is that,
18 as you heard earlier, that there was a discussion with
19 the staff that took all day yesterday. We have an
20 hour on our schedule to examine what was presented
21 there.

22 I believe that most all of the slides, if
23 not all of the slides that we presented yesterday, are
24 in the discussion package here. So, I don't believe
25 we are going to hear on each slide, but we shall see.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 But we are going to move into this
2 presentation right now, so that we can finish the
3 presentation that is non-proprietary. Then, we will
4 have comments and a short break, where we move the
5 room into an opportunity for proprietary information.

6 Denis, are you ready for the presentation?

7 MR. GROB: Yes.

8 CHAIRMAN SCHULTZ: Denis Grob is going to
9 lead this portion of the presentation.

10 MR. GROB: We just were talking -- first
11 of all, thank you to have this opportunity to
12 present --

13 CHAIRMAN SCHULTZ: Thank you.

14 MR. GROB: -- to this attendance.

15 We just saw that we might have a problem
16 in terms of time. I am going to start with a general
17 presentation about the filter of IMI. By the way,
18 there will be some differences. Sometimes it is IMI;
19 sometimes it looks like CCI. So, IMI is the mother
20 company of CCI. IMI is an English, a British company,
21 and IMI Nuclear is the nuclear part of it. CCI is a
22 company in Switzerland which is providing this filter.

23 Okay. So, I will try to be very fast to
24 let the non-public part be enough. Because starting
25 from the discussion we had with NRC yesterday, we

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 thought it would be good to show a study of
2 environment consequences, depending on future
3 decontamination efficiency. We think that this is a
4 contribution which is important in the context, and we
5 decided to introduce it in the last minute.

6 So, today I would like to show you an
7 overview about a filter we present, how it works,
8 experimental database results, showing an example of
9 installed filter containment venting, show what we
10 need to make a sizing, and why choosing the IMI
11 filter, and some conclusions. Again, I will try to
12 skip things which I think are self-explanatory and so
13 do not need more comments.

14 So, the problem, you know, it is a core of
15 mixed air. You might require depressurization of the
16 containment. The solution, first generation of filter
17 containment venting system has been installed on
18 approximately 120 reactors worldwide. So, this 120 is
19 the sum of all installed filter containment venting
20 systems, 60 of them being alone in France with the
21 same type filter.

22 Now a second generation has been developed
23 with a unique featuring efficiency. We will show you
24 what unique is. And safety authorities and utilities
25 have expressed their interest to the proposed

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 technology.

2 Next. So, this is a cut of the filter
3 which shows the three filtration stage and the
4 incoming gas. You will see the red arrow going down
5 into the vessel. The gas will be distributed all over
6 the section of the filter via 100 to 200 impact
7 nozzle. The gas will then climb up through what we
8 called a mixing element, which its biggest role is to
9 have a zigzag trajectory to the gas bubble in order to
10 increase the mass transfer between the bubble and the
11 liquid.

12 We do have a recirculation zone which is
13 particularly important for the low-flow efficiency
14 decontamination. And then, we go up to the water
15 level. We have a certain room, a gas room, which is
16 there to accommodate for the water level variation
17 during the operating time. And finally, we do have a
18 separator which is only to filter out the droplets and
19 let them go back into the water level.

20 So, basically, we have the full fission
21 product in water only. This is a characteristic of
22 the filter we present today.

23 Next. A cut through the lower part of the
24 filter. You have here, again, the incoming pipe and
25 the distribution system, side arms, and the sparger.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 You see the riser. You see the mixing element and the
2 recirculation zone with the outer section.

3 Next one. This is a third-stage
4 separator. Again, we have a triple deflection of the
5 stream which has a target to concentrate the remaining
6 droplets which might be entrained, especially at high
7 flow, in the lower part of this pot you see, and then
8 it goes down via drainline to the main filter water.

9 Next.

10 MEMBER POWERS: What size of droplets do
11 you anticipate?

12 MR. GROB: Pardon me?

13 MEMBER POWERS: What size of droplets do
14 you anticipate?

15 MR. GUENTAY: We will go into the
16 technical part in the next presentation, in the closed
17 session.

18 MR. GROB: So, this is the description of
19 the three stages I just gave to you. Basically, what
20 is the difference between the first installed
21 generation and the second one, I marked it in red in
22 the middle column. It is the chemistry of the scrub
23 and fixed volatile iodine species. This is unique to
24 the second generation.

25 Next. So, how does it work, this

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 chemistry? What we need is to decompose all incoming
2 iodine sources into ions and to dilute it in water.
3 This is done, of course, with chemistry. The effect
4 is a very well-known way, and we do it with a coagent
5 on top of this, which will accelerate the
6 decomposition to ions, make it possible to bind or to
7 decompose even the most volatile sort of iodines.
8 This is a first step.

9 The second is the efficient retention.
10 So, what we do is we suppress the thermal and
11 radiolytic oxidation, called revolatilization of
12 iodine, by use of this coagent. This first and second
13 step are the real characteristics of this filter. One
14 can conclude that the combination of phos reduction
15 and retention of iodine -- we have a patent on this --
16 is a unique feature of the second generation.

17 MEMBER SKILLMAN: Where is a sodium
18 thiosulfate process being used right now?

19 MR. GROB: Pardon me?

20 MEMBER SKILLMAN: Where is this being used
21 right now?

22 MR. GROB: This process is not installed
23 right now. It is tested. It is tested in a full
24 scale, and it is on the way to be introduced in
25 Leibstadt, which is now thinking of introducing this

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 in 2013, a great existing one. As I said, the
2 difference is not hardware; the difference is
3 chemistry.

4 MEMBER SKILLMAN: I understand the
5 chemistry and I understand the thiosulfate. I got it.
6 Thanks.

7 MR. GROB: Yes. Okay.

8 So, here is the simplified schematic. As
9 you see on the lefthand side, the containment of a
10 pressure reactor, the isolation valve. We have a
11 possibility to bypass the second isolation valve with
12 a rupture disc which will open at the given pressure,
13 which will be below, of course, the ultimate pressure
14 of the containment.

15 As the gas will go into the filter, as
16 shown before, distributed over the whole section,
17 scrubbed, goes through the third stage, and up to the
18 stack via the clean gas line. We have additives which
19 are pushed into the main filter vessel by the incoming
20 gas. This is very simplified. We might have a water
21 conditioning for a long-term because what we say is
22 that iodine will be kept in the vessel during six
23 months or a year, if necessary. So, the fission
24 product will stay in the filter vessel.

25 MEMBER ARMIJO: Where are your additives?

1 MR. GROB: The additives are sodium
2 hydroxide to make it aqueous. It is thiosulfate and
3 it is aliquot.

4 MEMBER ARMIJO: And they are located where
5 when they initially -- are they already in the water
6 or not?

7 MR. GROB: The sodium hydroxide is already
8 in the water. The thiosulfate and the aliquot are in
9 separate tanks. That is pushed by the gas into the
10 filter when the pressure rises.

11 Next. Very shortly, about the experience
12 data program. This is a summary. CCI developed this
13 filter in the eighties. It was at that time SULZER.
14 The reason why SULZER started in this was they had a
15 big, large experience on concurrent scrubbers and
16 distillation columns.

17 This was in the eighties. Later, we
18 installed these filters on two ponds, and the
19 verification test, and this is the time when the Paul
20 Scherrer Institute came into the game, was asked to
21 make verification tests.

22 The Paul Scherrer Institute continues as
23 the research and development, especially on iodine
24 research from 2002 to 2008. So, a large part of the
25 results we are showing today rely on the later

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 development phase.

2 These are a couple of examples of the test
3 bench here. We have one. It is a full-scale, one
4 nozzle, full height; one nozzle test bench, one of the
5 first of SULZER's time.

6 Next. Here we are already at psi between
7 93 and 95 with an aerosol generator on the lefthand
8 side. It is the same used as the test here, as EPRI.
9 I also added a steam gap. And finally, on the
10 righthand side is the bench again.

11 Specific test machinery had to be
12 developed, such as the example on the lefthand side,
13 iodine special generation and heat system. In the
14 middle of the two pictures you would have the test
15 bench on the righthand side. You have the iodine
16 species online grab sampling measurement system. All
17 has to be developed especially for this iodine
18 program.

19 The psi was not very successful until
20 2002. And next slide, please. Finally, between 2002
21 and 2008, as iodine chemistry was mastered in aqueous
22 phase, with a result I described before, efficient
23 destruction of volatile iodine and efficient fixation.

24 Now over 1,000 tests were done with
25 different parameter variation to make sure that this

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 aliquot was really doing what it does in different
2 boundaries. I mentioned a couple of them.

3 One of the most interesting is the
4 influence of the irrigation on this chemistry. Next
5 slide. And you will see this has been tested. These
6 tests are unique. On the lefthand side, an NC2 beta
7 irradiation test. And again, you see how big the
8 quantities of liquid now are concerned. We do not
9 need to have it full-scale since it is a chemistry
10 experiment. So, a small size will do. On the
11 righthand side, again, the irradiation chamber.

12 CHAIRMAN SCHULTZ: Now here it sounds as
13 if you are describing that these were demonstration
14 tests? They weren't development tests for the
15 process, but these were demonstration tests in this
16 timeframe?

17 MR. GROB: This was not only
18 demonstration. This was really development and
19 demonstration.

20 CHAIRMAN SCHULTZ: It is? Okay. Both?

21 MR. GROB: Yes, both, yes, because they
22 were kind of mixed.

23 And this is, very shortly, the numbers.
24 These are the numbers of decontamination we can
25 guarantee. So, we are talking here about minimum

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 decontamination numbers, which are for aerosol 10,000
2 and 1,000 for elemental and organic iodines. So, very
3 high values in comparison to the first generation
4 requirements -- I am talking about Swiss requirements
5 here -- of 1,000, 100, and none for the organic
6 iodine.

7 So, one has to be very precise when
8 talking about such high numbers. First of all, they
9 are minimum, and you have to define in which
10 boundaries they are valid. So, we guarantee these
11 values, commercially guarantee these values, with a
12 flow rate variation of 1 to 10. We guarantee them
13 with multiple venting. We guarantee them in a post-
14 venting phase, which can be as long as one year, as I
15 told you.

16 We certainly have no clogging of any
17 hotspot and neither hotspot risk. All our fission
18 products are kept in water, and the decontamination
19 factors are valid with pH down to 3, with different
20 temperatures, including a boiling condition, and for
21 all possible particle size.

22 Next one. This is a test curve showing
23 the decontamination factor versus pressure ratio. And
24 qualitatively now, the decontamination share of each
25 of the filtration stages I just showed to you,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 starting with a mixing element, which is very good at
2 low flow, and impact nozzle being good at mid and high
3 flows, and the droplets, of course, which will be very
4 effective at high flows, keeping the droplets
5 entrained into the tank.

6 Next one. This is an interesting slide,
7 which we think should interest everybody, talking
8 about iodine filtration and revolatilization. We know
9 that iodine has a strong tendency to revolatilize.
10 This diagram shows the revolatilization up to 100
11 percent in function of a radioactive irradiation with
12 or without both additives. And we see we do not have
13 any revolatilization with aliquot and the chemistry.

14 Next one. Here, this is an interesting
15 slide which shows our view on our own generation and
16 our own generation 2 filter. So, there is no
17 competition in here. But, based on the newest R&D
18 consideration, we split it into short-term and long-
19 term. The difference is there are conservative and
20 best-estimate values. As I said before, 10,000 is the
21 value for aerosol we have on the generation 2,
22 1,000/1,000 for both iodines.

23 And you will see the big difference here
24 between the generation 1 and generation 2 is the long-
25 term. Long-term means we are losing the iodine again,

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 after having filtrated it due to revolatilization.
2 This is maybe what this table says. The short- and
3 long-term decontamination factor for the generation 2
4 are identical.

5 The next one. A nice example for an
6 installation in Beznau, a Westinghouse two-loop
7 pressure water reactor with a filter building, a
8 shielded control room. Everything was manual.
9 Actuation of valves must be manual. Again, this
10 resource already is imposed as a bursting disc. So,
11 in the extreme case, no operator intervention would
12 start operation. The bursting disc would start
13 putting the system into operation.

14 The next one. This is the installation of
15 this filter. In the control room this is all manual.

16 Next one. This is the example of
17 Leibstadt with two vessels this time. Two vessels
18 were made because we didn't have space enough to
19 install one. They had no special building necessary
20 because the surrounding building took care of the
21 shielding.

22 Next one is the transport of the vessel.

23 Next one. Here you have these incoming
24 lines with the two valves and the bursting disc and
25 the horizontal line you see is the manual actuation of

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 the valve.

2 Next one. This is a control room of
3 Beznau with the manual electric actuation of the
4 valves in red. And you see the instrumentation
5 measurement without electricity, mainly the level and
6 pressures.

7 Next one. These are the sizing we need to
8 size a filter. I do not want to comment too much.
9 This we need from the customer to be able to size a
10 system. Mainly, it is how much thermal power we have
11 to cope with, how much fission product, what is the
12 depressurization time, what is the decay heat. These
13 are the main sizes we need to start sizing.

14 Next one. This is the continuation of
15 this. You just can skip and take the next one.

16 Of course, we are comparing this with the
17 CCI database, and we are sizing the system
18 accordingly.

19 Next one. And then, this other
20 calculation which is done by CCI, which is basically
21 the sizing of the system.

22 Next one. Next one. So, this is a short
23 description of what is on the market today, what are
24 the different technologies. We see we have on the top
25 left, this is the system I just described. The top

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 right, we have the full dry system with metal fiber
2 and molecular sieve. The bottom left, the Venturi
3 nozzle, chemistry, and metal fiber. And bottom right,
4 the Venturi nozzle, chemistry, metal fiber, and in a
5 separate tank not shown here, the molecular sieve.
6 These are the systems which are proposed today on the
7 market.

8 And next one. We just made an analysis of
9 these systems. Of course, this is our view based on
10 public domain information. I don't think that I have
11 to go too much in detail. This here is self-
12 explanatory. I would propose to the skip the next
13 three slides and to go to the conclusions.

14 The conclusion is to the question why
15 choosing the IMI filter. I will summarize here. We
16 think that the Venturi nozzles have a narrow flow
17 range decontamination efficiency, and that allows the
18 transfer of the filtration function to the next
19 filtration stage. In other words, what you don't
20 filter in the Venturi, you will filter in the fine
21 mesh or the molecular sieve. This brings certain
22 practical problems Salih will describe.

23 The Venturi nozzle and dry filter
24 technology, fine mesh/molecular sieve, do not allow
25 for fast depressurization, which would mean, due to

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 flow limitation, they are very limited in this.

2 The metal fibers have a high clogging risk
3 with uncontrollable materials and liquid/solid
4 particle mixture. The molecular sieve needs
5 preheating and preconditioning. They are subject to
6 uncontrollable poisoning.

7 Dry-only filter technology, that is with
8 fine mesh or a molecular sieve, has to cope with the
9 total amount of fission product heat. In other words,
10 revaporization and filter damage is expected for this
11 solution.

12 And last, but not least, the ACE tests,
13 late eighties, from today, are not representative for
14 high aerosol load, as the tests were very short. They
15 are not representative for large flow range and
16 irrigation influence on filtration.

17 The revaporization and resuspension are
18 not addressed up to now. And I would jump to the next
19 slide. Yes, the revaporization is, of course,
20 concerning the cesium. Now we are leaving the pure
21 iodine field and revaporization of cesium is being
22 trapped into fine mesh or zeolite in this particular
23 case.

24 Next one. These are the reasons why we
25 would propose or the answer to why choosing the IMI

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 filter. We think the highest decontamination factor
2 for aerosol with a very wide operation flexibility.
3 In other words, fast depressurization and without
4 compromise on filtration. This is valid for the
5 smallest flow as well. We are talking about early
6 venting, and this will be connected to very small
7 flows.

8 So, the highest decontamination factor for
9 iodine by aliquot chemistry, we see that the issue of
10 revolatilization of iodine is solved under many
11 possible conditions. The revaporization of aerosol
12 and iodine issue is solved because we keep as the
13 fission product in the filter water, and for the same
14 reason, excludes a re-entrainment when multiple
15 venting cycles occur.

16 And finally, last but not least, we have
17 the best laboratory worldwide ready to answer the
18 specific utilities' requests for verification tests.

19 Okay. These are my conclusions. We think
20 we have now a second generation of filter containment
21 venting system with a unique feature efficient system.
22 The first time in the nuclear power industry we can
23 guarantee filtration of active aerosol and iodines.
24 The installed is approximately 120, mainly in Europe,
25 have efficiencies as a reactor worldwide, do not have

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 any filtering capability, despite the fact that
2 approximately half of the core damages might require
3 containment venting.

4 So, the nuclear safety authorities and
5 utilities may consider the installation of a second
6 generation filter containment venting.

7 I think we have it. We have a disclaimer,
8 self-explanatory. I would like to thank you for your
9 attention.

10 Was I fast?

11 (Laughter.)

12 CHAIRMAN SCHULTZ: Yes, you were very
13 fast. Very good.

14 (Applause.)

15 MEMBER ARMIJO: I had a couple of
16 questions.

17 CHAIRMAN SCHULTZ: Yes, I would like to
18 open the floor to questions now from the Committee.

19 MEMBER ARMIJO: First of all, the
20 difference between the first-generation-type system
21 and the second-generation, is that just the chemistry?
22 As far as the geometry and all of the things on, let's
23 say, your page 4?

24 MR. GROB: I can confirm it is just the
25 chemistry.

1 MEMBER ARMIJO: Just the chemistry, right.

2 And the other thing, in your development
3 test did you deal with the inlet bringing in a
4 combination of steam, hydrogen, nitrogen, a whole
5 witch's brew of things coming in?

6 MR. GUENTAY: Cold conditions, hot
7 conditions, low flow, high flow, lots of drop
8 generation, small drop generation, swell level due to
9 the gas or boiling.

10 MEMBER ARMIJO: Okay.

11 MR. GROB: Irradiation.

12 MR. GUENTAY: Irradiation, a separate
13 test.

14 MEMBER STETKAR: These are separate, yes.

15 MR. GUENTAY: But as long as the
16 concentrations are the same, then you should expect
17 the same behavior, whether it is a small --

18 MEMBER ARMIJO: And those variables didn't
19 affect your chemistry treatments?

20 MR. GUENTAY: No. No, because the
21 chemistry portion was done also hot conditions, you
22 know, cold conditions, all those, but on a small
23 scale, because we have to use activity and you cannot
24 use huge activity in big volumes. That is the reason.

25 MEMBER SKILLMAN: I would be curious about

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 the relationship between the molecular sieve, which is
2 zeolite, and the thiosulfate.

3 MR. GUENTAY: These are different things.
4 The thiosulfate is a reducing agent of any iodine
5 species, say molecular iodine or organic iodide. And
6 it works in water. Molecular sieve is an absorbent,
7 and the gas containing iodine species has to go
8 through the absorbent. And these are very small
9 spheres in which there are lots of holes. The iodine,
10 because it is gas, gets through and absorbed on the
11 surface.

12 Now there are hundreds of different
13 zeolite types, and the most common one that people
14 would like to use is the silver-coated zeolites
15 because silver has got a higher affinity to keep
16 iodine, so that it is an irreversible reaction. If
17 you do not have it done because you have, again, gas,
18 it can desorb and get out, right?

19 The other problem is zeolite also absorbs
20 krypton and xenon, also water vapors, and also some
21 other contaminants that might be at the same time
22 affecting the absorption properties.

23 One problem is, if you have hydrogen,
24 suppose you have silver iodine reaction which keeps
25 the iodine. You decompose silver iodine due to the

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 hydrogen, and then the iodine gets out in terms of HI,
2 a special formula of iodine.

3 The other problem is silver is a catalyst
4 for the hydrogen/oxygen reaction if you do have oxygen
5 in the system, which brings the temperature very up,
6 and the absorption capacity is gone.

7 And the other problem is this so-called
8 molecular seas. These are also steam or humidity is
9 being absorbed. Then, the higher the humidity level,
10 either you have steam condensation, which blocks the
11 surface and absorption capacity is also very down.
12 And the main problem is suppose nothing happens. You
13 have iodine and all the rest, you know, xenon and
14 krypton. You bring the temperatures, because of the
15 decay heat, if you have enough amount, you are keeping
16 about 500 kilograms of xenon and krypton. You can
17 assume how much heat that you are going to generate.
18 Whatever you absorb there will get out.

19 MEMBER POWERS: Isn't the problem with
20 zeolite that, under gamma radiation, the silicon
21 component of it just dies and you lose structure?

22 MR. GUENTAY: You would not find any
23 single information in the public domain of how
24 resistant is the silica solution and aluminum oxide
25 because there is a certain relation.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER POWERS: Yes.

2 MR. GUENTAY: Are against the irradiation.
3 I have not found anything, but I am not sure whether
4 these two are resistant to the irradiation. And there
5 is huge irradiation.

6 MEMBER POWERS: Yes, my recollection is
7 that three years ago somebody came back and said that,
8 at relatively-modest dose rates they were losing the
9 zeolite core structure, and it was because of the
10 sensitivity of the silicon --

11 MR. GUENTAY: To radiation.

12 MEMBER POWERS: -- to radiation. They
13 were getting a reduction down to the silicon monoxide,
14 essentially, and that was in the framework of the
15 zeolite. And they were losing the pour structure.

16 MR. GUENTAY: I believe you, but, quite
17 frankly, irradiation, the biggest effect is the
18 poisoning --

19 MEMBER POWERS: Obviously.

20 MR. GUENTAY: -- because you generate lots
21 of acids. There are nitrogen oxides, nitric acid,
22 hydrochloric acid, cable pyrolysis. These are deadly
23 things, kills the zeolite. And in order to avoid
24 them, you have to have water scrubbers with lots of
25 sodium hydroxide in it in order to remove. And in a

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 dry filter configuration, you don't have this
2 possibility.

3 In the best scrubber solution, you are not
4 going to control your pH above 910. Then, you have
5 again a problem because of the loss of acid fume
6 coming into the zeolite which will be killing it.

7 MEMBER SKILLMAN: What happened to the
8 water vapor that was coming in with the gas?

9 MR. GUENTAY: Okay. Now water vapors, you
10 know, there is huge information available in the late
11 sixties and seventies that they conducted. You have
12 to bring the temperature to about 140 to 150 Celsius,
13 and heat up around 16 hours long, in order to
14 passivate the system; plus, you have to have a little
15 bit of hydrogen, about 6 percent hydrogen, so that you
16 avoid reaction of the silvers. This is established
17 information.

18 Therefore, I don't know whether you will
19 be having 16 hours' time in a severe accident
20 environment to precondition this, but then it refers
21 to 16 hours' time to precondition in order to avoid
22 steam condensation.

23 What people do, or what they are planning,
24 they have to have a trickling system after the metal
25 fiber filters or Venturi scrubber system in order to

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 have a little bit of super-heating, so that by the
2 hope that you are not condensing the steam, but
3 spraying something that is very low heat content. You
4 just lose it. Then, you have steam condensation.
5 Therefore, it is a very key aspect of this type of
6 filtration media.

7 There are many things working against you,
8 and all this is not new. If you just open a
9 manufacturer's site on the internet, they will tell
10 you exactly what you should have and what you should
11 not have.

12 MEMBER SKILLMAN: I can tell you what
13 happened to TMI. With enough water in the zeolite,
14 there was radiolytic decomposition and you got
15 stoichiometric hydrogen and oxygen.

16 MR. GUENTAY: Exactly. If you have a high
17 amount of activity stored there -- this is also being
18 recognized in the cultures, you know, investigations,
19 that you have to also be careful.

20 MEMBER SKILLMAN: Let's go back to the
21 thiosulfate.

22 MR. GUENTAY: Yes.

23 MEMBER SKILLMAN: Why is the zeolite
24 immune from the thiosulfate?

25 MR. GUENTAY: Zeolite is an absorbent

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 media outside of the filtration elements. CCI filter,
2 IMI filter does not use any zeolite. This is being
3 used by two companies.

4 MEMBER SKILLMAN: I thought you said the
5 molecular sieve is in the base of the pressure vessel.

6 MR. GUENTAY: No, no, no. No, no, no, no,
7 no. The molecular sieve is a part of either dry
8 technology or scrubber technology. It is not used by
9 my filtration --

10 MEMBER SKILLMAN: It is not part of this
11 vessel?

12 MR. GUENTAY: No, no. No, no, no.

13 MEMBER SKILLMAN: All right. Thank you.

14 MR. GUENTAY: Only scrubbing. Only water
15 chemistry, water scrubbing, nothing else.

16 MEMBER SKILLMAN: Okay. Got it. Thank
17 you.

18 CHAIRMAN SCHULTZ: Other questions from
19 the Committee on this presentation?

20 (No response.)

21 Before we move to the proprietary session,
22 as I mentioned earlier, I would like to provide an
23 opportunity for the Committee to provide comments
24 based upon the discussions we have had this afternoon;
25 recognize that, as the staff has indicated, we do have

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 another meeting coming up in October. And some of the
2 elements that were presented today are preliminary and
3 will be discussed between the staff and industry
4 groups between now and the October presentation. But,
5 with that proviso, I would like to provide the
6 opportunity for anything that members would like to
7 put on the record today.

8 Dick?

9 MEMBER SKILLMAN: I do. In the
10 calculation results that we saw today, there were a
11 number of comparisons between with and without filter,
12 with and without spray. I struggled to understand
13 those pairings. And so, it would be helpful for me
14 for the next presentation to be able to read a
15 presentation that shows the pairings in like-for-like
16 comparison, so I really know what the difference is
17 between the two states.

18 I think one of the other members may have
19 mentioned that. But that would at least be valuable
20 for me, so I could really understand what the benefit
21 is.

22 CHAIRMAN SCHULTZ: I feel we have strong
23 agreement from other members of the Committee just
24 along those lines. So, I appreciate your bringing
25 that forward.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 MEMBER SKILLMAN: Thank you. Thank you.

2 CHAIRMAN SCHULTZ: Harold?

3 MEMBER RAY: No. I think, for the reasons
4 that you said, Steve, that is, we are going to hear
5 more and there is going to be more work done, I will
6 reserve any comments.

7 CHAIRMAN SCHULTZ: Dennis, further
8 comments?

9 MEMBER BLEY: Nothing additional.

10 CHAIRMAN SCHULTZ: Dana, further comments
11 at this time?

12 MEMBER POWERS: Well, I think would like
13 to just emphasize a couple of things. One is that in
14 many cases we are looking at fine details of the late
15 stage of core degradation accidents in boiling water
16 reactors and comparing among small changes in
17 response. Quite frankly, I lack confidence in the
18 ability of computer codes to finally resolve those
19 late stages because of a really thin database that we
20 have on how boiling water reactors degrade.

21 In the early stages of core degradation
22 in-vessel, you have some confidence because it is not
23 going to deviate very much from what you see for PWRs.
24 But, as you go to the more extensive degradation, and
25 especially the relocation phase, we have got no

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 experimental data. And so, things like when the
2 vessel fails or how much of the core is actually
3 deposited in the lower plenum, I lack confidence in
4 the ability of our codes to analyze those things.

5 How much of the material comes ex-vessel
6 and the subtleties that happen there, actually, there
7 is nothing subtle about it. It is a very dramatic
8 thing when it comes ex-vessel.

9 You know, there are initial conditions and
10 venting and things like that. I am not sure we are in
11 a position to make fine judgment. I think our trends
12 are very reasonably reliable. But to distinguish
13 between things like do I have valves open all the time
14 or closed all the time, and things like that, I am not
15 sure the codes are that reliable.

16 I think it is going to be a while before
17 we get into the Fukushima reactors and really
18 appreciate what is going on and can recalibrate those
19 codes to make those judgments with the confidence we
20 can for PWR accidents, where we do have a calibration
21 against a major accident and do have calibrations
22 against a large number of fairly-well-designed
23 experiments.

24 In that regard, I come back to say, gee,
25 hydrogen is a real problem for us. I think we are

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 going to learn lots of things from the reactor
2 accidents, like where the vulnerable areas are. As we
3 talk about filtration, I can call to the fact that,
4 when you are looking for decontaminations in excess of
5 100, maybe 30, you are really saying that the system
6 is intact, so that leak rates of less than 3 percent
7 don't exist.

8 And I think we are identifying lots of
9 ways in which it is possible to get leaks in the
10 system that will bypass either the ordinary filtration
11 systems that are there, that is, the suppression pool
12 and the sprays, or any engineered system that is added
13 on.

14 For instance, I have pointed to the
15 drywell head and its elastomeric seal up there, and I
16 have pointed to the Japanese work that shows that that
17 seal is relatively vulnerable to irradiation. I will
18 remind the Committee we pointed this out when
19 containment overpressure credit was being asked.
20 Quite frankly, the staff said, "Oh, well, that is a
21 beyond-design-basis consideration and we don't take
22 that into account." Well, I think we had better take
23 it into account because it looks like it is a
24 vulnerable area, either from degradation of the seal
25 material or just the elongation of bolts and stresses

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 on it when you go to high pressures.

2 And finally, I would just say that, again,
3 to my mind, the one area that we can absolutely say
4 that the Fukushima accident brought our attention to
5 things that are pertinent to our plants is hydrogen in
6 the reactor building. Regardless of how it got into
7 the reactor building in the particular accidents, we
8 have identified enough ways that it could get into the
9 reactor building, that we really need to think
10 seriously about should we mitigate that threat.
11 Because even under design-basis conditions, there is
12 safety-related equipment in the reactor building that
13 you do not want to fail.

14 And I say again that, had you asked me
15 prior to the Fukushima accident if there could have
16 been a hydrogen detonation based on hydrogen release
17 into the reactor building, I would have said, "No way.
18 It will just burn. That is the worst that can
19 possibly happen." Well, you can see how reliable my
20 estimates are. We clearly got detonation. So, don't
21 trust me on those issues.

22 (Laughter.)

23 And quite frankly, I don't understand why
24 we got detonations. It seems to me we ought to be
25 looking at that fairly aggressively.

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 CHAIRMAN SCHULTZ: Sam?

2 MEMBER ARMIJO: No, I don't have -- I
3 agree with the prior comments by Dana and the others.
4 I am still curious about the in-vessel hydrogen
5 production rates being so much different when you
6 vent, higher when you vent than when you don't vent,
7 but there may be a chemistry explanation that the
8 staff could explain that when they show their work.

9 The rest of the stuff, you know, there
10 were so many analyses, and I am sure the staff
11 understands them. But, again, we need some set of the
12 key scenarios that you would base a decision on that
13 says, hey, a filter on top of what we already have has
14 this magnitude of benefit. I would like to see that.

15 MEMBER POWERS: Again, I think the effect
16 of venting on metal/water reaction to produce hydrogen
17 is that, when you vent, you drop the pressure and you
18 create more steam that can react. Typically, in a
19 boiler there is so much zirconium present that you are
20 nearly always steam-starved in the reactions.

21 MEMBER ARMIJO: Yes, yes. It could be
22 that.

23 MEMBER POWERS: Venting, if the water
24 level gets below the level of the core plate, you get
25 almost no heat flux to it. And so, the only way you

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 can generate steam is drop the pressure and boil that
2 water up.

3 CHAIRMAN SCHULTZ: John, nothing else?

4 MEMBER STETKAR: No.

5 CHAIRMAN SCHULTZ: Mike?

6 MEMBER RYAN: I would just like to thank
7 our international colleagues for a very thorough
8 briefing on a very large number of slides in a very
9 short period of time.

10 (Laughter.)

11 It was well-done. Thank you very much,
12 and I appreciate your taking the time to come to share
13 it with us.

14 MEMBER POWERS: He is not done yet.

15 (Laughter.)

16 Now he is going to tell us the secrets.

17 MEMBER SHACK: I find it interesting. I
18 think we will have a better understanding of how all
19 this can be integrated into the SAMGs, even if we
20 decide we don't want to really do filtered venting.

21 CHAIRMAN SCHULTZ: Charlie?

22 MEMBER BROWN: No.

23 CHAIRMAN SCHULTZ: Joy, nothing else?

24 MEMBER REMPE: No.

25 CHAIRMAN SCHULTZ: Well, I would like to

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 add my thanks to this presentation. We have an
2 opportunity for more discussion following.

3 I would like to open up the floor to any
4 comments from members of the public.

5 MEMBER POWERS: And why didn't Joy say
6 anything about instrumentation in the spent-fuel pool?

7 (Laughter.)

8 MEMBER REMPE: I have been wanting to say
9 something, too, while you were explaining the results,
10 about the vessel failing earlier, would be good to
11 understand, too.

12 MEMBER POWERS: Oh, you want to put strain
13 gauges on the vessel.

14 (Laughter.)

15 MEMBER REMPE: But I decided to let it go.

16 MEMBER POWERS: Or put it under the
17 insulation.

18 CHAIRMAN SCHULTZ: I see no members of the
19 public who would like to make comments at this time.

20 On the telephone, if there are members of
21 the public, I believe we hear -- could you please let
22 me know that you are there? And if you have comments
23 at this point, please signify that you do.

24 Hello on the telephone.

25 (No response.)

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 The phone line should be open.

2 MEMBER POWERS: Nobody wants to talk to
3 you, Steve.

4 (Laughter.)

5 CHAIRMAN SCHULTZ: We are not hearing any
6 comments. So, we will close the public comment
7 period.

8 MR. LEYSE: Hello?

9 CHAIRMAN SCHULTZ: Oh, hello.

10 MR. LEYSE: Hello?

11 CHAIRMAN SCHULTZ: Bob, do you hear me?

12 MR. LEYSE: Yes.

13 CHAIRMAN SCHULTZ: Do you have any
14 comments you would like to make?

15 MR. LEYSE: Yes, very brief.

16 CHAIRMAN SCHULTZ: Please proceed.

17 MR. LEYSE: Hearing the first
18 presentation, I believe it was --

19 CHAIRMAN SCHULTZ: Bob? Bob, could you
20 please provide your name first?

21 MR. LEYSE: Oh, yes, Bob Leyse, L-E-Y-S,
22 as in Sam, E.

23 CHAIRMAN SCHULTZ: Thank you.

24 MR. LEYSE: Anyway, I believe the Chair
25 made a remark during the first presentation, and I

NEAL R. GROSS

COURT REPORTERS AND TRANSCRIBERS
1323 RHODE ISLAND AVE., N.W.
WASHINGTON, D.C. 20005-3701

1 just pick out three words: chagrin, hydrogen, and
2 detonation. And if EPRI is still around, I would like
3 them to get the transcript, do a word search, pull out
4 that phrase, that sentence, that presentation, and
5 give it to those great owners' groups and SAMG
6 experts.

7 End of comment.

8 CHAIRMAN SCHULTZ: Thank you, Bob.

9 Are there other members of the public on
10 the telephone that would like to comment at this time?

11 (No response.)

12 Hearing none, I would like to, again,
13 thank the Committee, encourage the staff and the
14 presenters today to continue their interactions over
15 the course of September, so we can come back in
16 October and get some of these questions further
17 answered.

18 And with that, I would like to close this
19 portion of the session.

20 We will take a break at this point in time
21 and go into proprietary session.

22 (Whereupon, the foregoing matter went off
23 the record at 5:28 p.m. and went back on the record in
24 closed session at 5:43 p.m.)

25



Evaluation of Strategies for Mitigating Radiological Releases in Severe Accidents: *Assumptions, Models, Input, and Data*

BWR Mark I and Mark II Studies

ACRS Meeting of the Fukushima Subcommittee

Rockville, Maryland

September 5, 2012

Topics

- EPRI's use of MAAP and MAACS2 to evaluate strategies to reduce radioactive release following a severe accident
 - Introduction and Insights
 - Selection of representative scenarios and viable strategies
 - MAAP models, input, and assumptions
 - MAAP output
 - Sensitivity analyses

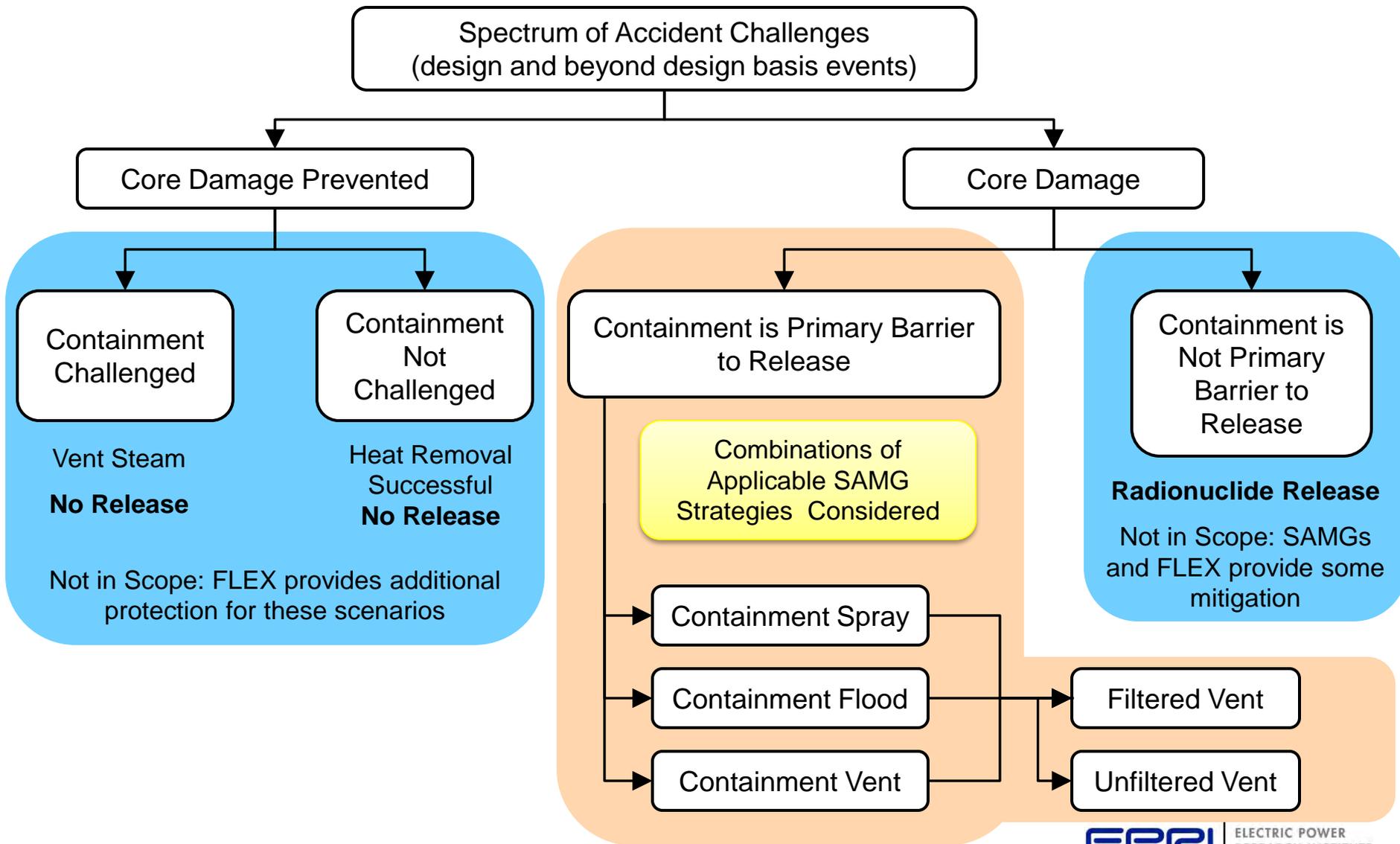
Introduction

- Best way to avoid radiological release is to prevent core damage
- Containment function is to retain fission products and the most effective strategies should maximize the retention within containment
- The goal of the EPRI work is to assess strategies for mitigating releases to the environment in a severe accident

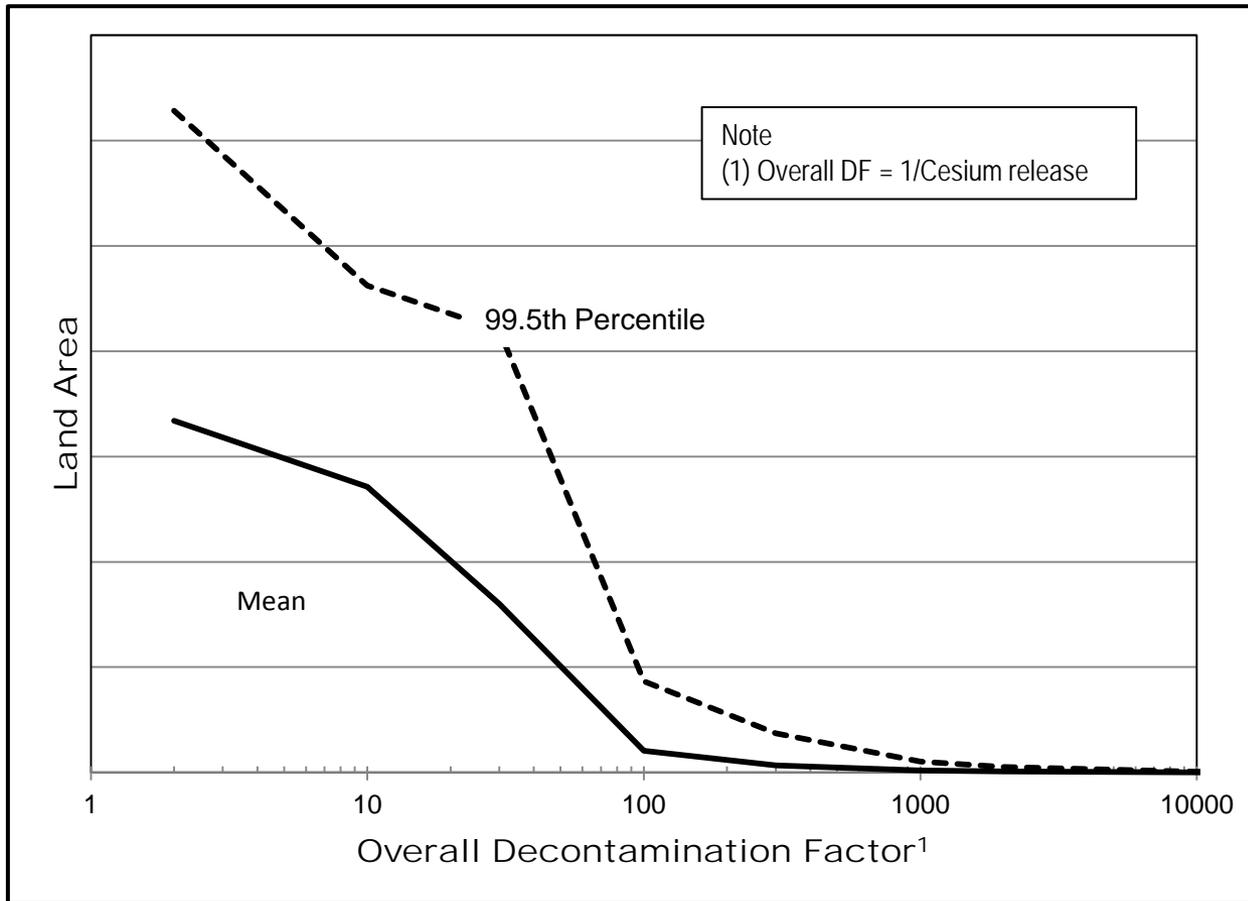
Insights

- Existing SAMG Strategies Provide Substantial Benefit
 - *Active Core Debris Cooling Is Required*
 - *Spraying the Containment Atmosphere Is Beneficial*
 - *Venting Prevents Uncontrolled Release and Manages Hydrogen*
- Additional Insights on Reducing Radiological Releases
 - *No Single Strategy Alone is Effective*
 - *Control of the Vent Provides Benefit*
 - *A Low DF Filter Can Further Reduce the Radionuclide Release*
 - *Protection of Sump Drain Lines in Mark II Containment Beneficial*

Containment Enhancement Scenarios Evaluated

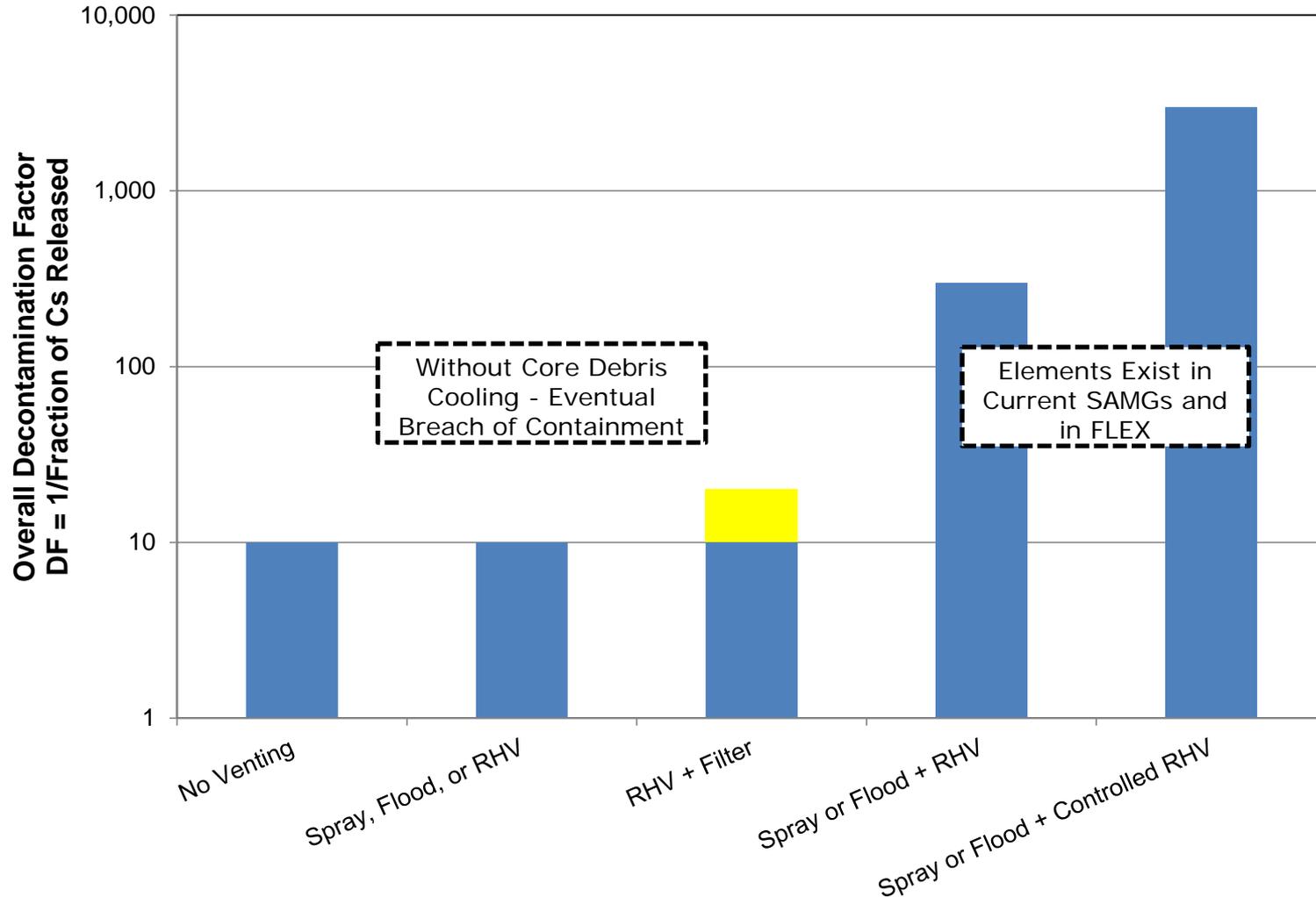


Land Contamination Figure of Merit

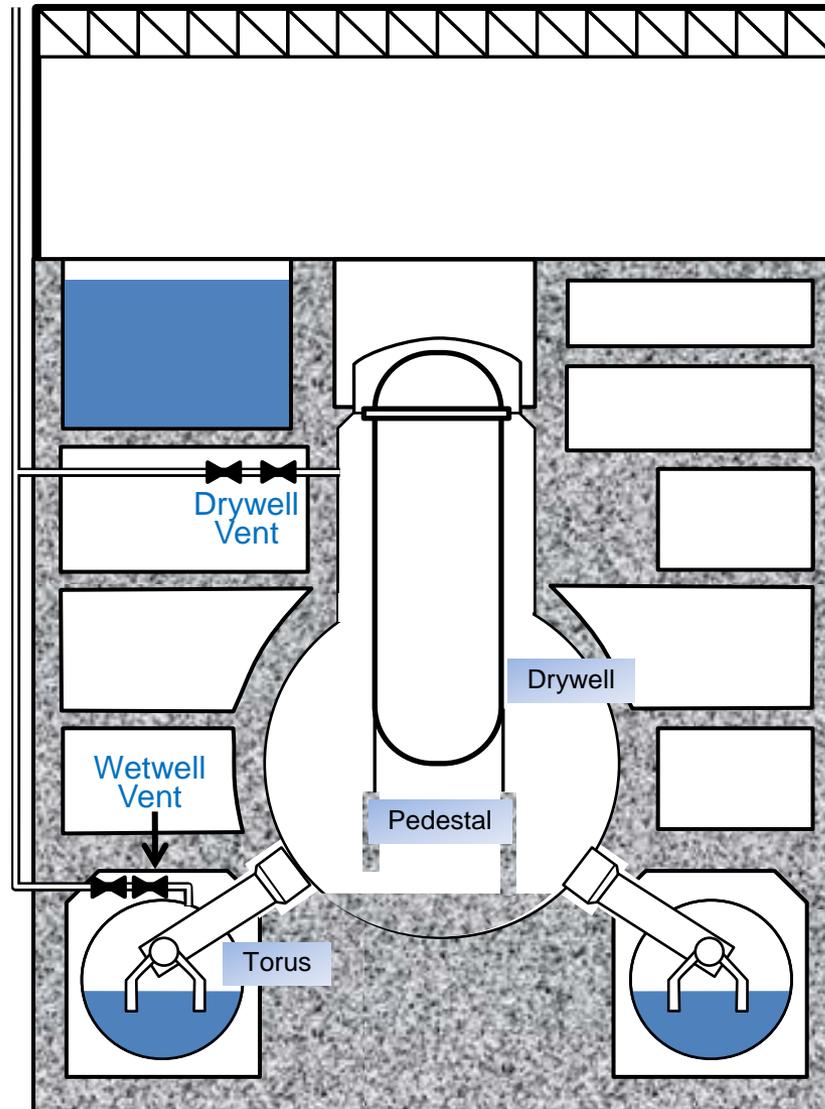


Diminishing Benefit as DF Approaches 1000

Representative Output for BWR Mark I Strategies

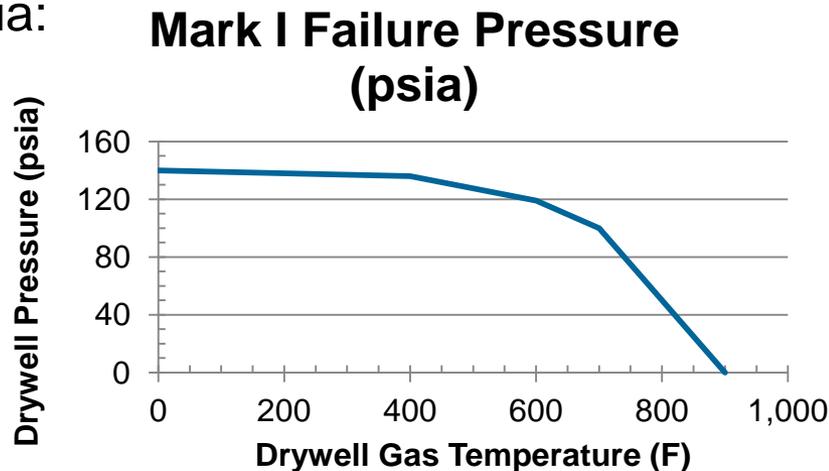


Mark I Containment Control Volumes/Junctions



Mark I Containment – Baseline Assumptions

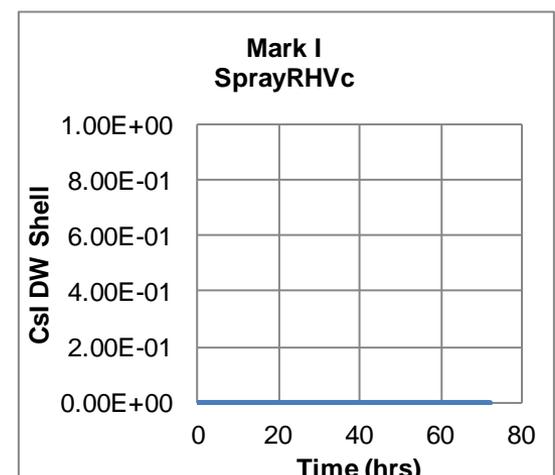
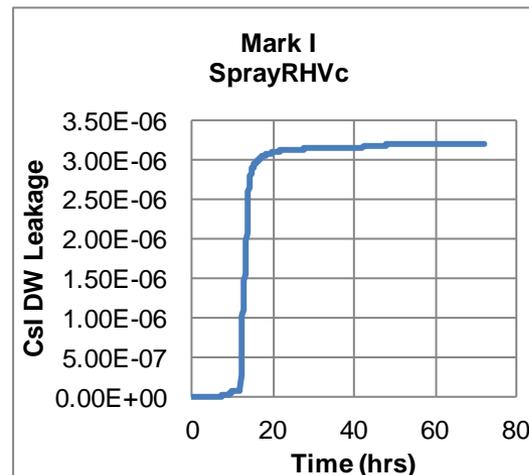
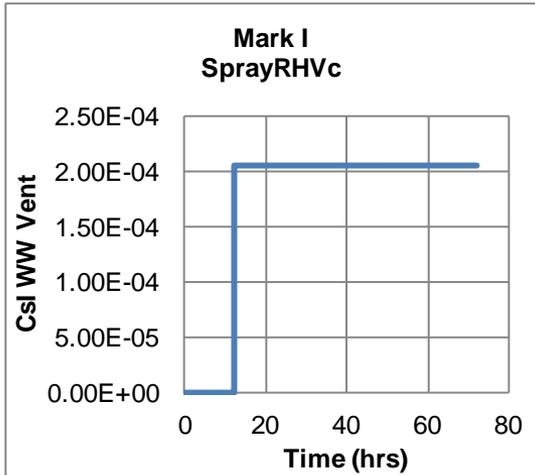
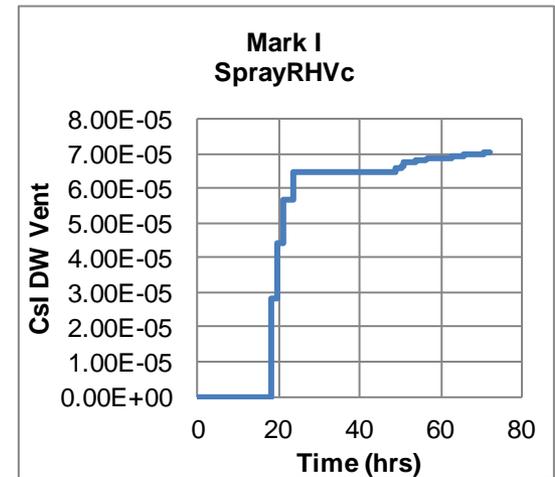
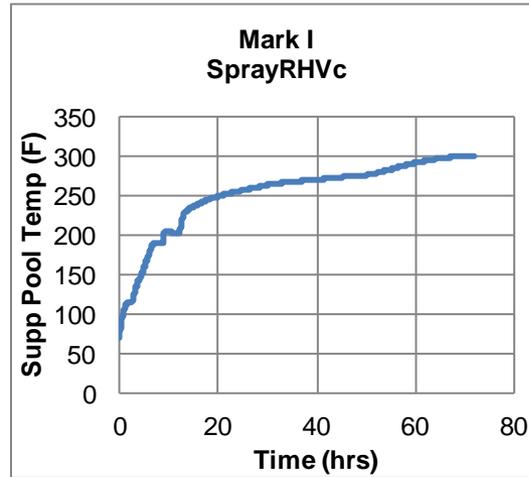
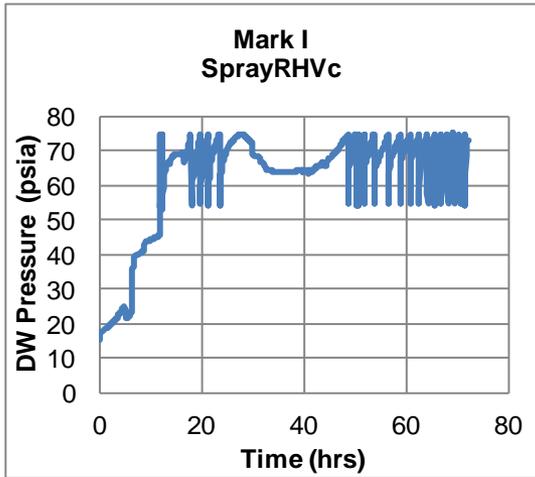
- SBO with RCIC for 4 hours
- 36 GPM seal leakage at t=0
- Single SRV seizes open at onset of core damage
- Vessel breach due to melting of CRD penetration weld
- Drywell shell failure assumed to occur 15 minutes after vessel breach if no injection or spray
- Wetwell vent closed if pool level exceeds 21 feet
- Vent controlled between 60-40 psig
- Secure flood/spray if drywell water level exceeds 59 feet
- Drywell failure area = 2 ft²
- Mark I failure criteria:



Mark I Output – Spray and Controlled RHV

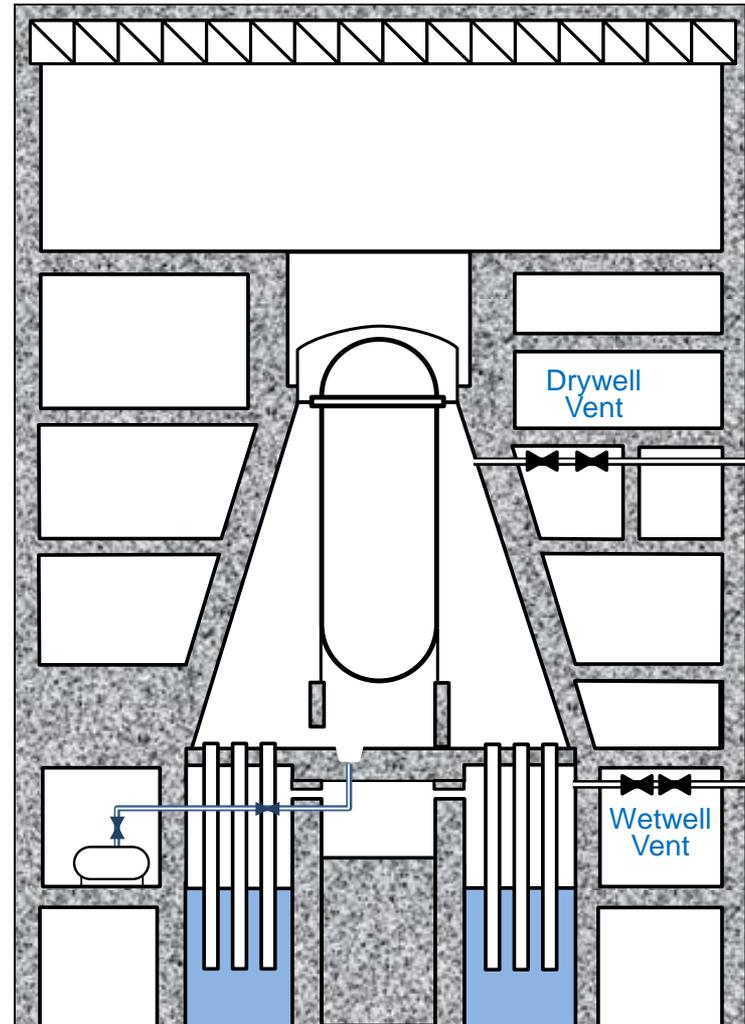
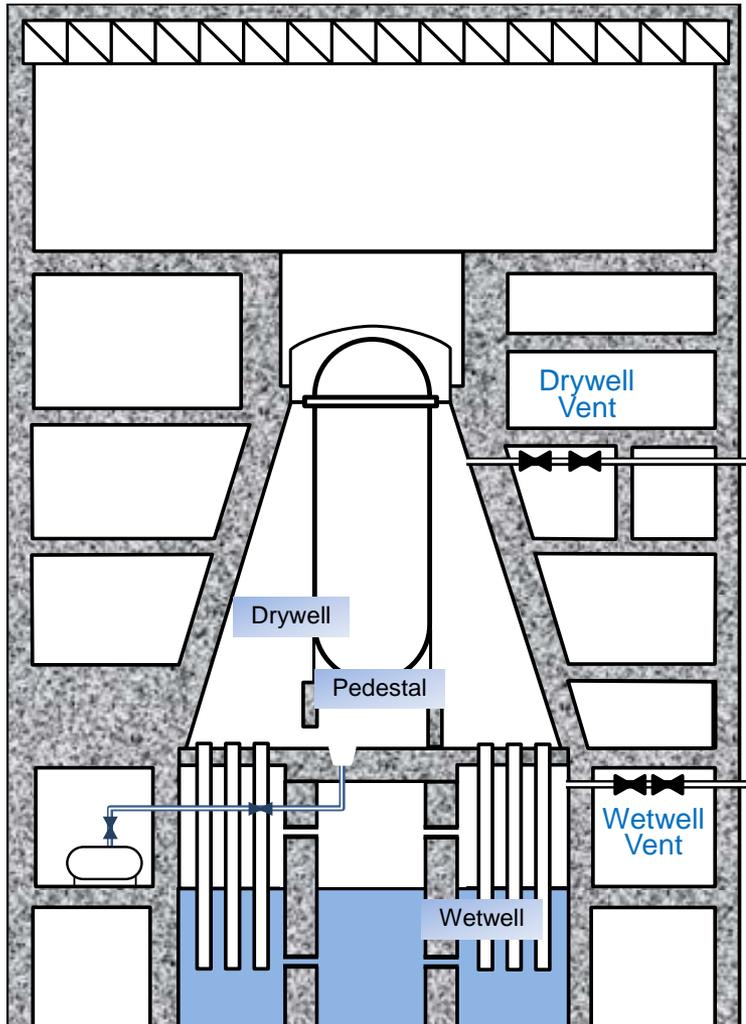
Phenomenon	Time (hr)
Reactor trip	0
RCIC lost due to loss of DC	4.0
Initiate Drywell sprays	5.0
Core Uncovered	5.2
Onset of Core Damage	6.1
Single SRV assumed to seize open	6.1
Core material relocation to the lower plenum	8.7
Reactor vessel breach	11.8
Wetwell Vent Initially Opened	11.9
Wetwell vent cycled open/close	11.9-17.9
Wetwell vent closed due to high pool level	17.9
Drywell Vent Initially Opened	19.7
Drywell Vent cycled open/close	19.7-72.0
Secure sprays due to high Drywell level	48.6

Mark I Output – Spray and Controlled RHV



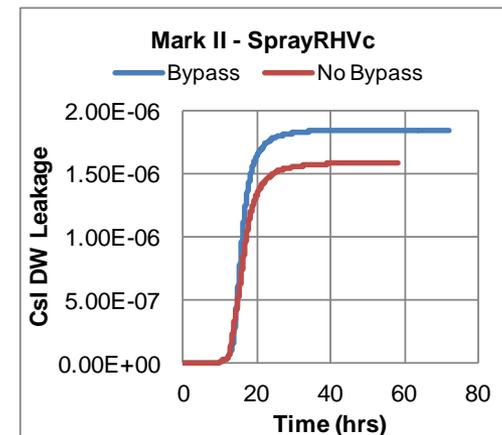
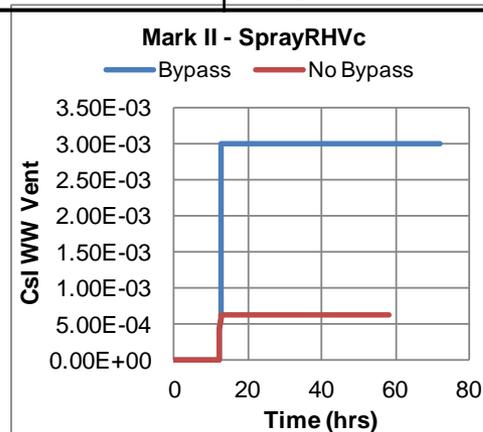
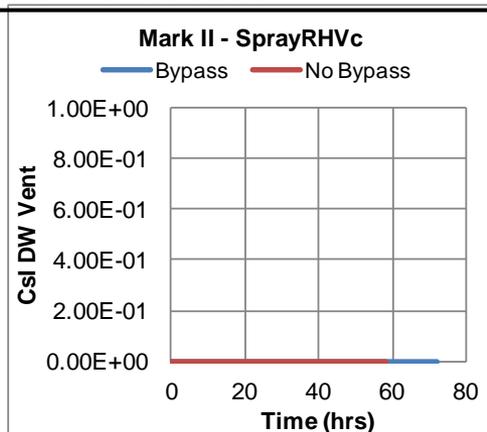
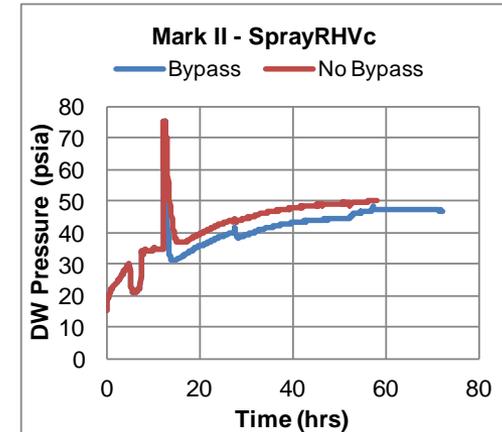
DRAFT

Mark II Containment Control Volumes/Junctions



Mark II Output – Spray and Controlled RHV

Phenomenon	Time (hr)
Reactor trip	0
RCIC lost due to loss of DC	4.0
Initiate Drywell sprays	5.0
Core Uncovered	6.2
Onset of Core Damage	7.2
Single SRV assumed to seize open	7.2
Core material relocation to the lower plenum	9.8
Reactor vessel breach	12.3
Wetwell Vent Initially Opened	12.4
Pedestal drain line failure	12.5 (NA)
Wetwell vent cycled open/close	12.4-12.9
Wetwell vent closed	12.9



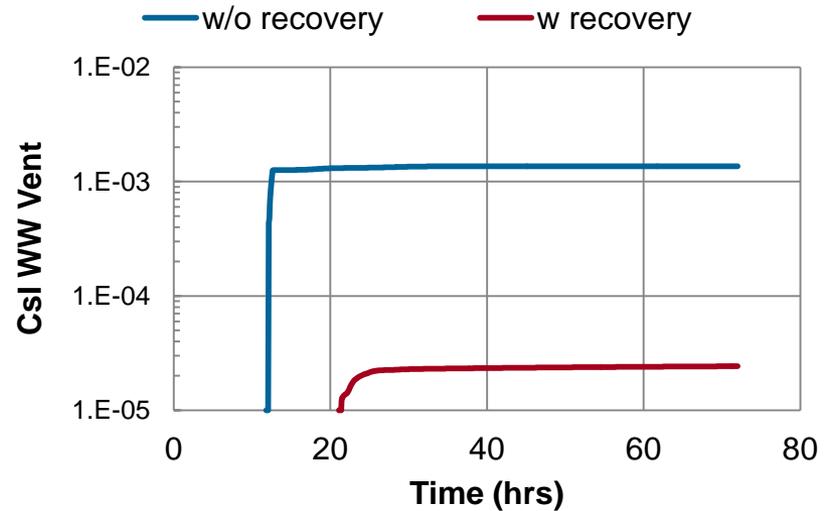
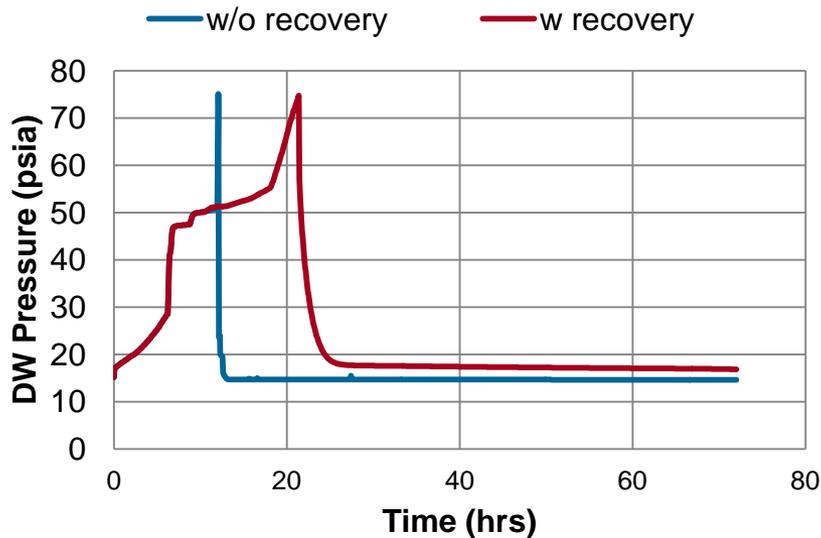
DRAFT

Sensitivity Analysis

- In-vessel recovery
- Early Venting
 - Open at 40 psia and close at 18 psia
- RPV Pressure
- Drywell spray droplet diameter
 - Nominal value = 0.012 ft
 - Sensitivity value = 0.12 ft
 - Sensitivity value = 0.12 ft plus early wetwell venting
 - Performed for Spray and Controlled RHV case
- Drywell spray aerosol removal efficiency
 - Nominal value = 0.02
 - Sensitivity value = 0.002 and 0.0002
 - Performed for Spray and Controlled RHV case
- RCIC operation timing
 - 0,4,8, and 12 hours
 - Performed on Spray and RHV case
- Spray/Injection flow rate
 - 100, 500 gpm
 - Flood and spray
 - Performed on RHV case

Sensitivity Analysis – In-Vessel Recovery

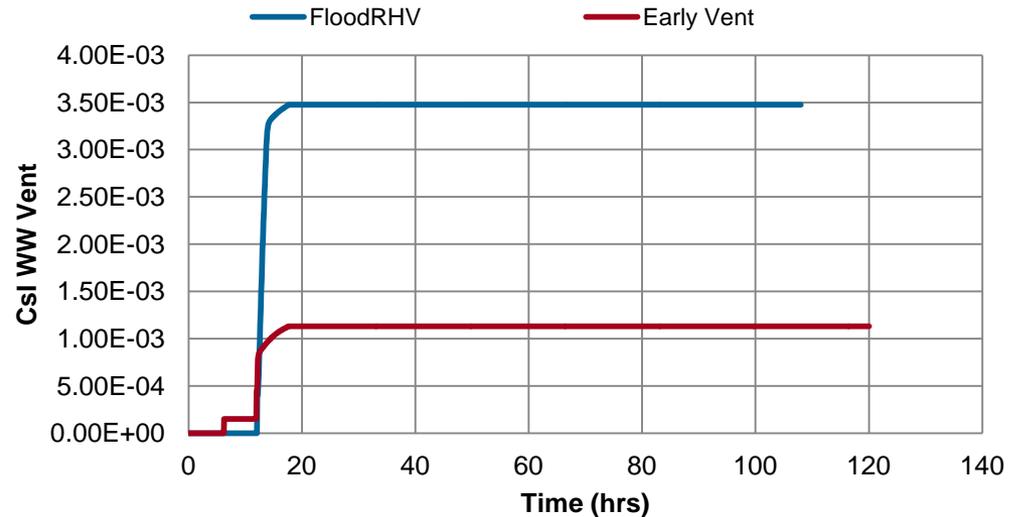
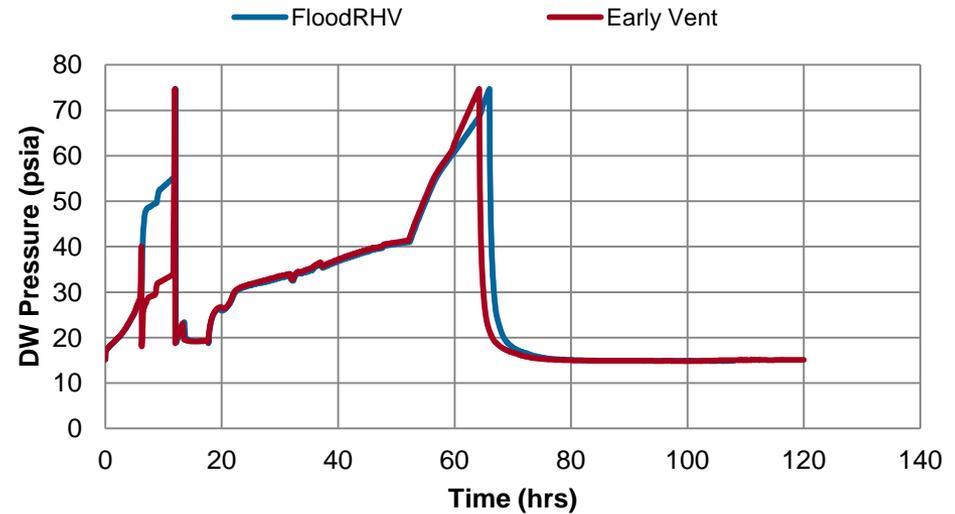
- Establish 500 gpm at 10 hours
- Vessel breach prevented
- Delayed demand for venting



DRAFT

Sensitivity Analysis – Early Venting

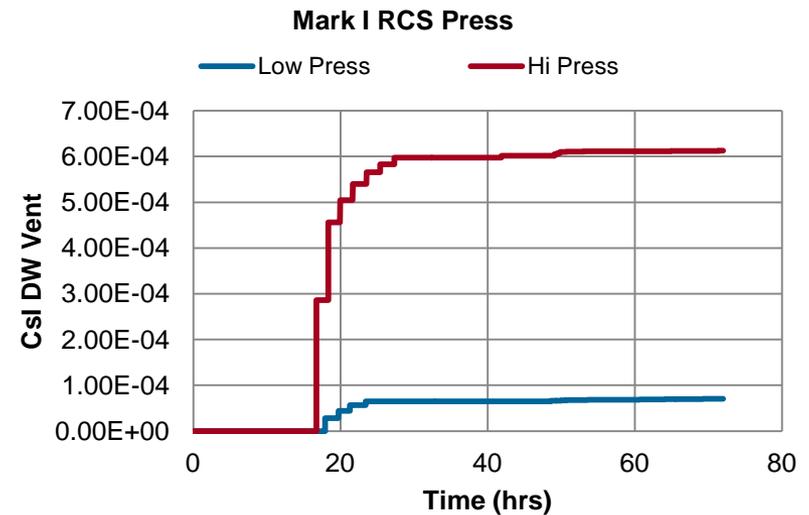
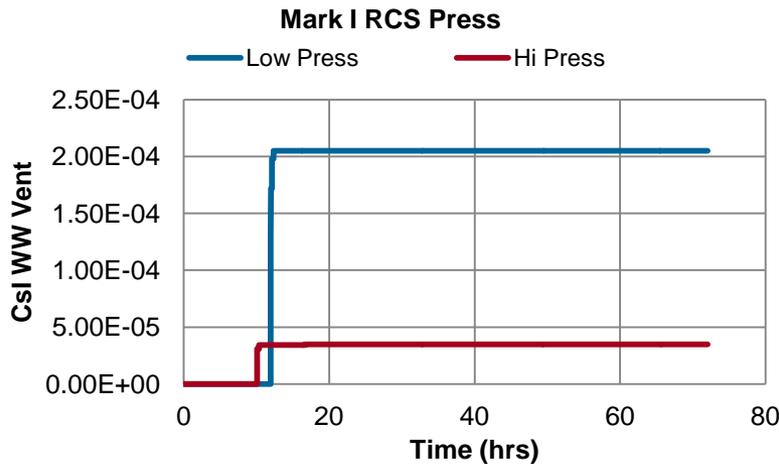
- Flood and RHV
- Base case output:
 - Core damage: 6.1 hr
 - Vessel breach: 12 hr
 - Wetwell vent open: 12.1 hr
- Early Vent
 - Open 40 psia: 6.2 hr
 - Close 18 psia: 6.3 hr
- Comparison shows smaller release due to early venting



DRAFT

Sensitivity Analysis – RPV Pressure

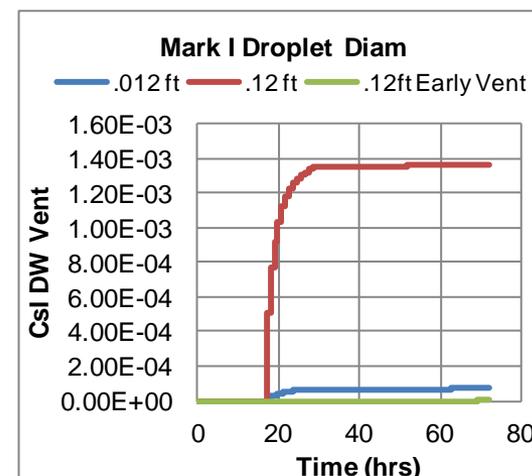
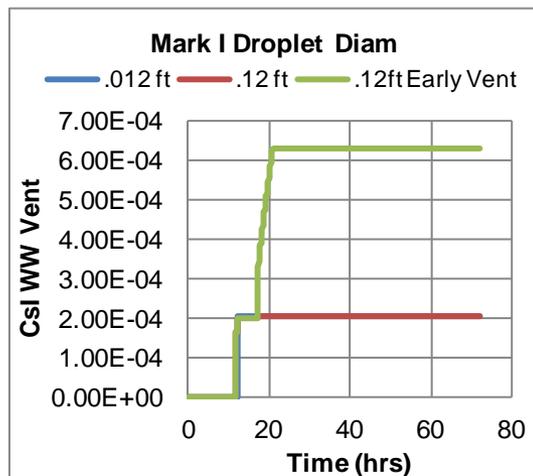
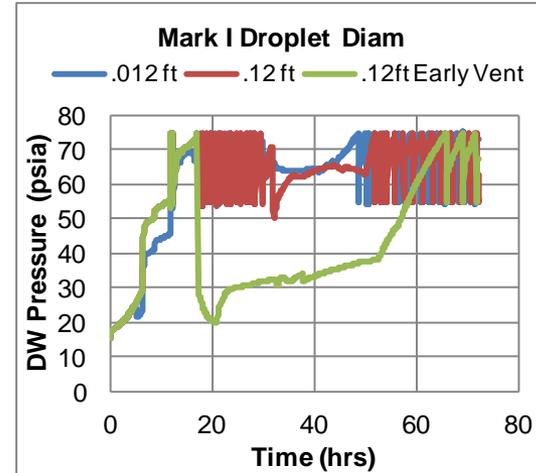
Event	Low RPV Pressure	High RPV Pressure
RCIC tripped	4 hr	4 hr
Sprays initiated	5 hr	5 hr
Level at TAF	5.2 hr	5.2 hr
SRV stuck open	6.1 hr	NA
Vessel Breach	11.8 hr	10.1 hr
Drywell Pressure at Vessel Breach	45 psia	37 psia



DRAFT

Sensitivity Analysis – Spray Droplet Size

- Spray and Controlled RHV
- Smaller spray droplet
 - Reduced aerosol removal
- Reduced DF can be offset with other strategies such as early venting
 - Depressurize containment just prior to isolation of wetwell vent



DRAFT

Sensitivity Analysis – Aerosol Removal Efficiency

Phenomena

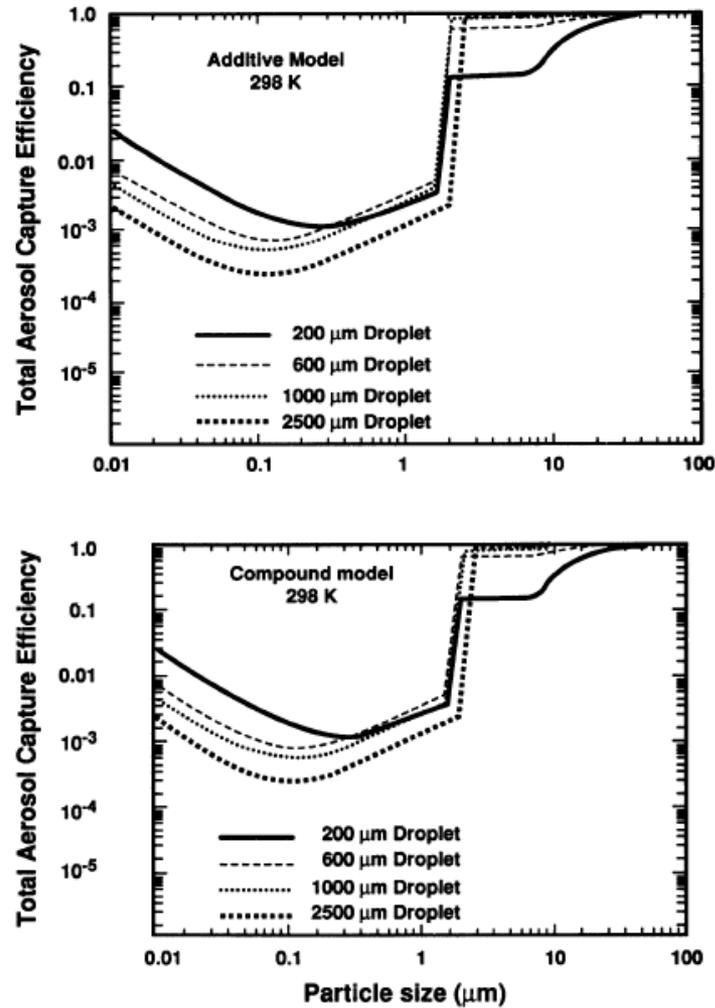
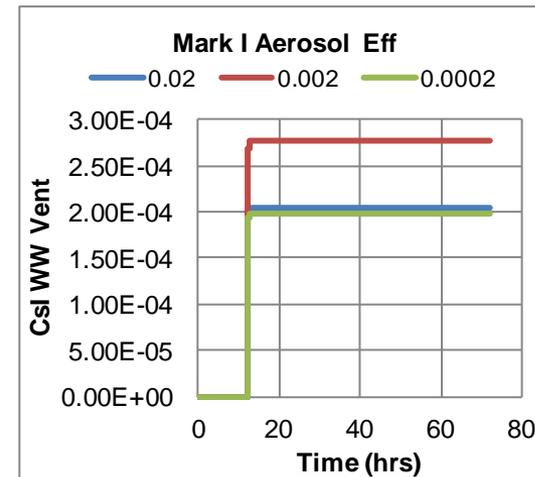
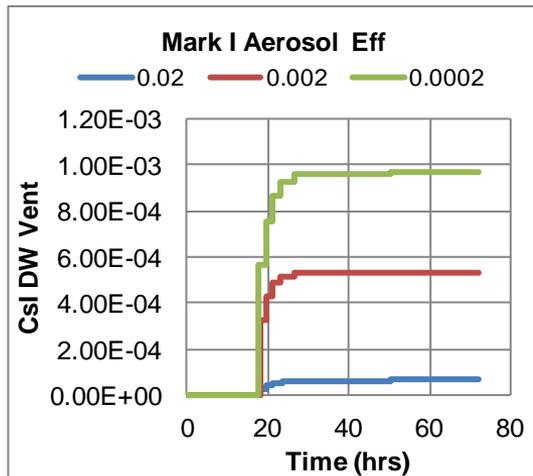
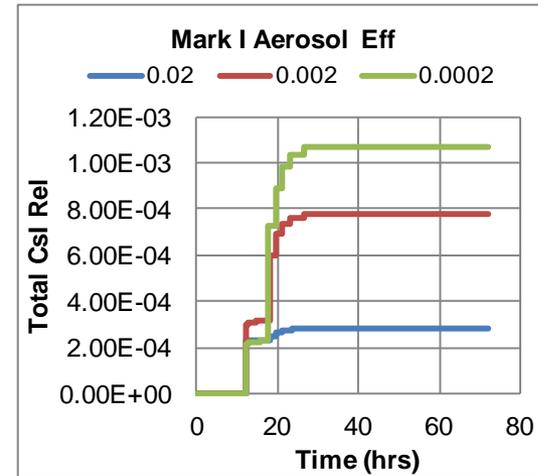


Figure 19 $\epsilon'(\text{total})$, the compound model, and $\epsilon(\text{total})$, the additive model, as functions of aerosol particle size and water drop size

Sensitivity Analysis – Aerosol Removal Efficiency

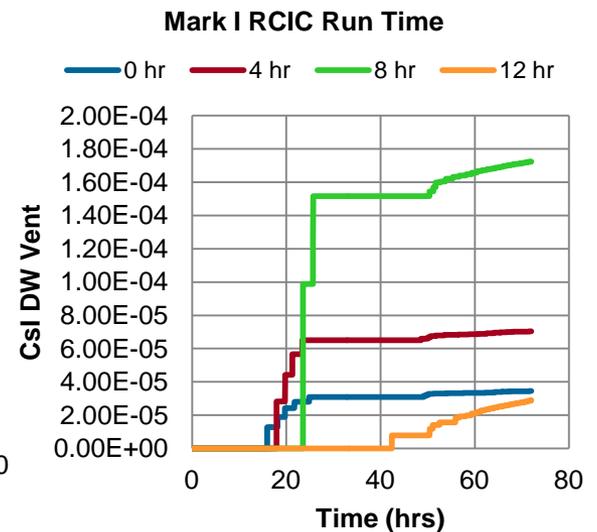
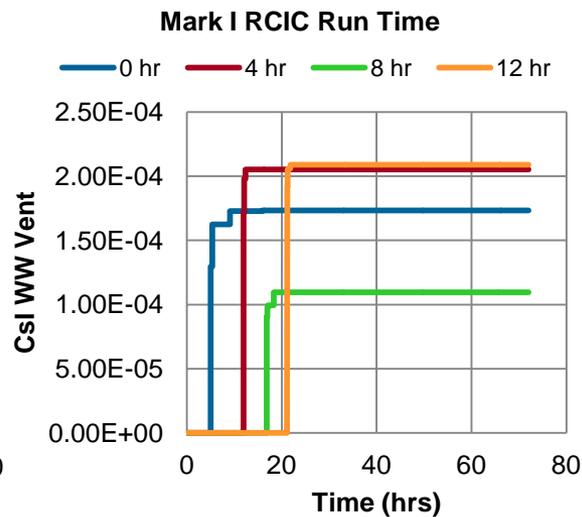
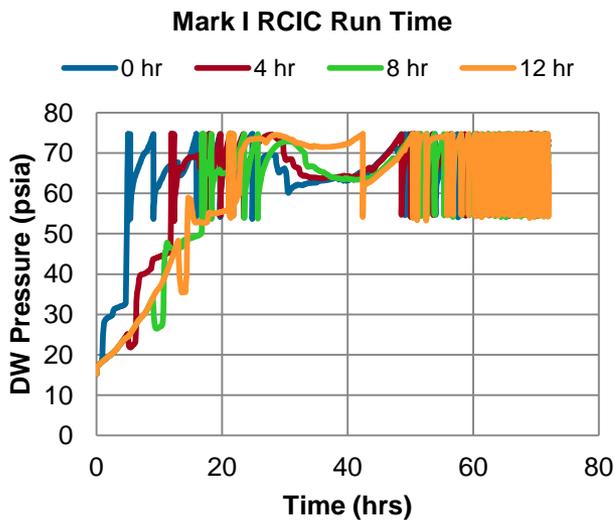
- Spray and Controlled RHV
- Reduced aerosol capture efficiency
- Even with extremely low capture efficiency, overall DF > 500
- Typical values yield DF > 1000



DRAFT

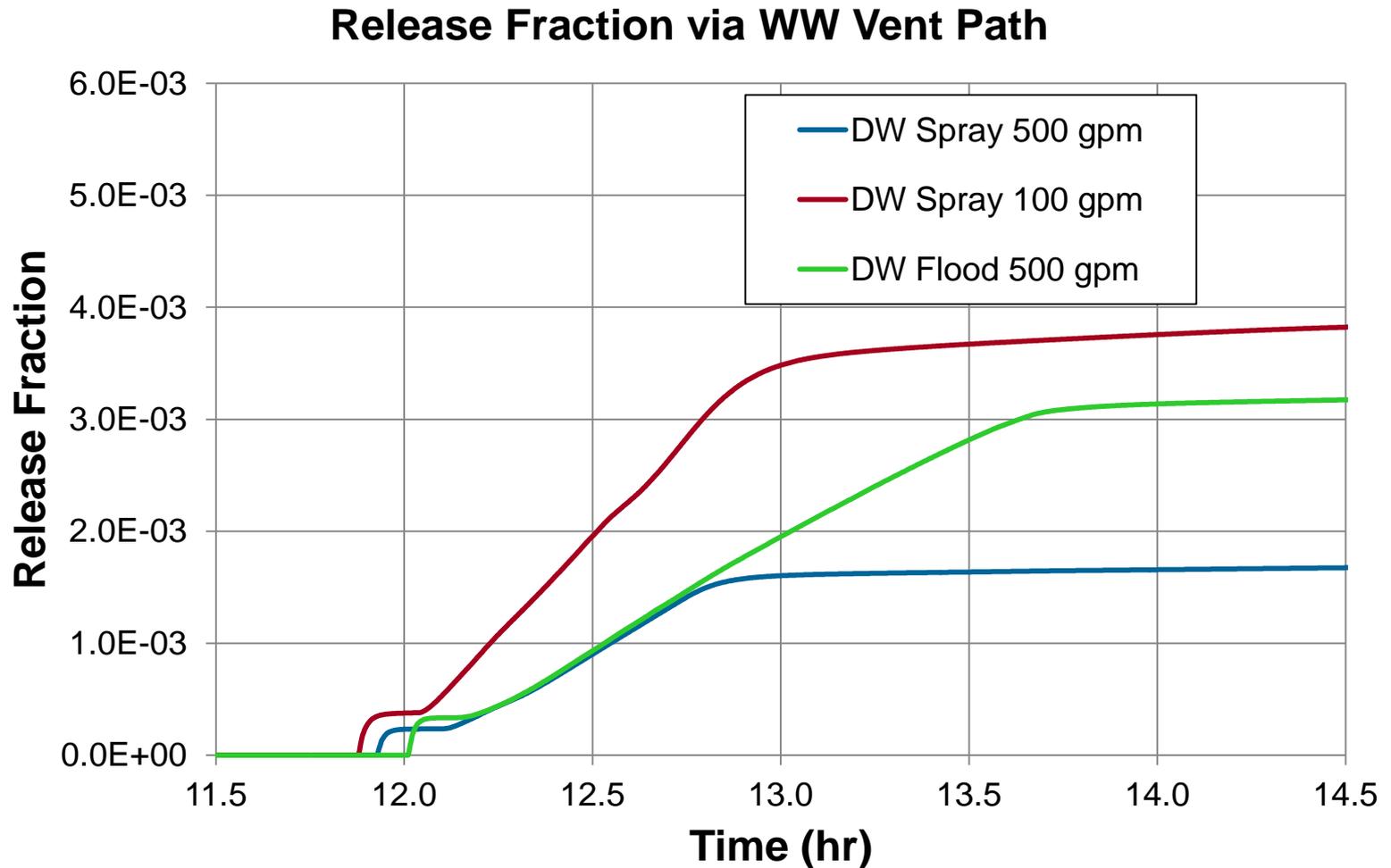
Sensitivity Analysis – RCIC Operating Time

Event	RCIC 0 hrs.	RCIC 4 hrs.	RCIC 8 hrs.	RCIC 12 hrs.
Level at TAF	.4 hr	5.2 hr	9.6 hr	13.2 hr
Sprays initiated	1 hr	5 hr	9 hr	13 hr
Vessel Breach	4.7 hr	11.8 hr	16.8 hr	21.1 hr
WW first open	5.0 hr	11.9 hr	16.8 hr	21.1 hr
Drywell Pressure at Vessel Breach	32 psia	46 psia	50 psia	56 psia



DRAFT

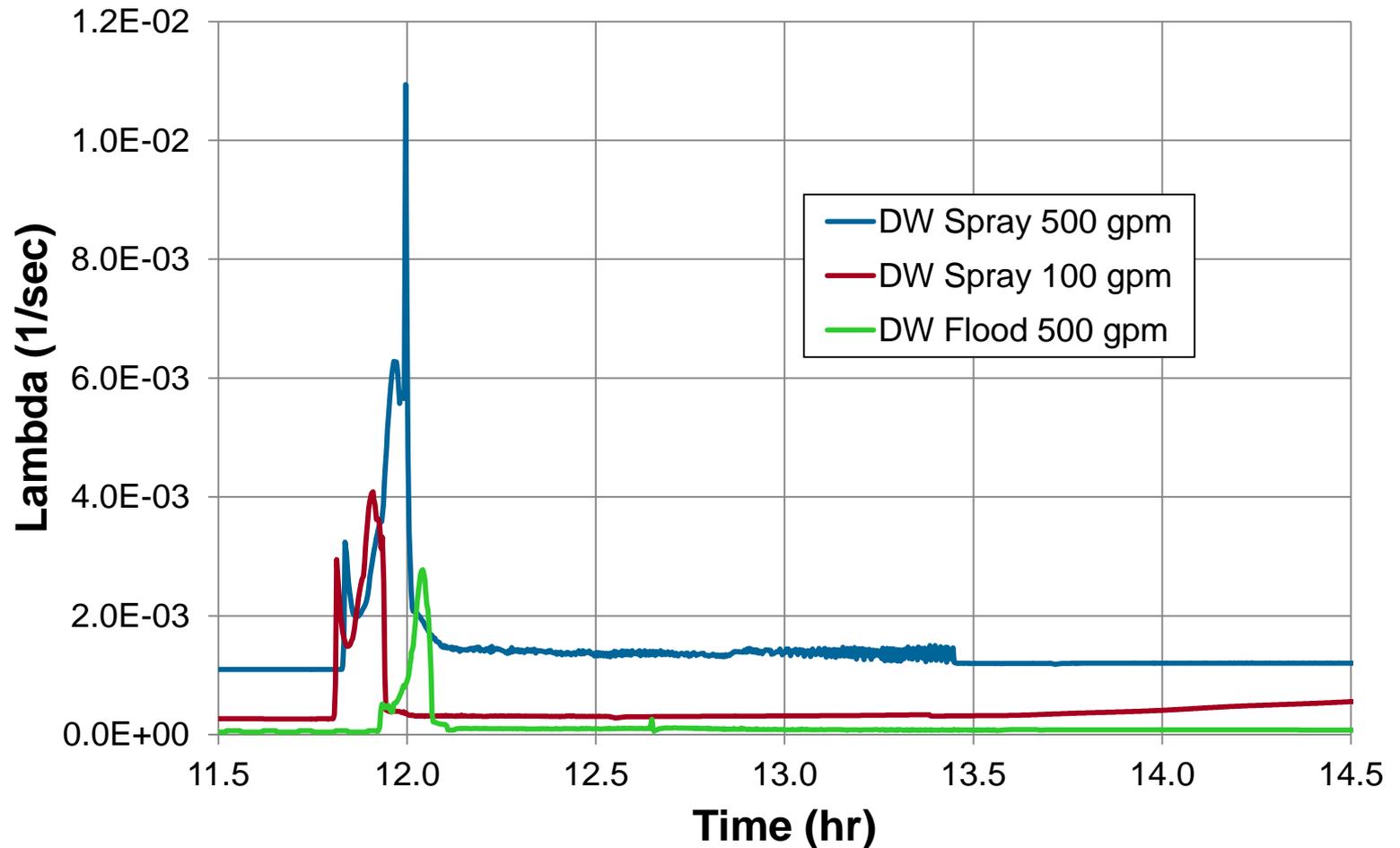
Sensitivity Analysis – Spray/Flood Flow Rate



DRAFT

Sensitivity Analysis – Spray/Flood Flow Rate

Drywell Lambda

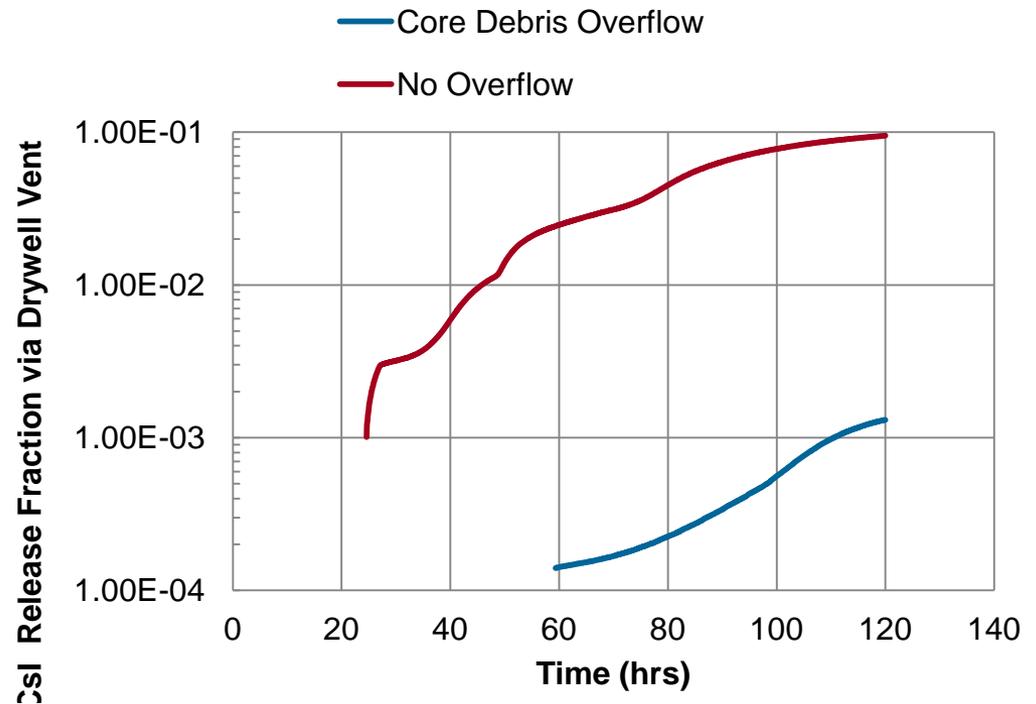


DRAFT

Sensitivity Analysis – Mark II

Core debris flow to Suppression Pool

- Sensitivity to amount of core debris remaining in the drywell for Mark II
- Without core debris cooling
 - Core/Concrete interactions
 - Late failure of the drywell



DRAFT

Insights

- Existing SAMG Strategies Provide Substantial Benefit
 - *Active Core Debris Cooling Is Required*
 - *Spraying the Containment Atmosphere Is Beneficial*
 - *Venting Prevents Uncontrolled Release and Manages Hydrogen*
- Additional Insights on Reducing Radiological Releases
 - *No Single Strategy Alone is Effective*
 - *Control of the Vent Provides Benefit*
 - *A Low DF Filter Can Further Reduce the Radionuclide Release*
 - *Protection of Sump Drain Lines in Mark II Containment Beneficial*

Effectiveness of Strategies

Strategy	Containment Initially Intact		Containment Initially Failed		
	Wet	Dry/SBO	TW/ATWS	Non-Isolation	ISLOCA
Containment Flooding	Green	Green	Green	Green	Red
Containment Sprays	Green	Green	Green	Green	Red
RHV – Unfiltered	Green	Red	Red	Red	Red
ACHR	Green	Red	Red	Red	Red
Filtered vents	Green	Red	Red	Red	Red
RHV & Spray	Green	Green	Green	Green	Red
ACHR & Spray	Green	Green	Green	Green	Red
Filter & Spray	Green	Green	Green	Green	Red

Backup Slides

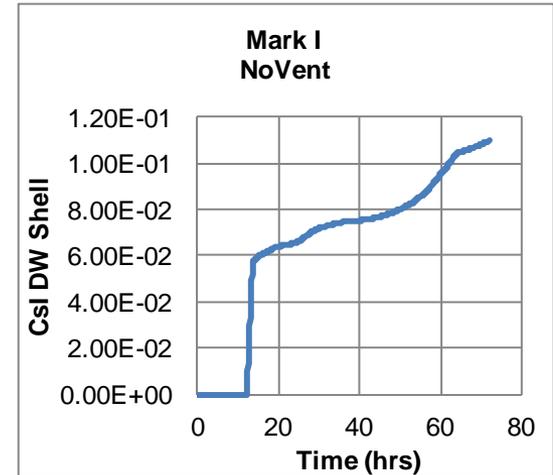
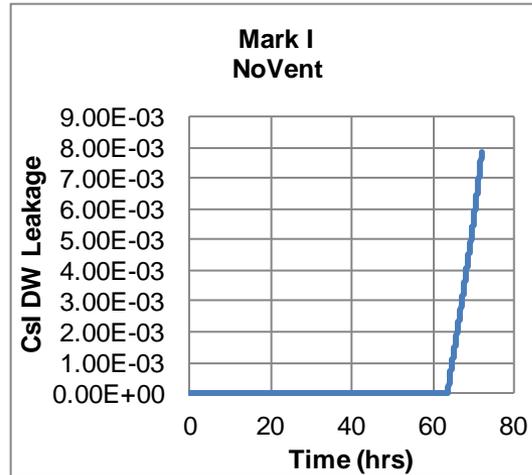
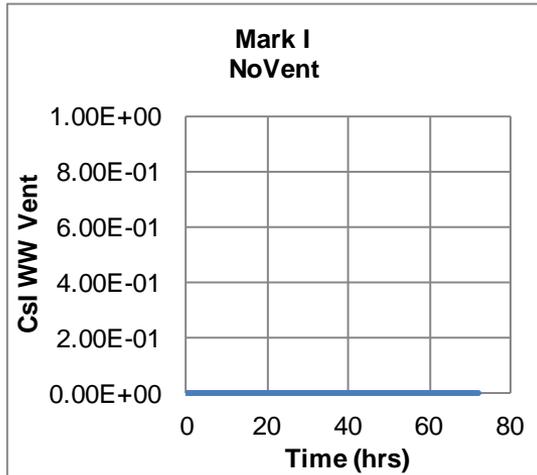
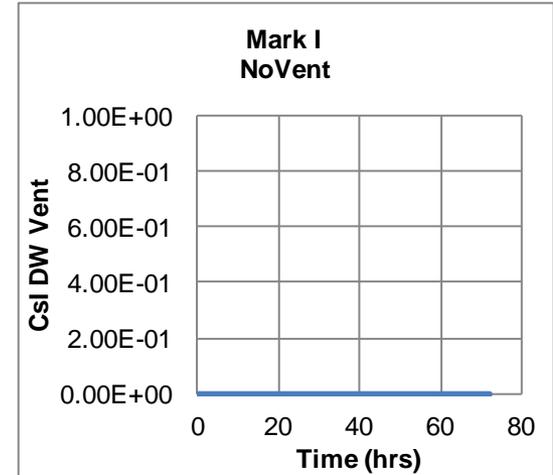
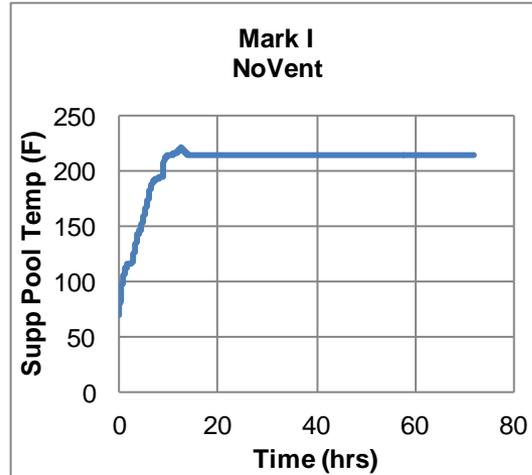
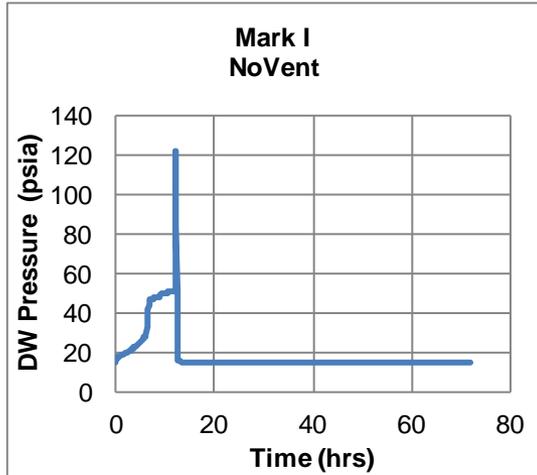
Summary of Strategies

Strategy	Severe Accident Function	Release Mitigation Benefit	Potential Limitations
Containment Flooding (Inject into containment)	<ul style="list-style-type: none"> Cool ex-vessel core debris Reduce magnitude of fission products released to cont. atmosphere 	<ul style="list-style-type: none"> Protect containment boundary Reduce release magnitude for many scenarios 	<ul style="list-style-type: none"> Use of external water for makeup creates need for inventory control and may require drywell vent
Containment Spray	<ul style="list-style-type: none"> Cool ex-vessel core debris Remove fission products from containment atmosphere 	<ul style="list-style-type: none"> Protect containment boundary Reduce release magnitude for many scenarios 	<ul style="list-style-type: none"> Use of external water for spray creates need for inventory control and may require drywell vent
Alternate Containment Heat Removal (ACHR)	<ul style="list-style-type: none"> Maintain containment boundary and avoid even controlled releases 	<ul style="list-style-type: none"> Limits release to leakage 	<ul style="list-style-type: none"> May not always be readily feasible depending on plant design Cannot protect for dynamic effects at vessel breach
Reliable Hardened Vents (RHV) – Unfiltered	<ul style="list-style-type: none"> Remove fission products from a controlled release to maintain containment boundary 	<ul style="list-style-type: none"> Reduce release magnitude for selected scenarios 	<ul style="list-style-type: none"> Not effective if containment boundary is compromised
Controlled Use of the RHV	<ul style="list-style-type: none"> Same as RHV 	<ul style="list-style-type: none"> Greater reduction in release magnitude than RHV for selected scenarios where RHV is effective 	<ul style="list-style-type: none"> Not effective if containment boundary is compromised
Filtered Vents	<ul style="list-style-type: none"> Remove fission products from a controlled release to maintain containment boundary 	<ul style="list-style-type: none"> Reduce release magnitude for selected scenarios 	<ul style="list-style-type: none"> Not effective if containment boundary is compromised
Combinations of the above	<ul style="list-style-type: none"> Varies, depending on combination Some combinations are synergistic, e.g., flood & ACHR 	<ul style="list-style-type: none"> Varies but generally greater than individual strategy 	<ul style="list-style-type: none"> Varies, depending on combination Some combinations can effectively eliminate limitations of individual strategies

Mark I Output – No Vent

Phenomenon	Time (hr)
Reactor trip	0
RCIC lost due to loss of DC	4.0
Core Uncovered	5.2
Onset of Core Damage	6.1
Single SRV assumed to seize open	6.1
Core material relocation to the lower plenum	8.8
Reactor vessel breach	12.0
Drywell shell failure	12.3
Increased Drywell leakage	63.7

Mark I Output – No Vent

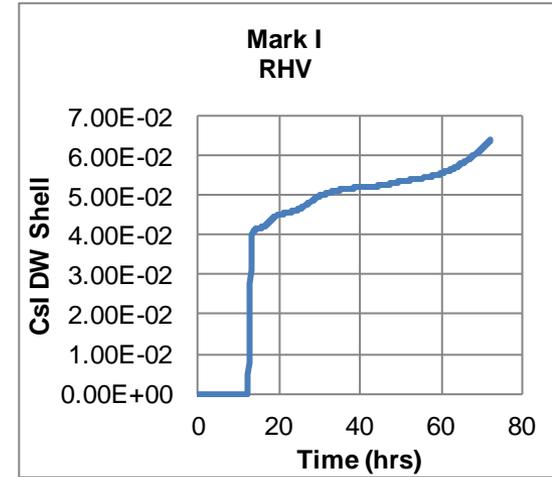
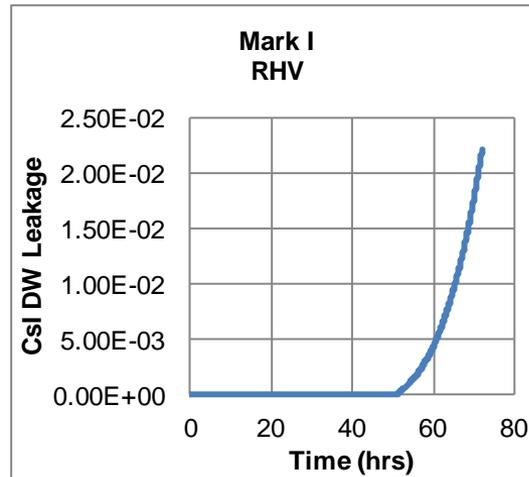
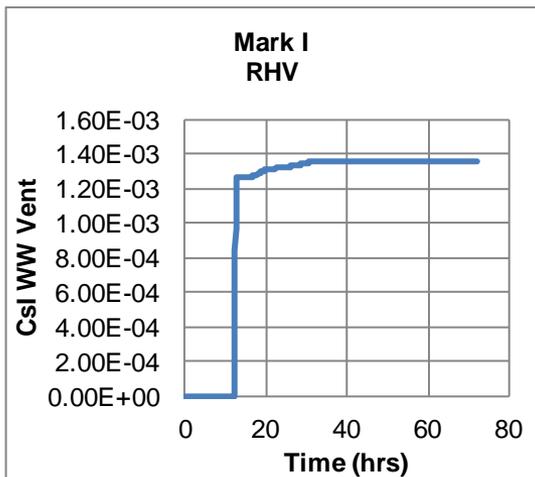
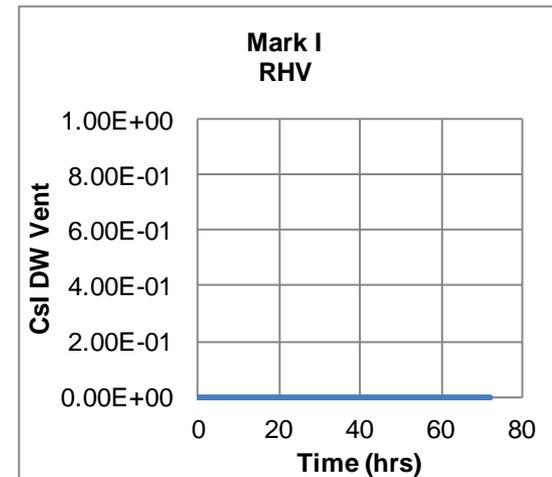
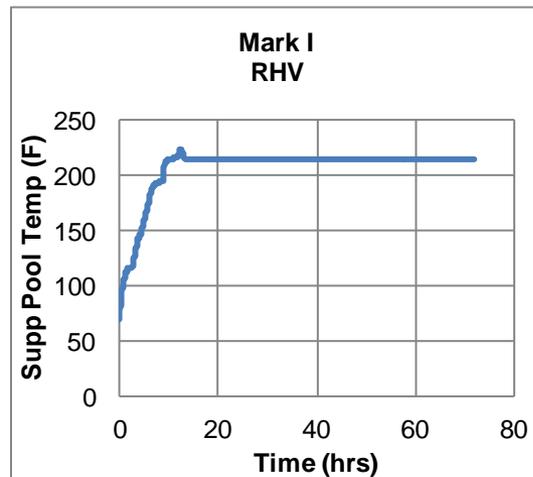
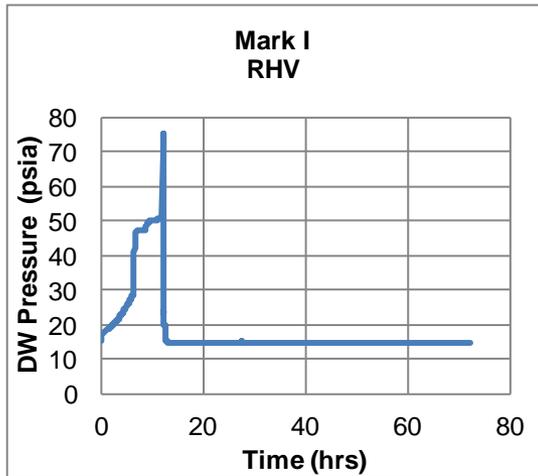


DRAFT

Mark I Output – RHV

Phenomenon	Time (hr)
Reactor trip	0
RCIC lost due to loss of DC	4.0
Core Uncovered	5.2
Onset of Core Damage	6.1
Single SRV assumed to seize open	6.1
Core material relocation to the lower plenum	8.8
Reactor vessel breach	12.0
Wetwell Vent Open	12.1
Drywell shell failure	12.3
Increased Drywell leakage	50.5

Mark I Output – RHV

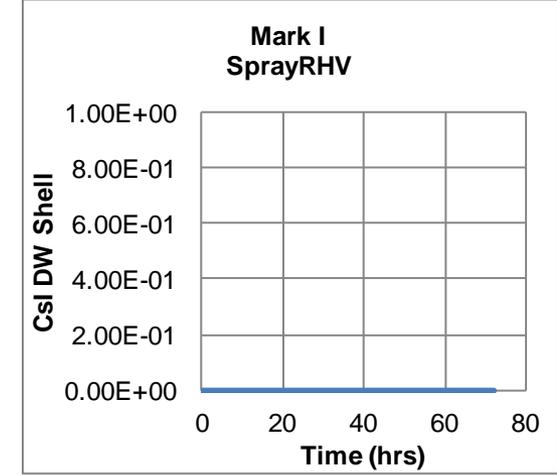
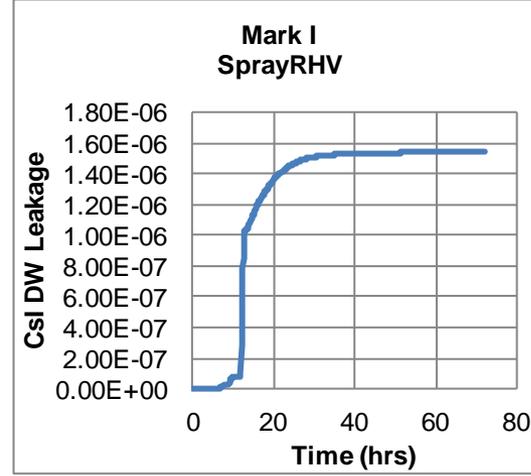
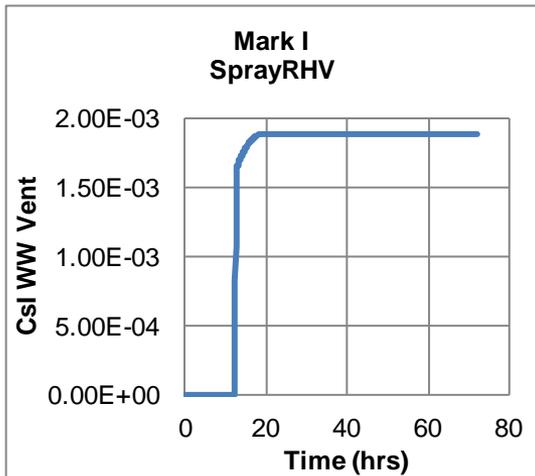
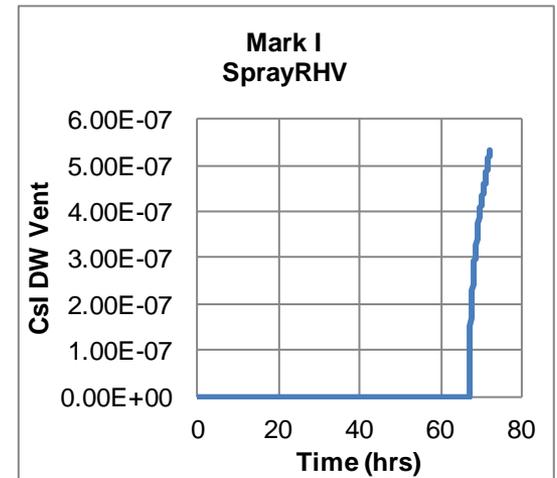
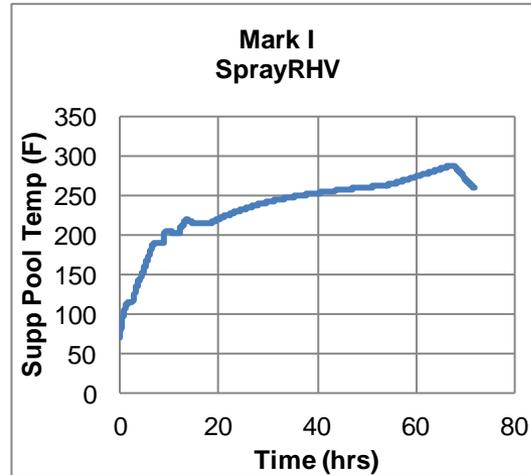
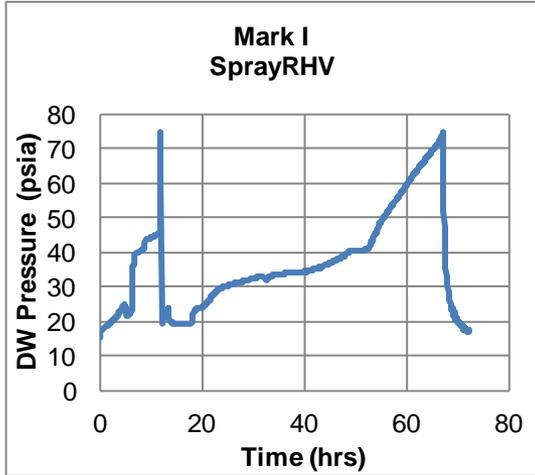


DRAFT

Mark I Output – Spray and RHV

Phenomenon	Time (hr)
Reactor trip	0
RCIC lost due to loss of DC	4.0
Initiate Drywell sprays	5.0
Core Uncovered	5.2
Onset of Core Damage	6.1
Single SRV assumed to seize open	6.1
Core material relocation to the lower plenum	8.7
Reactor vessel breach	11.8
Wetwell Vent Open	11.9
Wetwell vent closed due to high pool level	17.9
Secure sprays due to high Drywell level	52.2
Open Drywell Vent	67.0

Mark I Output – Spray and RHV



DRAFT

Together...Shaping the Future of Electricity



Analysis of Filtered Venting for BWR Mark I Containments

Briefing to the
Advisory Committee on Reactor Safeguards
September 5, 2012

Topic Agenda

- Background
- Staff Actions
- Project Plan
- Office of Nuclear Regulatory Research (RES)
Presentation

Background

- In December 2011, the Commission directed the staff in SRM-SECY-11-0137 to take certain actions and provided additional guidance related to reliable hardened vents.
 - Supported recommendation to order licensees to include a reliable hardened vent in BWR Mark I and Mark II containments
 - Supported recommendation to perform a long-term evaluation (Tier 3) on reliable hardened vents for other containment designs.

Background

- In addition, the Commission directed the staff to
“...quickly shift the issue of ‘Filtration of Containment Vents’ from the ‘additional issues’ category and merge it with the Tier 1 issue of hardened vents for Mark I and Mark II containments...”

Background

- In February 2012, the staff recommended the following actions in SECY-12-0025:
 - Proposed order to require a reliable hardened vent for BWR Mark I and Mark II containment designs
 - Prevention of core damage
 - No requirements for severe accident service
 - Severe accident service and filtration to be treated as a separate (Tier 1) issue
 - Commission Policy Paper to address these issues
 - Original date of July 2012 is now November 2012

Staff Actions

- March 12, 2012 - Reliable Hardened Vents Order issued
- Following issuance of the order, the staff has been reviewing issues relating to severe accident service and filtration
 - Review Past Regulatory Actions
 - Insights from Fukushima
 - Foreign Experience
 - Technical Analysis
 - MELCOR/MAACS Cases
 - PRA Risk Insights
 - Analysis of FCVS in Severe Accident Management
 - Public/Stakeholder Outreach

Staff Actions

- Consulted Foreign Regulators and Licensees
 - Swedish Radiation Safety Authority (SSM)
 - Swiss Federal Nuclear Safety Inspectorate (ENSI/HSK)
 - Canadian Nuclear Safety Commission (CNSC)
 - Vattenfall (Sweden)
 - Kernkraftwerk Leibstadt (KKL)
 - Kernkraftwerk Mühleberg (KKM/BKW)
 - NB Power (Point Lepreau Owner/Operator),
 - Ontario Power Generation (OPG).
- Sites Visited
 - Forsmark Unit 2 – similar to Mark II
 - Ringhals Unit 1 – similar to Mark II
 - Leibstadt – Mark III
 - Mühleberg – similar to Mark I
 - Point Lepreau Nuclear Generating Station (Large Dry)

Staff Actions

- Public Meetings
 - Overview of filtered venting issue: May 2 and May 14
 - FCVS technology, research and testing: July 12 (AREVA) and September 4 (PSI)
 - Industry strategies for mitigating radiological releases: August 8 (EPRI)
- ACRS
 - May 22, 2012
 - September 5, 2012

Project Overview

- Upcoming Public Meetings
 - MELCOR Analysis of Filtered Vents for Boiling Water Reactor Mark I Containments (RES) and Public Stakeholder Input (9/13)
 - Tentative October Meeting
- Steering Committee Alignment and Review of Draft Commission Paper
- ACRS Review
 - October 3, 2012 (Subcommittee)
 - November 1, 2012 (Full Committee)
- November 20 – Final SECY Paper to OEDO

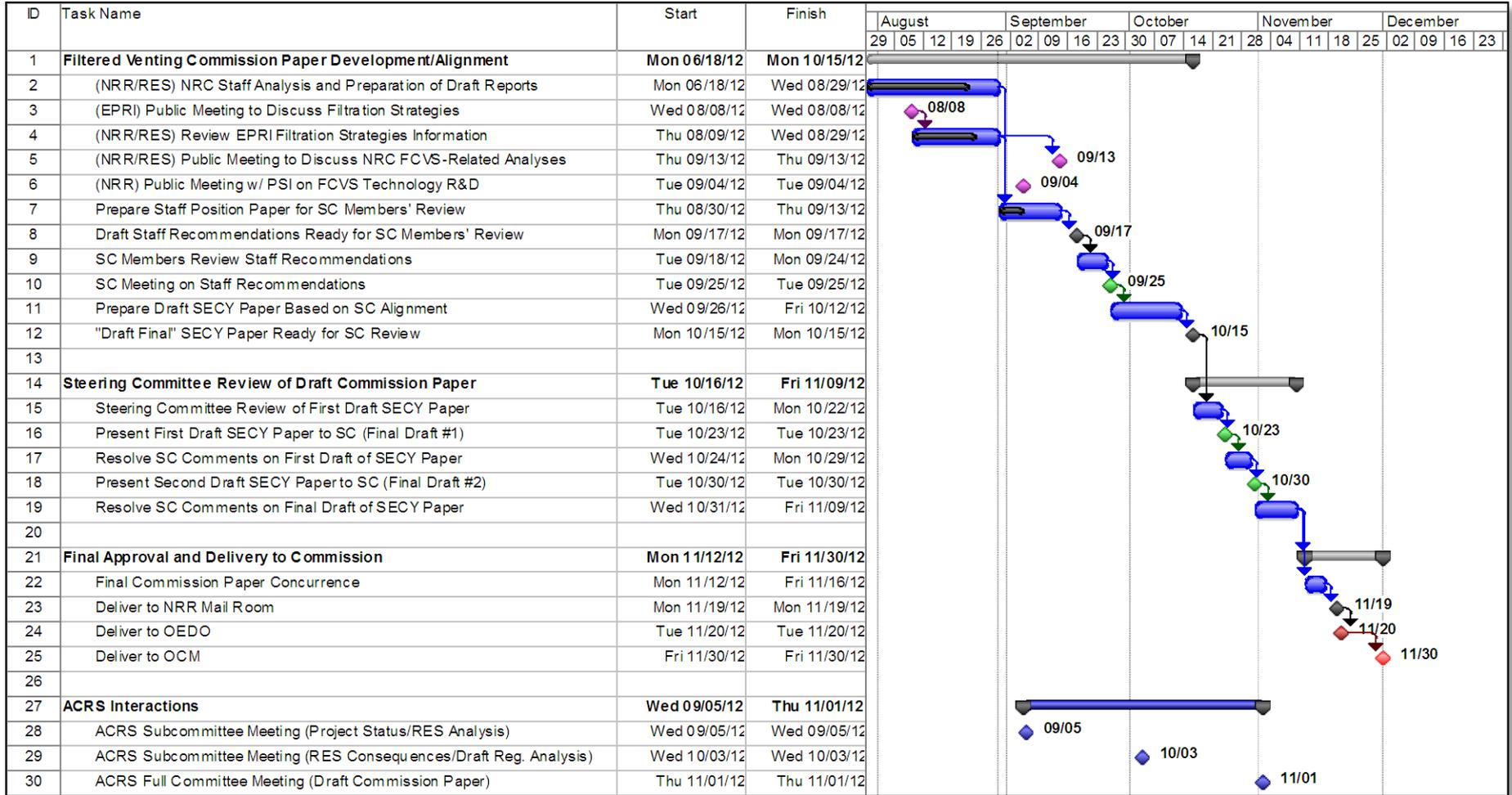
Office of Nuclear Regulatory Research

MELCOR Analysis of Filtered Vents for Boiling Water Reactor Mark I Containment

Analysis of Filtered Venting for
BWR Mark I Containments

Backup Slides

Project Milestone Schedule



Order EA-12-050 - Reliable Hardened Vents

- Applicable to BWR Mark I and Mark II containments
- Control containment pressure by removing heat, if normal capability is lost
- Prevention of core damage
- Must be able to function under SBO conditions
- Recommendation on filtration of vents proposed to be presented to Commission in November

Order EA-12-050 - Reliable Hardened Vents

- ✓ Issue draft guidance – Complete
- ✓ Issue final guidance – Complete
- Initial implementation update – October 31, 2012
- Implementation plan submittal – February 2013
- Full implementation complete – December 2016

MELCOR Analysis of Filtered Vents for Boiling Water Reactor Mark I Containment

Presentation to:
ACRS Fukushima Subcommittee
September 5, 2012

S. Basu, A. Notafrancesco, and R. Lee
RES/DSA/FSCB

Presentation Outline

- Objective and Scope
- MELCOR Calculations
- Discussion of Results
- Decontamination Factor
- Insights from MELCOR Analysis
- Follow-on Activities

Objective

- Objective
 - Provide technical support to NRR/JLD in addressing the containment venting issue (SRM for SECY-11-0137):
 - *The staff should quickly shift the issue of “Filtration of Containment Vents” from the “additional issues” category and merge it with the [NTTF] Tier 1 issue of hardened vents for Mark I and Mark II containments such that the analysis and interaction with stakeholders needed to **inform a decision on whether filtered vents should be required** can be performed concurrently with the development of the technical bases, acceptance criteria, and design expectations for reliable hardened vents.*

Scope

- Scope
 - Perform MELCOR calculations
 - Various prevention/mitigation actions
 - Venting with and without filter
 - Calculations informed by SOARCA and Fukushima
 - Perform MACCS consequence calculations using MELCOR output
 - Provide event sequences and probabilities for risk assessment
- Products
 - Consequence and frequency estimates for regulatory analysis

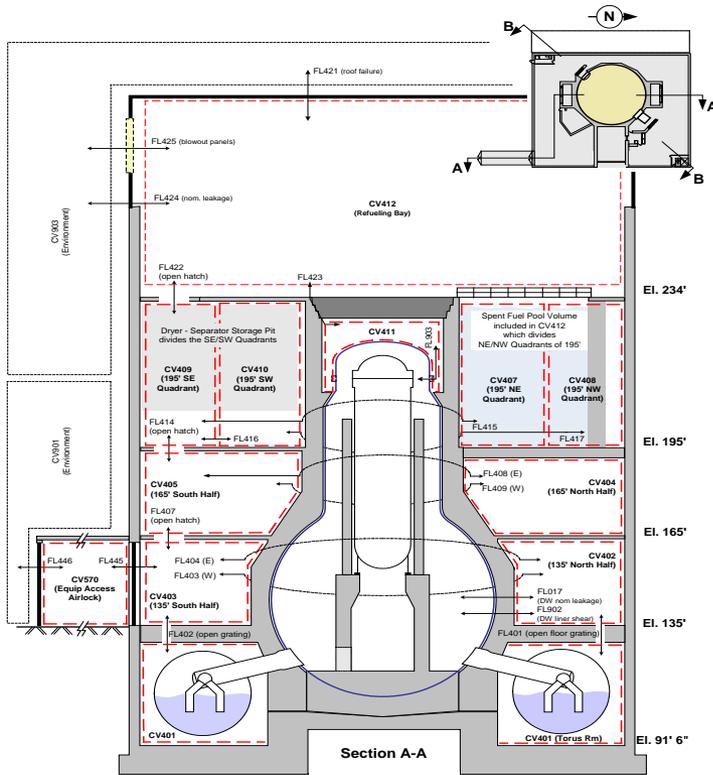
MELCOR Calculations

- Accident scenarios
 - Informed by SOARCA and Fukushima
 - Focus on long-term SBO
- Prevention/mitigation actions
 - RCIC, core spray, drywell spray
 - Containment venting (with and without filters)
- Sensitivity analysis
 - Spray flow rate
 - Spray actuation timing
 - Passive versus active venting
 - RCIC duration

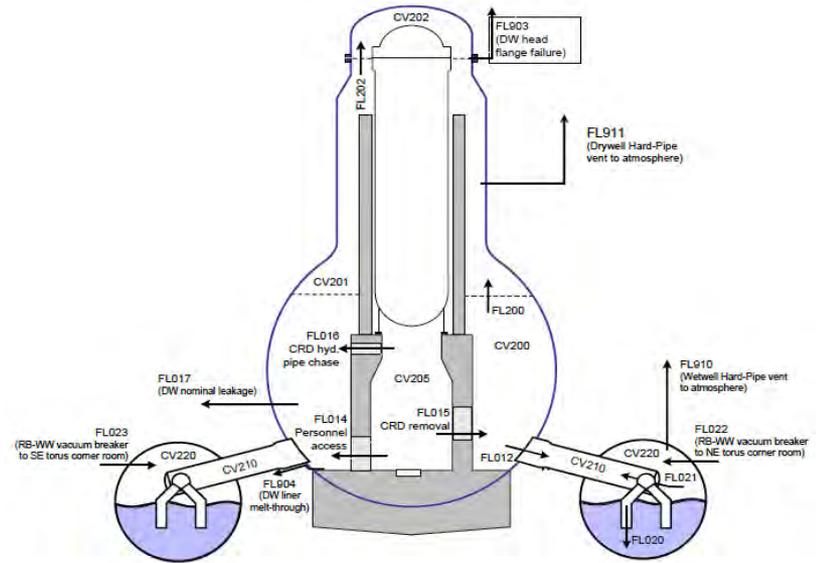
MELCOR BWR Model

- Based on Peach Bottom SOARCA Model
 - Control volume and flow path representation of RPV, RCS, and containment
 - Modeling of mitigation features (RCIC, spray)
 - Representation of pressure control (e.g., SRV logic, vent cycling)
- Modifications made for containment venting study
 - Solidus-liquidus revised for melt spreading
 - Finer nodalization of wetwell volume
- Same MELCOR version as in SOARCA uncertainty analysis

MELCOR BWR Nodalization



Reactor Building Nodalization



Containment Nodalization

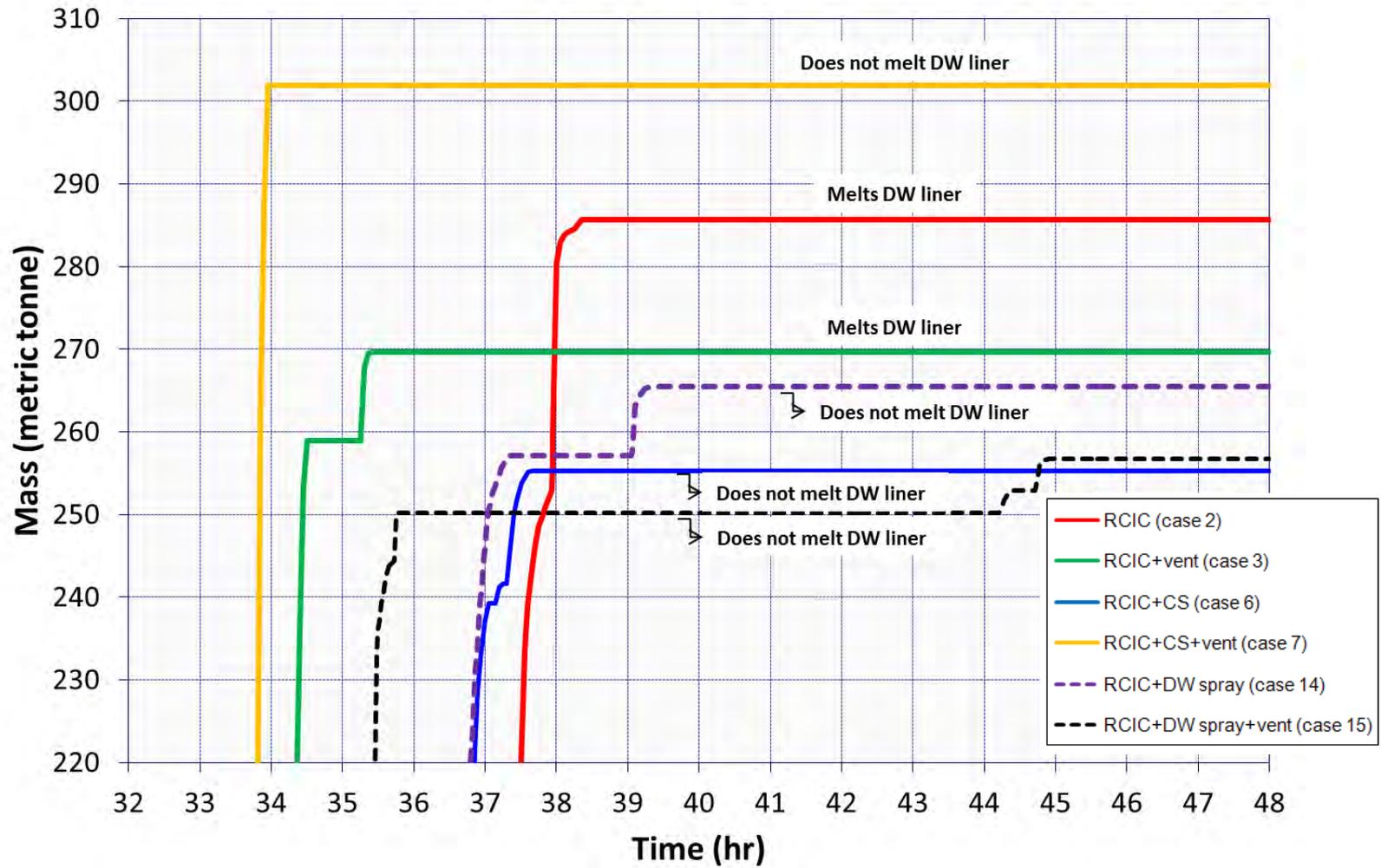
Example Matrix of MELCOR Calculations

Event Timing (hr.)	Case 2 RCIC only	Case 3 RCIC + vent	Case 6 RCIC + core spray	Case 7 RCIC + core spray + vent	Case 14 RCIC + drywell spray	Case 15 RCIC + drywell spray + vent
Station blackout	0.0	0.0	0.0	0.0	0.0	0.0
RCIC flow terminates	17.9	17.9	17.9	18.0	17.9	17.9
Core uncover	22.9	22.9	22.9	22.9	22.9	22.9
Relocation of core debris to lower plenum	25.9	25.9	25.9	25.8	25.7	25.6
RPV lower head failure	37.3	34.3	36.7	33.8	36.6	35.3
Drywell pressure > 60 psig	22.8	22.8	23.3	23.2	23.2	23.3
Drywell head flange leakage (>80 psig)	25.5	---	25.4	---	25.8	---
Drywell liner melt-through	40.3	36.6	---	---	---	---
Calculation terminated	48	48	48	48	48	48

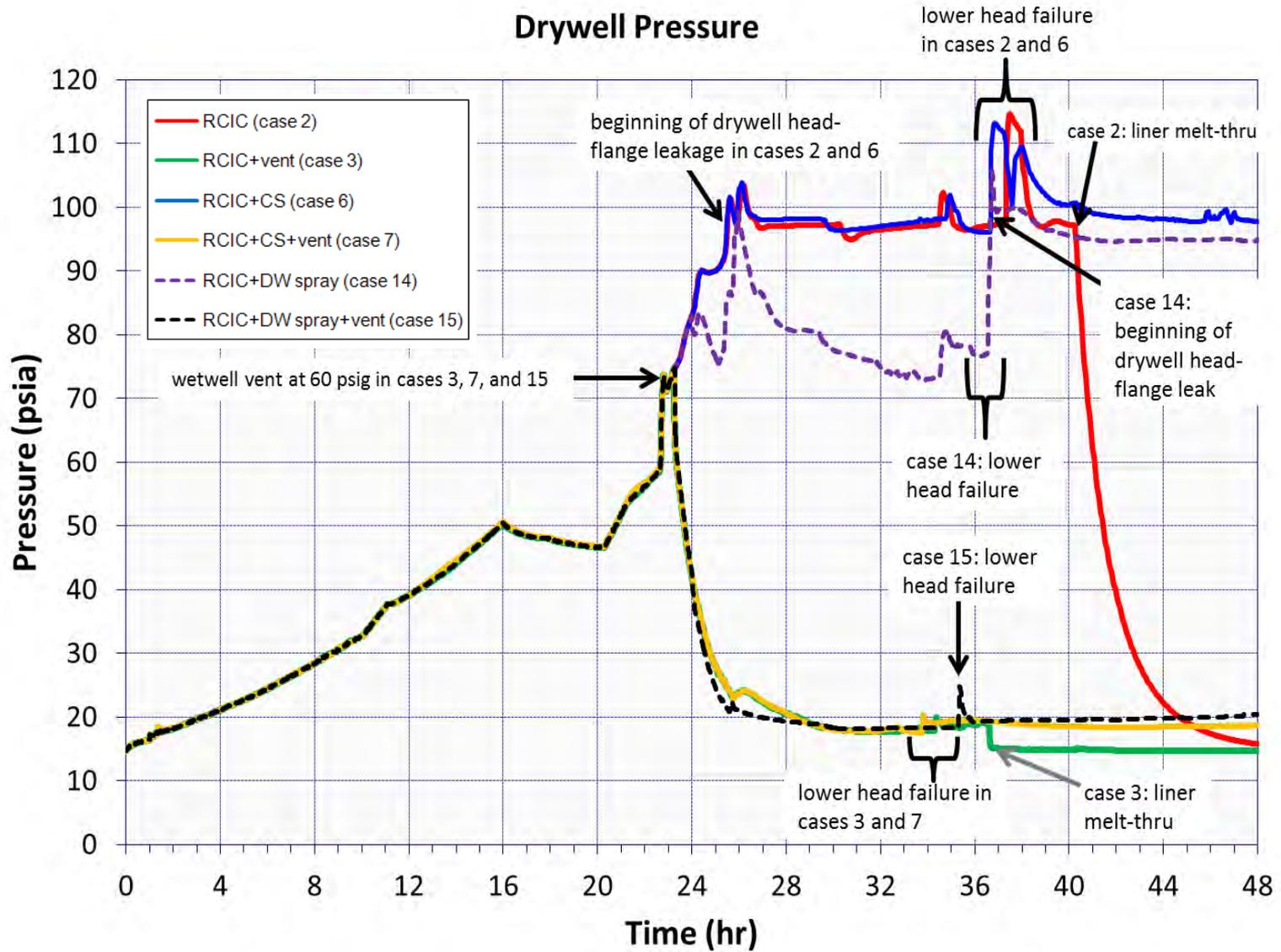
Selected Results of MELCOR Calculations

Selected MELCOR Results	Case 2 RCIC only	Case 3 RCIC + vent	Case 6 RCIC + core spray	Case 7 RCIC + core spray + vent	Case 14 RCIC + drywell spray	Case 15 RCIC + drywell spray + vent
Debris mass ejected (1000 kg)	286	270	255	302	267	257
In-vessel hydrogen generated (kg-mole)	525	600	500	600	614	650
Ex-vessel hydrogen generated (kg-mole)	461	708	276	333	327	276
Other non- condensable generated (kg-mole)	541	845	323	390	383	270
Cesium release fraction at 48 hrs.	1.32E-02	4.59E-03	3.76E-03	3.40E-03	1.12E-03	3.01E-03
Iodine release fraction at 48 hrs.	2.00E-02	2.81E-02	1.70E-02	2.37E-02	5.41E-03	1.86E-02

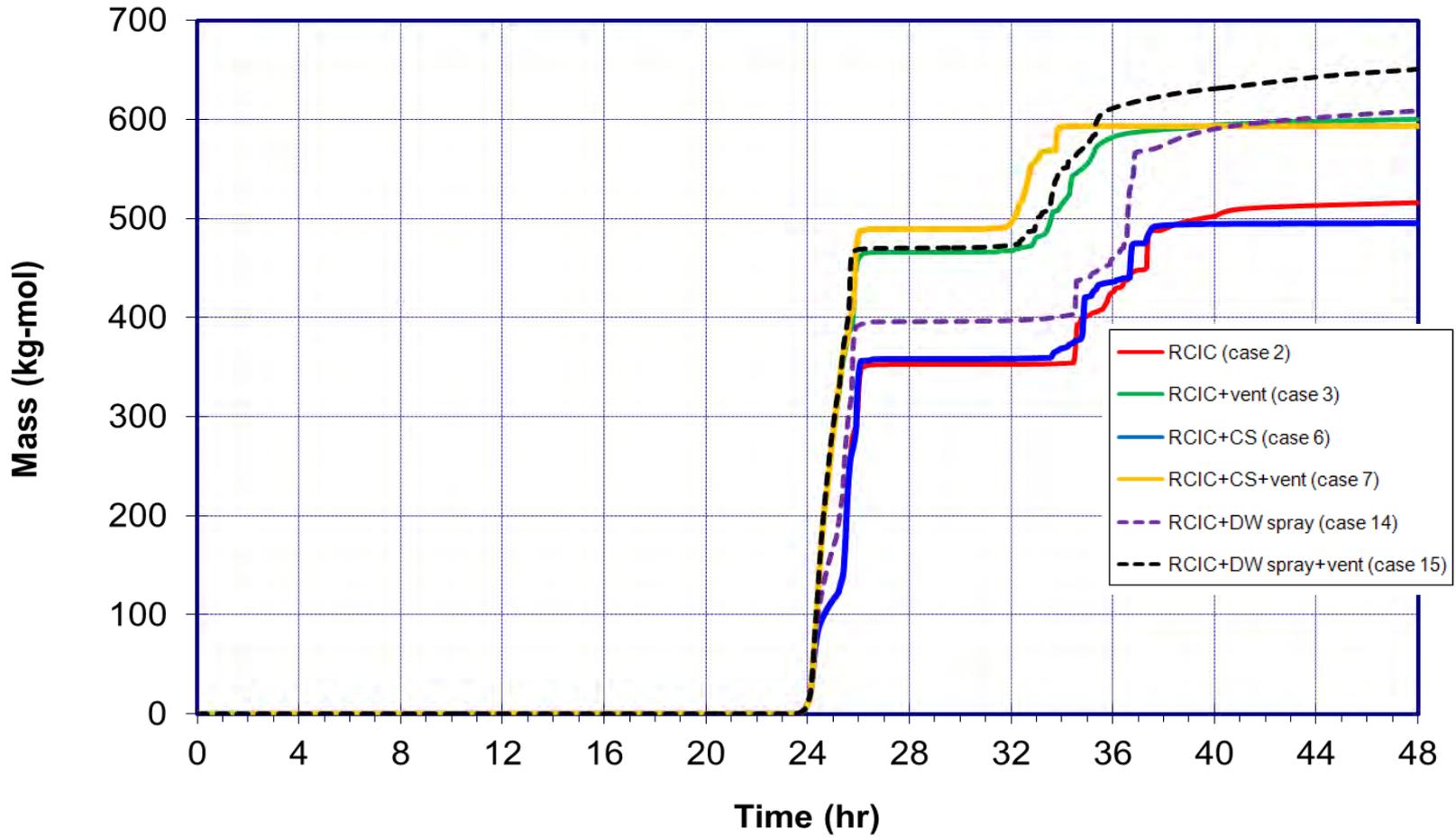
Debris Mass Exiting RPV



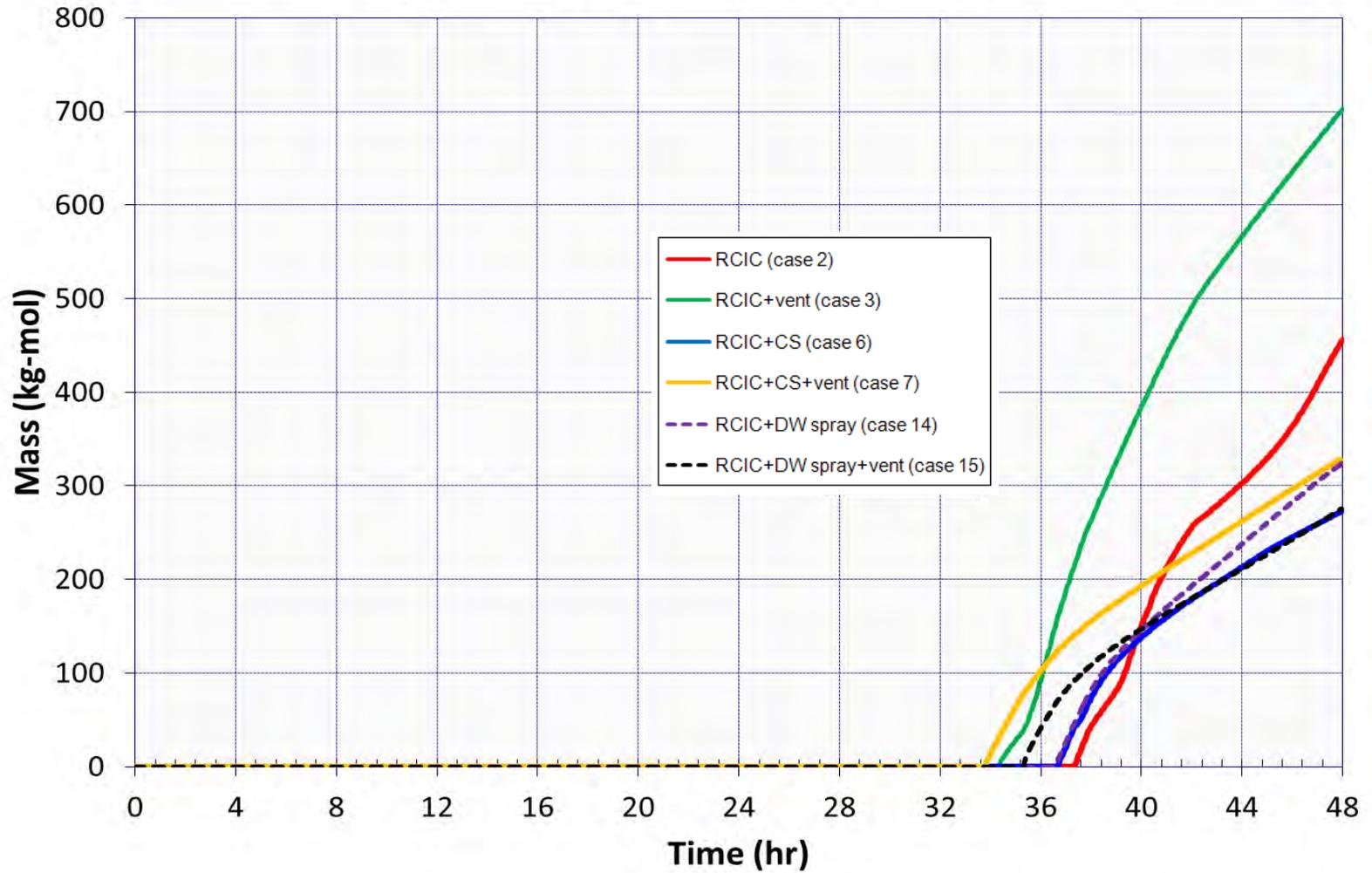
Drywell Pressure



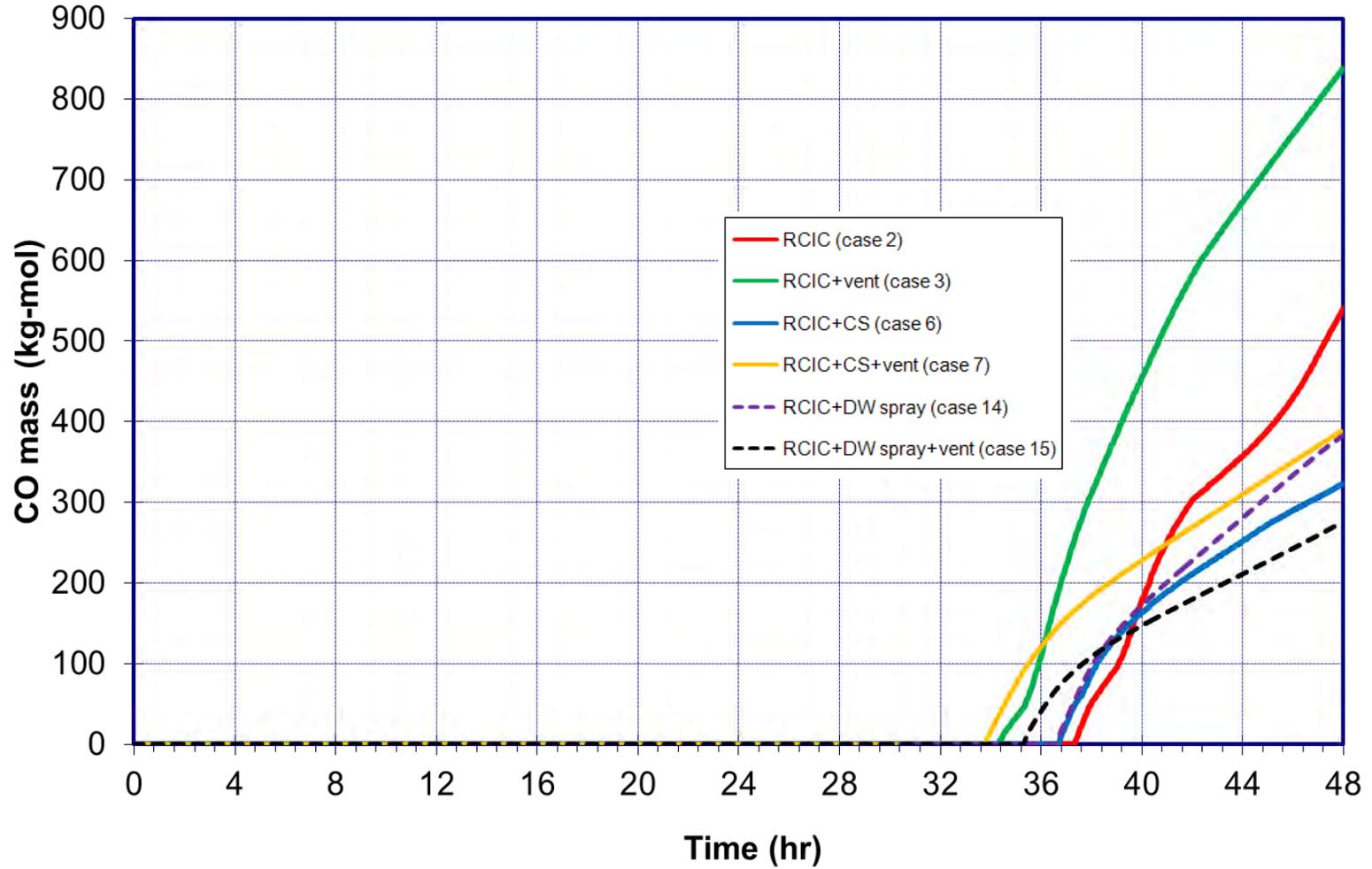
In-vessel Hydrogen Production (kg-mol)



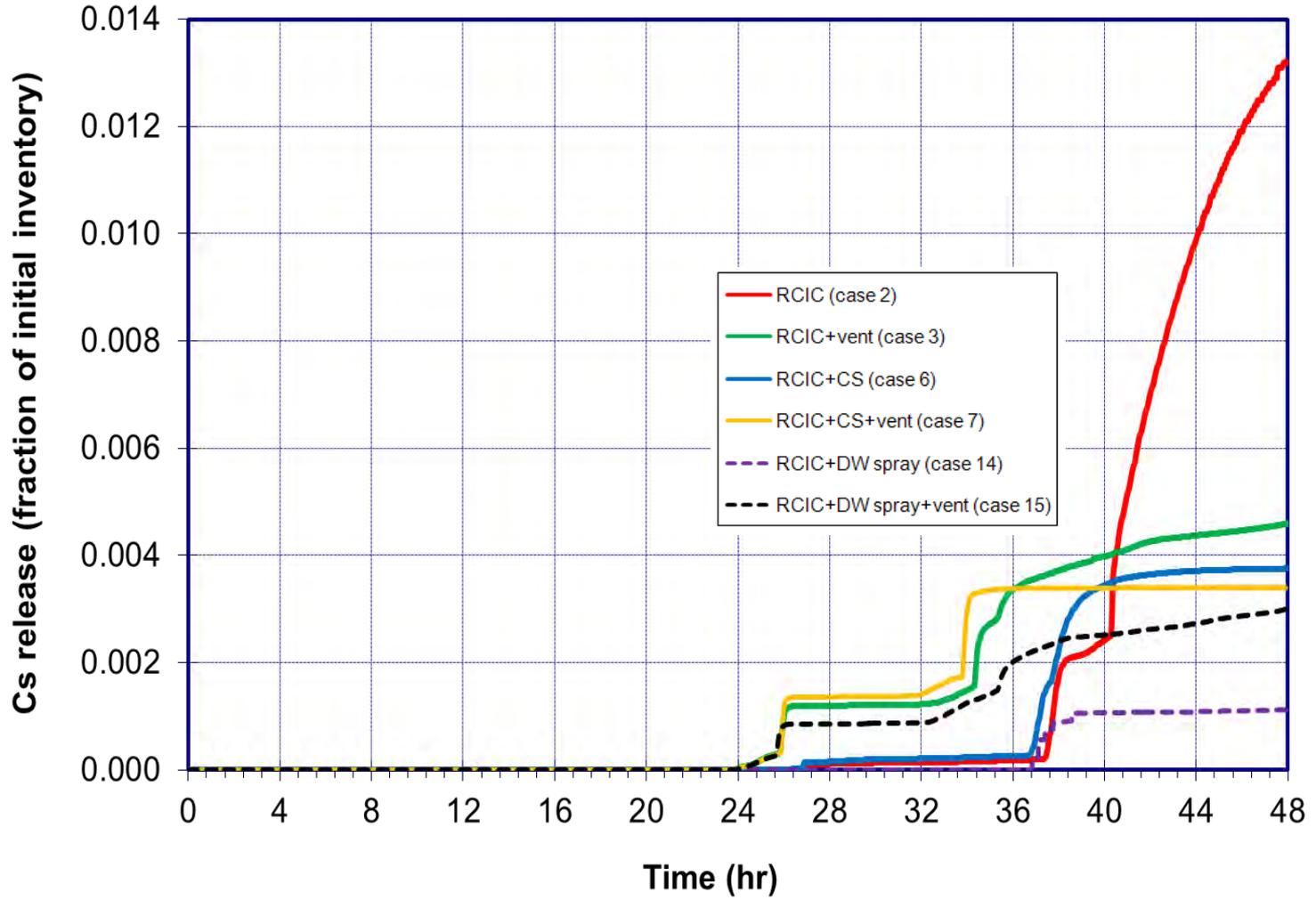
H2 Gas Generation from Core-Concrete Interaction



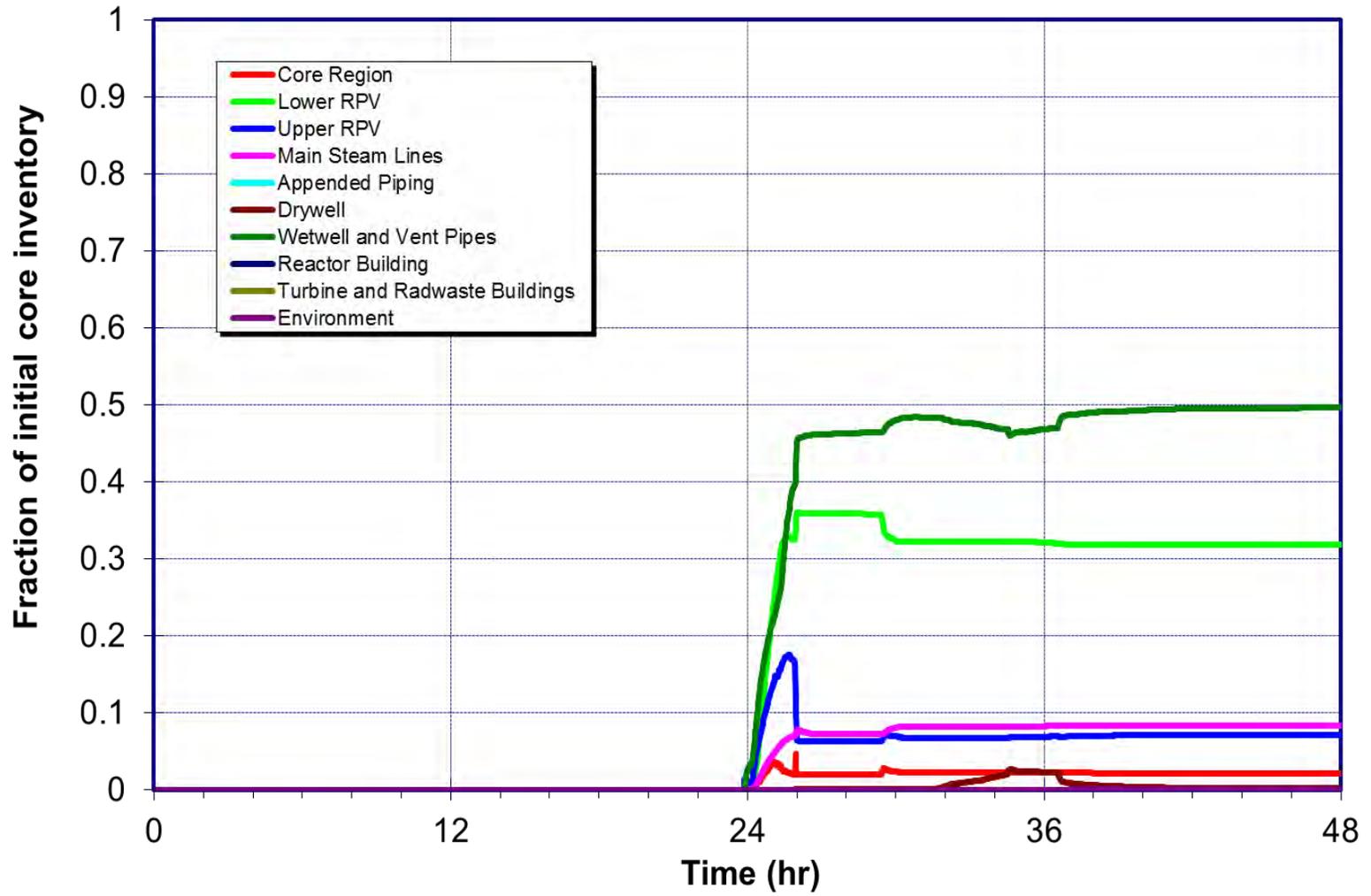
CO Generation by Core-Concrete Interaction



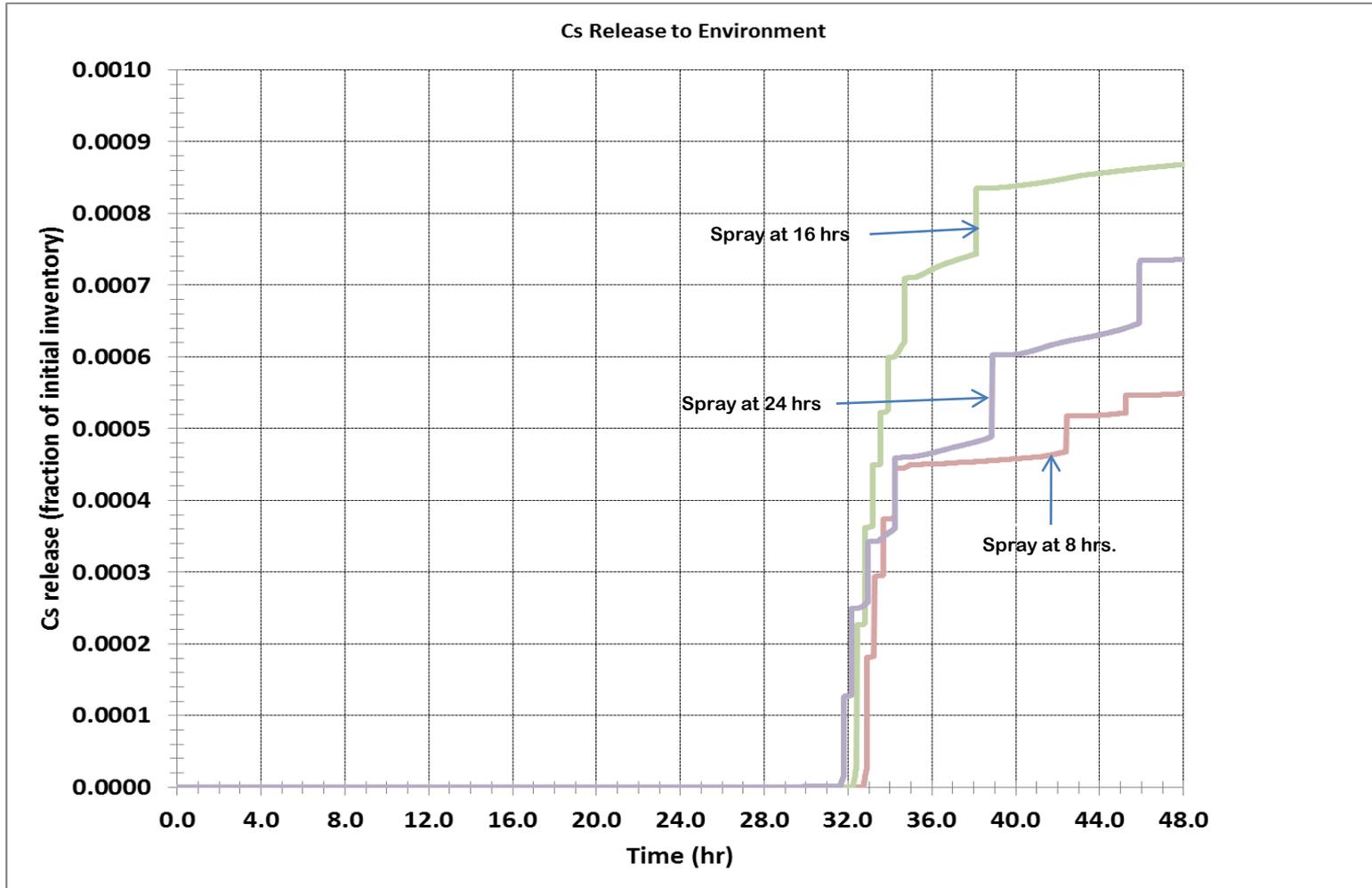
Cs Release to Environment



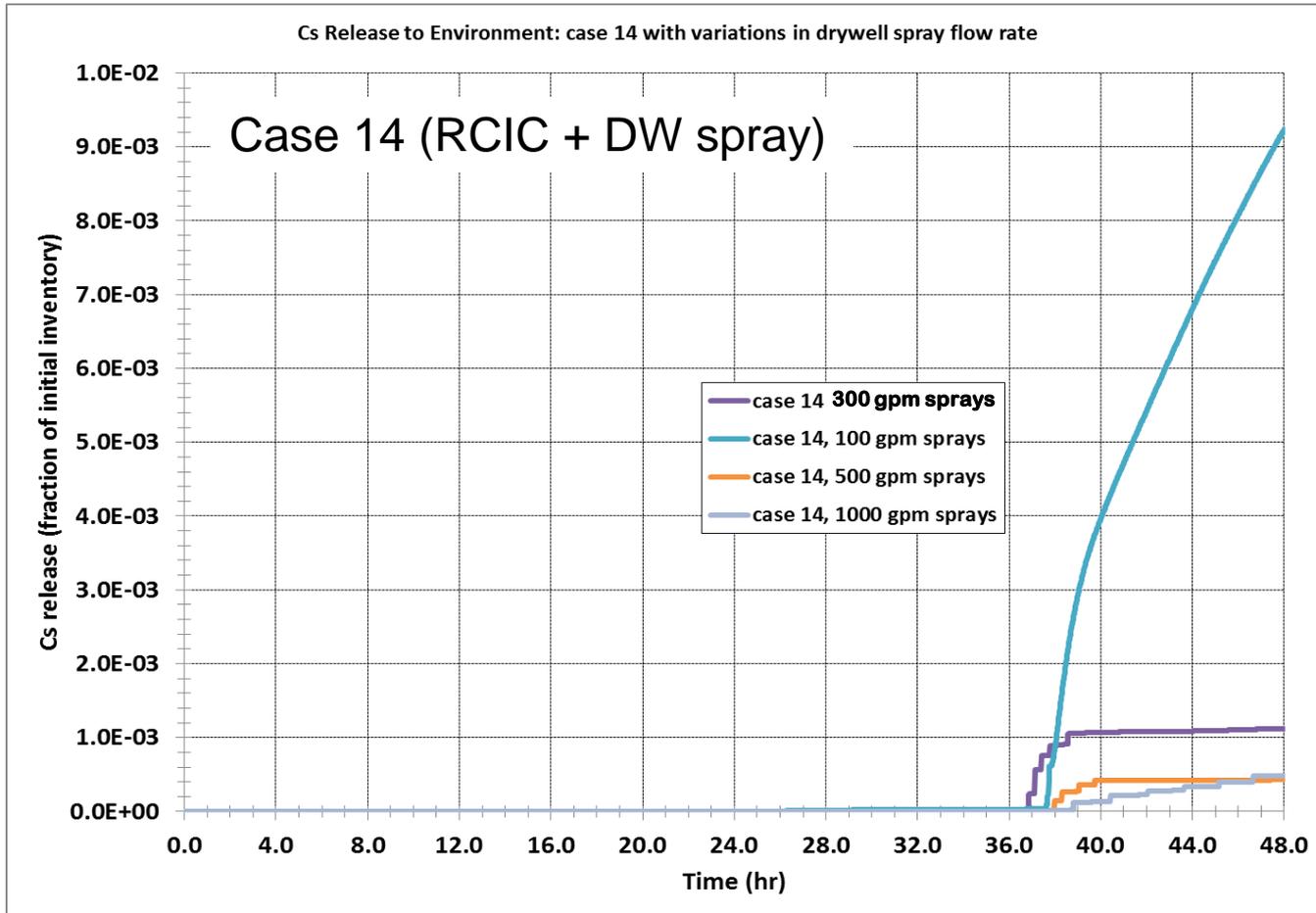
Cs Distribution - Case 14



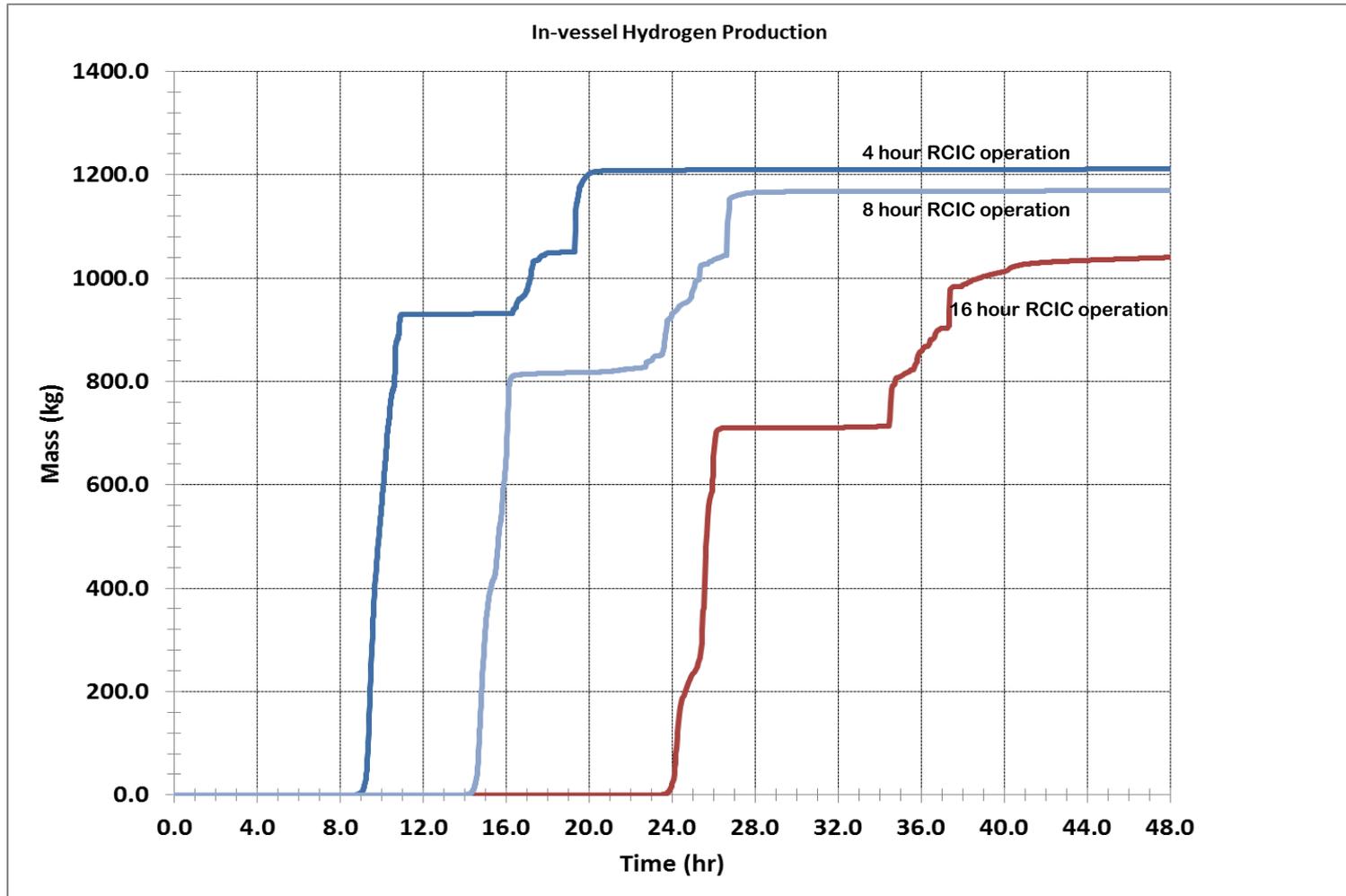
Effect of Spray Actuation Time



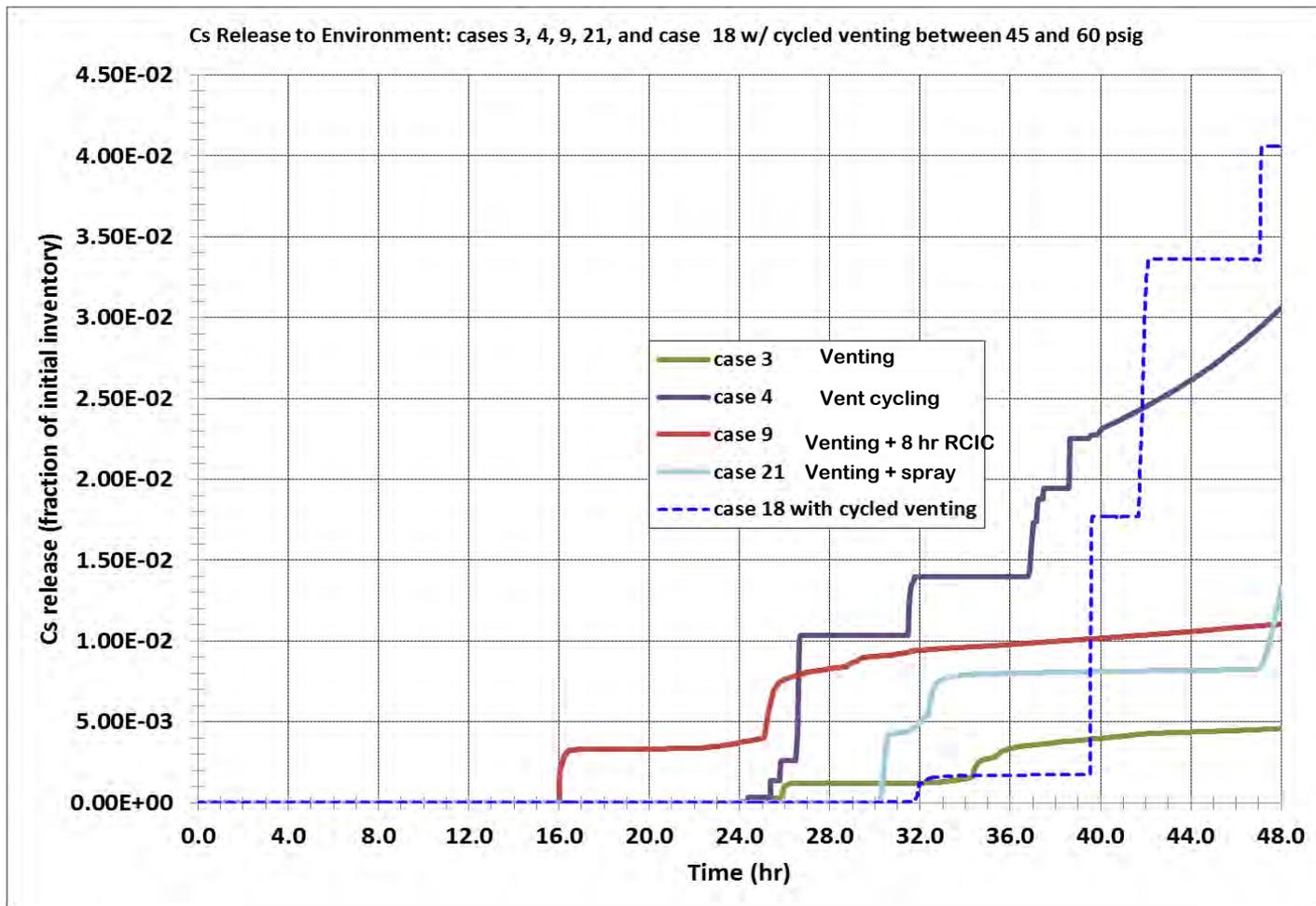
Effect of Spray Flow Rate



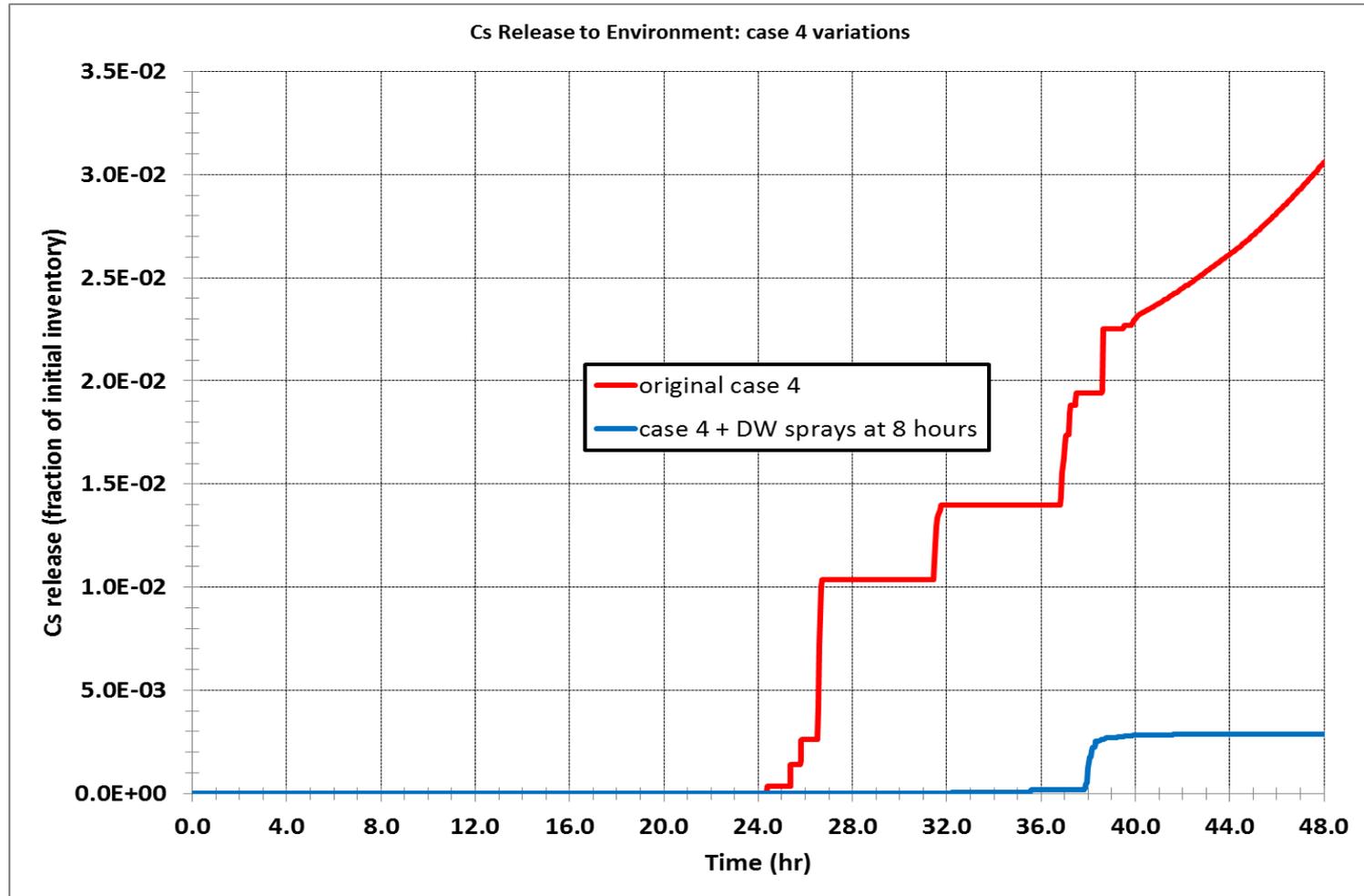
Effect of RCIC Duration



Effect of Vent Cycling



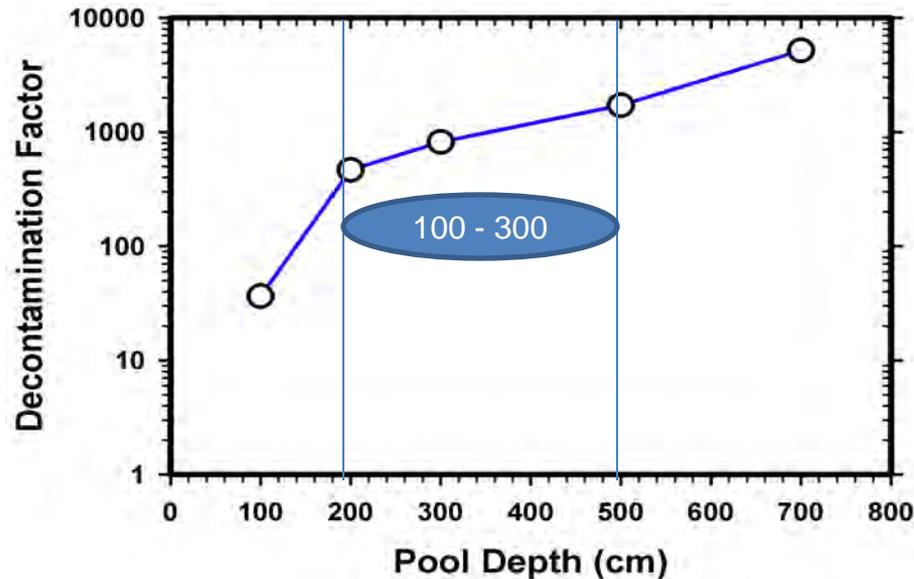
Effect of Vent Cycling (case 4)



Decontamination Factor

- Simply stated, decontamination factor is the ratio of aerosol mass in to aerosol mass out
- A good indicator of how much aerosol/fission products can be retained; alternatively, how much will be released to the environment
- Decontamination factor varies; range can be wide depending on the mechanism
- There are uncertainties in calculated decontamination factor; validation data base for decontamination models is limited

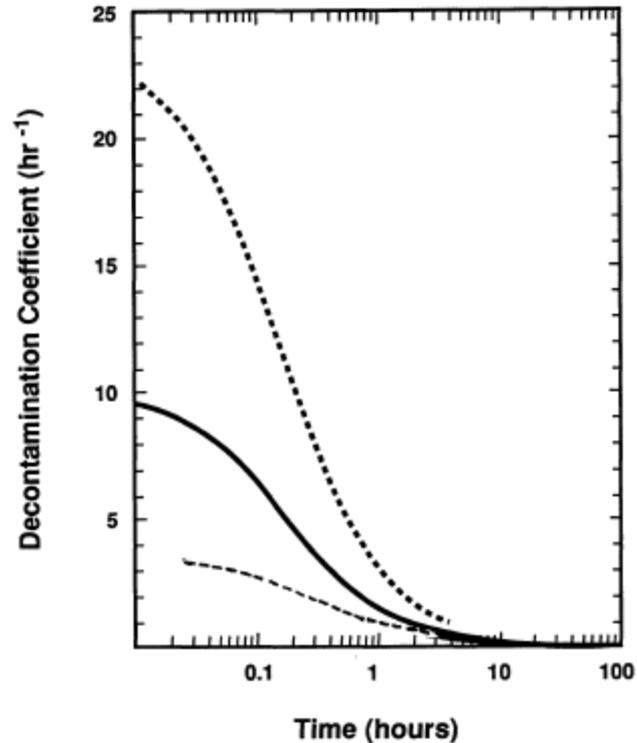
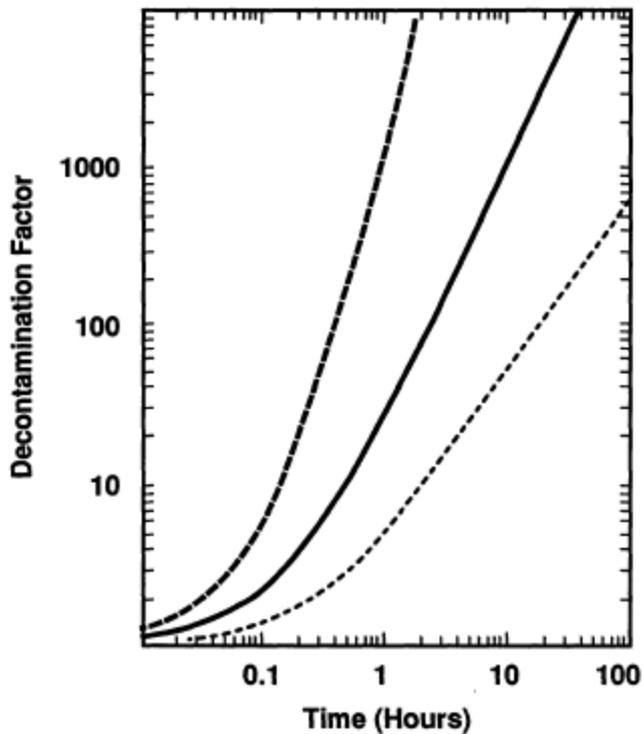
Estimated Suppression Pool Decontamination Factor (Ref: Dr. Dana Powers)



Case	Final DF at 48 hours
3	237
4	120
7	247
9	106
11	110
15	280
21	145
25	168

Estimated Containment Spray Decontamination Factor and Decontamination Coefficient

(Ref: Dr. Dana Powers, NUREG/CR-5966)



External Filtration Effect

- External filter is capable of providing additional fission product attenuation of already scrubbed aerosols
- Thus, external filtering has a direct influence on the amount of fission product release to environment, and consequent health effects and land contamination
- Traditional filter technology likely to provide very modest DF; however, improved filtration technology appears to be promising with regard to achieving high DF
- MELCOR does not have a mechanistic model for external filter; a prescribed value of DF is assumed for MACCS calculations

Insights from MELCOR Calculations

- Presence of water on the drywell floor (through spray or flooding action) is beneficial in preventing liner failure
- Venting or spraying alone is not likely to provide adequate reduction in fission product release to the environment
- Venting, however, prevents overpressurization failure
- MELCOR calculations do not show vent cycling to be more effective than once-open venting
- Combination of venting and spraying (or any mitigation action including water on the drywell floor) results in more reduction of fission product release

Insights from MELCOR Calculations

- Venting through wetwell provides an opportunity for fission product scrubbing in the suppression pool
- Pool scrubbing efficiency can be appreciable (decontamination factor in the range between 100 and 300 in the calculations)
- Venting through drywell does not have pool scrubbing benefit; as such, fission product release through drywell vent is significantly higher
- Spray and drywell flooding also provide some scrubbing of fission products

Follow-on Activities

- MACCS calculations
 - MELCOR generated release estimates are used for MACCS calculations
 - MACCS provides the following information
 - Population dose
 - Site boundary dose
 - LCF and prompt fatalities risk
 - Land contamination estimates
 - Economic consequences
- Regulatory Analysis
 - MACCS output used for cost-benefit analysis within the regulatory framework
 - Consideration given to event sequences and probabilities for risk assessment

Filtered Containment Venting System

**ACRS Public Meeting, September 5th 2012
Rockville, MD**

IMI Nuclear (CCI AG)

Denis Grob – Manager Nuclear Services Division

Content

- Overview**
- How it works**
- Experimental base**
- Results**
- Installed Filtered Containment Venting System (FCVS)**
- Sizing**
- Why choosing the IMI Filter?**
- Conclusions**

Overview

- **The problem: The core damage scenario might require depressurization (venting) of the containment**
- **The solution: A first generation of filtered containment venting system (FCVS) has been installed on approximately 120 reactors worldwide**
- **A second generation of FCVS with a **unique filtering efficiency** has been developed by CCI and is ready for implementation**
- **Safety authorities and utilities have expressed interest to the proposed technology**

How does it work?

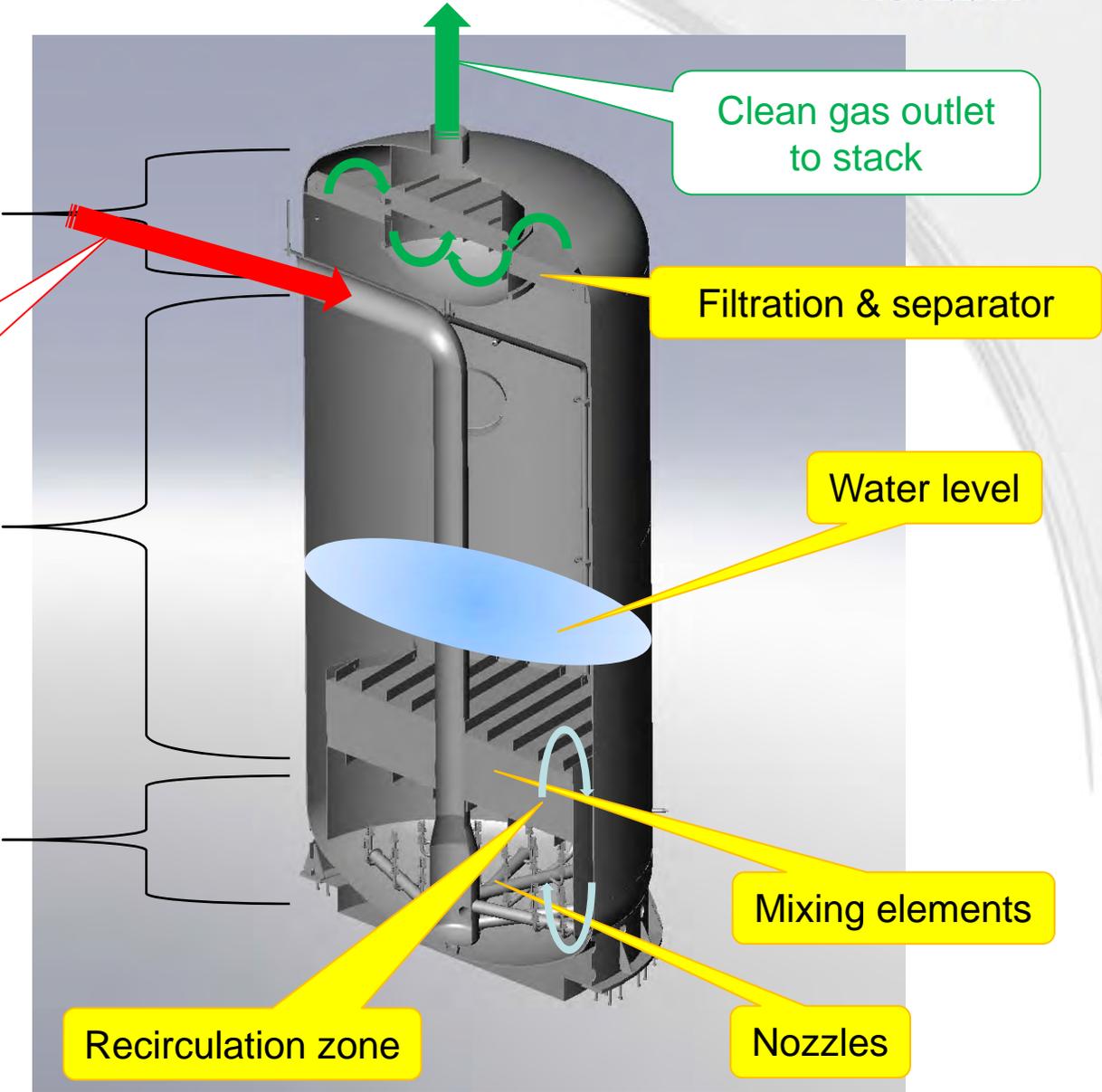
The filter vessel

Stage 3: End Separator

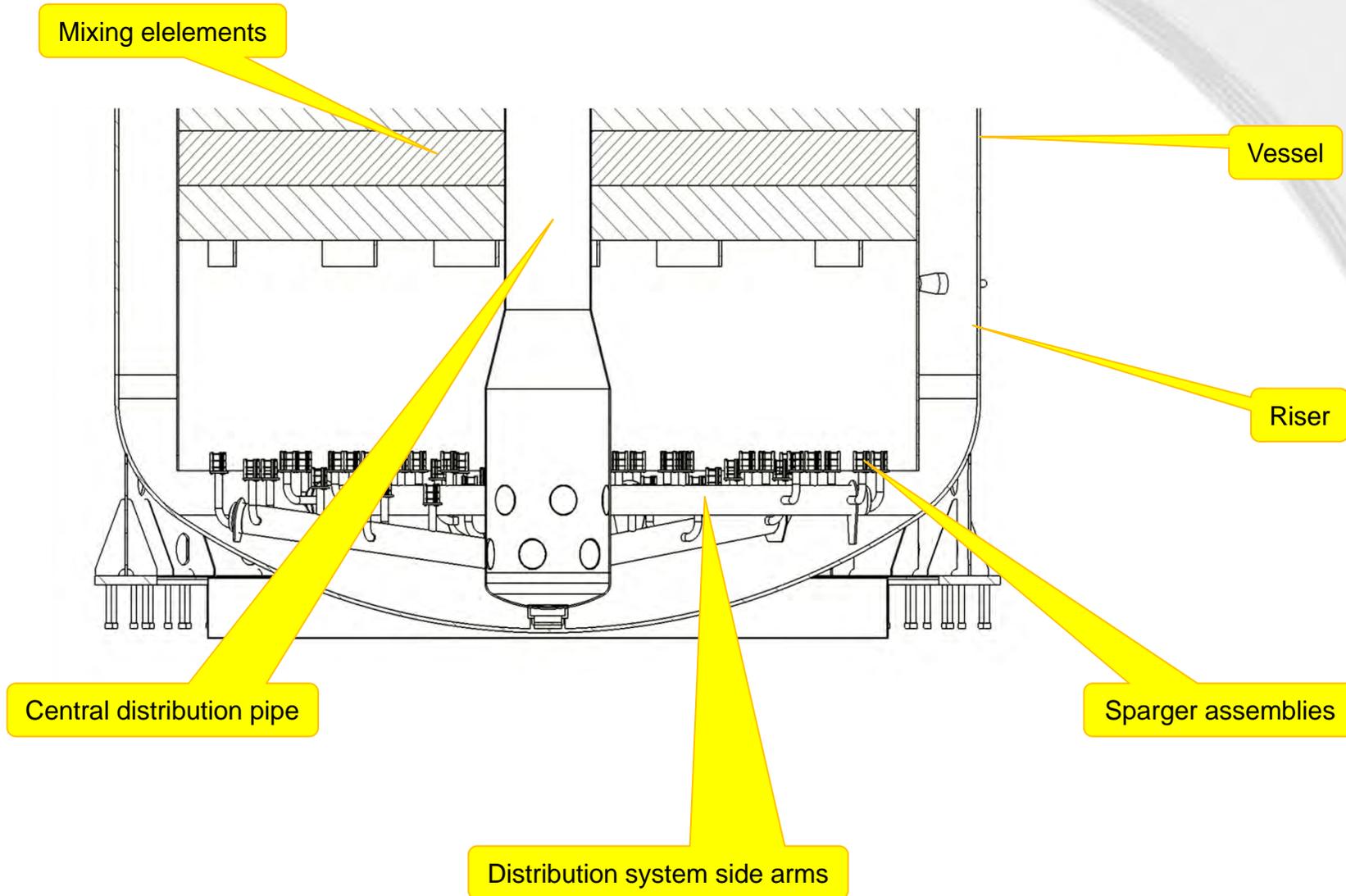
Contaminated gas inlet from containment

Stage 2: Co-current Scrubber & Gas volume

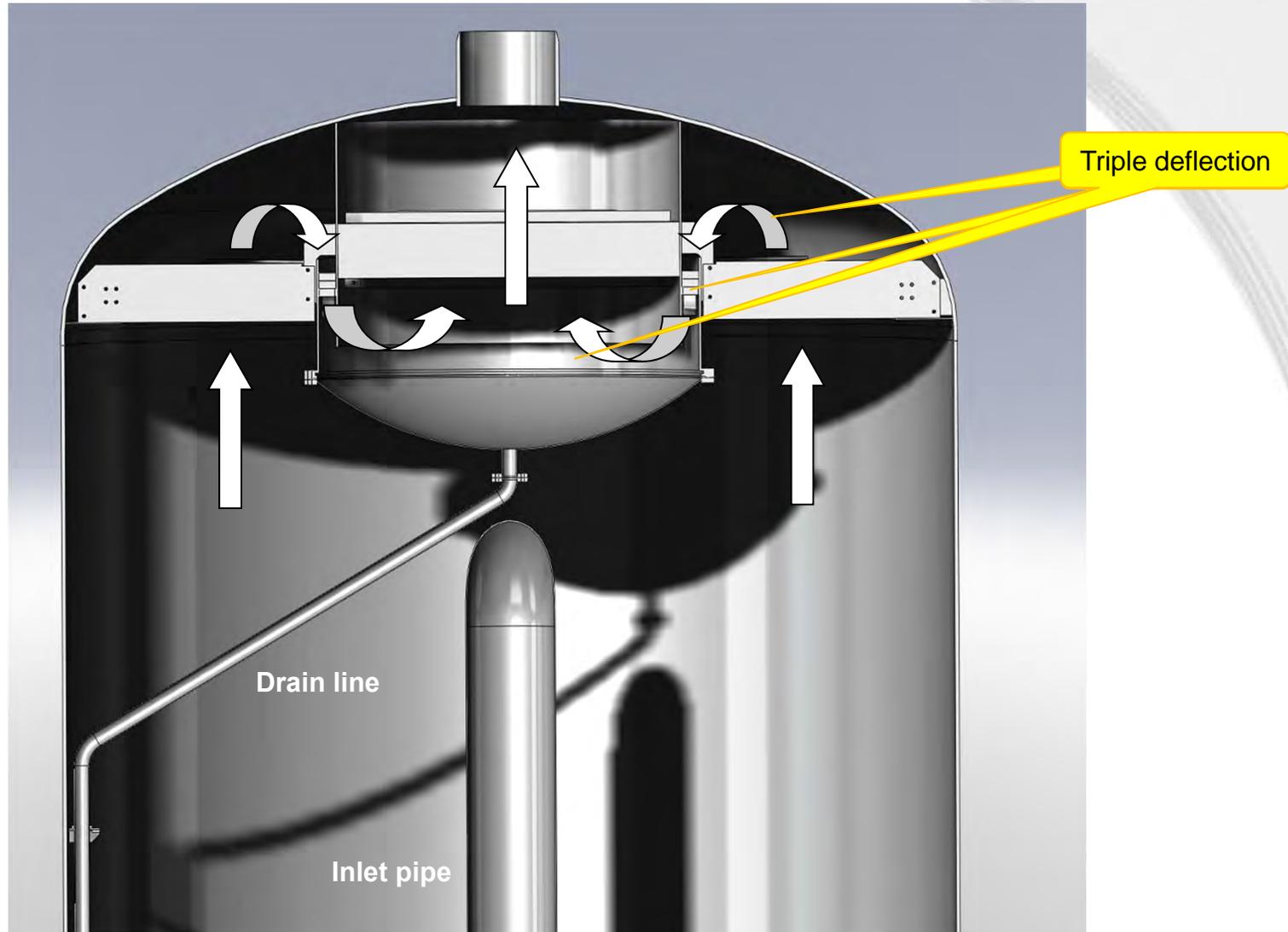
Stage 1: Nozzle Scrubber



How does it work – Stage 1, Nozzle scrubber



How does it work – Stage 3, end separator



How does it work – Summary

First Stage

- Efficient scrubbing by flow injection nozzle with special baffle plates:
 - disintegrating gas jet
 - strong turbulence for high mass and heat transfer
 - distribution of gas bubbles over whole cross section
 - Efficient bubble break-up
- Specified depressurization rate defined by flow limiting nozzle
- Arrest any flame propagation from containment by the water in the filter
- *Excellent decontamination for mid to high flows*

Second Stage

- Co-current scrubber within the core section increases mass transfer
- Large residence time through trapped bubbles in recirculation zone
- Gas volume for water level variation and suppression of droplet carry-over
- *Excellent decontamination for mid to low flows*
- **Chemistry to scrub and fix volatile iodine species unique to 2nd generation**

Third Stage

- Droplet separator

How does it work – Chemistry

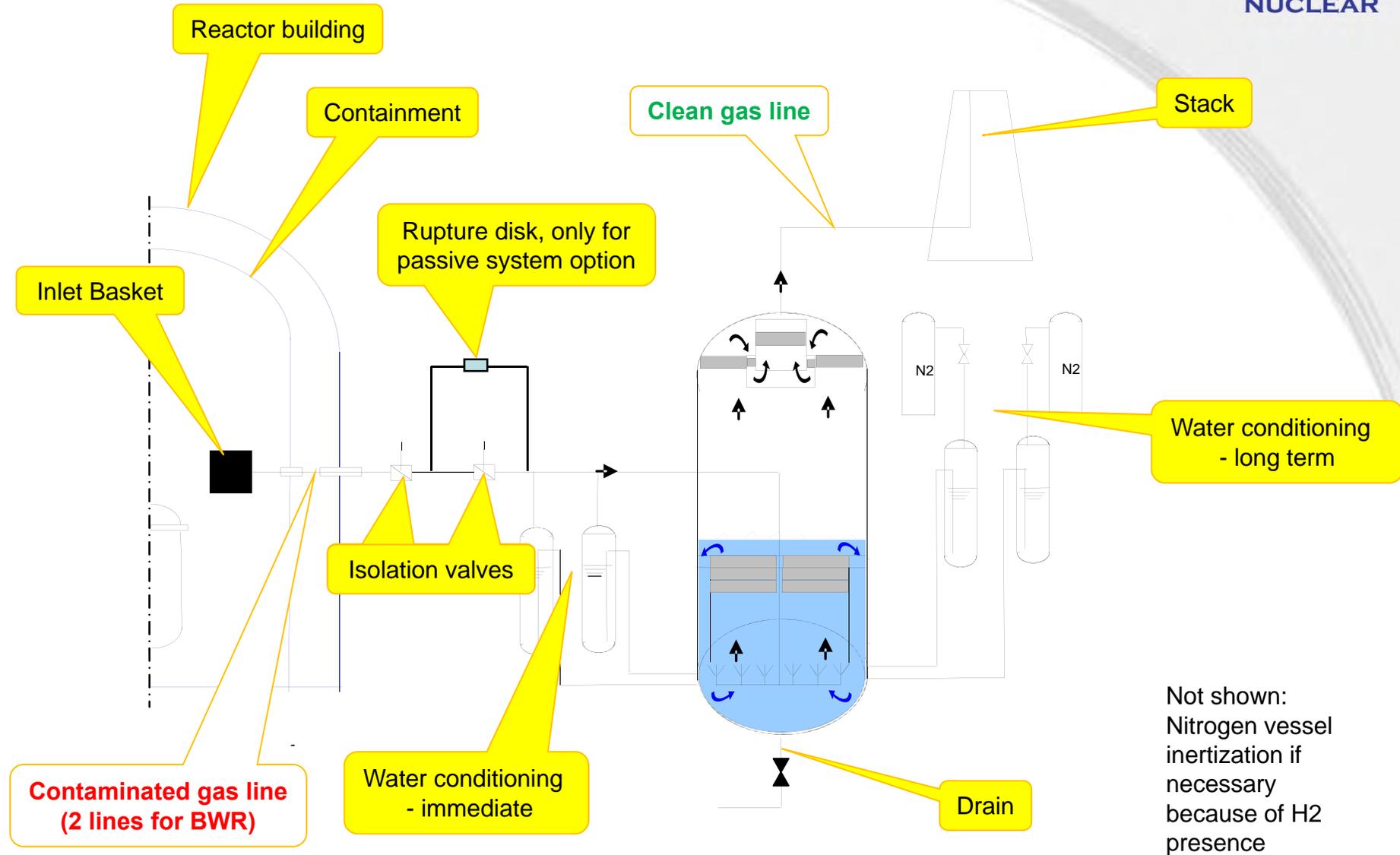
Efficient retention of iodine species in an aqueous solution with two processes occurring simultaneously and starting with the operation of the system:

1. **Faster reduction** (decomposition to I-) of all iodine species, especially the most volatile ones, with any oxidation level entering into the solution or generated in the solution into iodide ions by simultaneous use of a reducing agent (sodium thiosulfate) and a co-agent (phase transfer catalyst)
2. **Efficient retention** of iodide ions generated in the aqueous solution and/or entering into the solution in form of iodine salts **by suppressing the thermal and radiolytic oxidation (re-volatilization) of iodide ions by the use of the co-agent**

These faster reduction and retention processes are efficient at any state of the aqueous solution; strong acidic to strong basic solutions, cold to very hot solution, and under irradiation. **This allows for a long term retention of all iodines species in the filter vessel.**

The combination of fast reduction AND retention of iodines (patent granted) is the unique feature of the 2nd generation FCVS

How does it work – Layout



Experimental data base

R&D on FCVS – a short History

- CCI developed a FCVS in the 1980 time frame based on:
 - Extensive SULZER Experience in Filtration systems on:
 - Concurrent scrubbers (mixing elements) and distillation columns
 - SULZER mixing and filtration elements

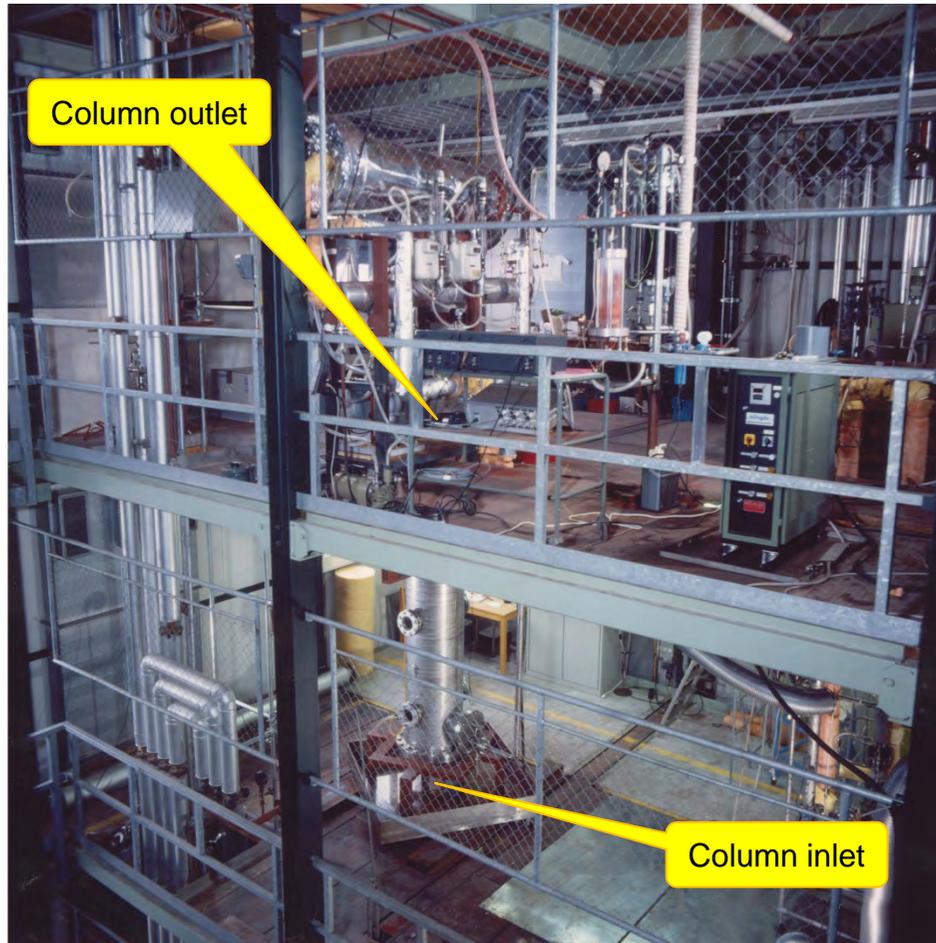
- An extensive development and qualification program was conducted at SULZER in the late 1980's and the early 1990's

- Verification tests and further qualification tests were conducted at the Paul Scherrer Institute (PSI) during 1994 to 2003

- Absolute retention of all gaseous iodine activity: Tests series with new chemistry dedicated to obtain fast and efficient destruction of volatile iodine species from 2002 to 2008

Experimental data base – Initial R&D

Aerosol test loop used for initial development and qualification <1993



Basic Testing of filtration Elements:

- Nozzles
- Co-current mixing elements
- Droplet separator

Full Scale Segment Testing:

- Filter qualification and variation of main parameters such as flow, temperature, aerosols
- Re-suspension (and clogging) of last stage

Experimental data base – Verification & further tests

Test loop used for Further Qualifications for Aerosol Retention at PSI (1993-1995)



Plasma used to evaporate tin powder. After condensation of tin vapor, SnO₂ particles are generated



Facility to prepare aerosol laden steam-gas mixture flow



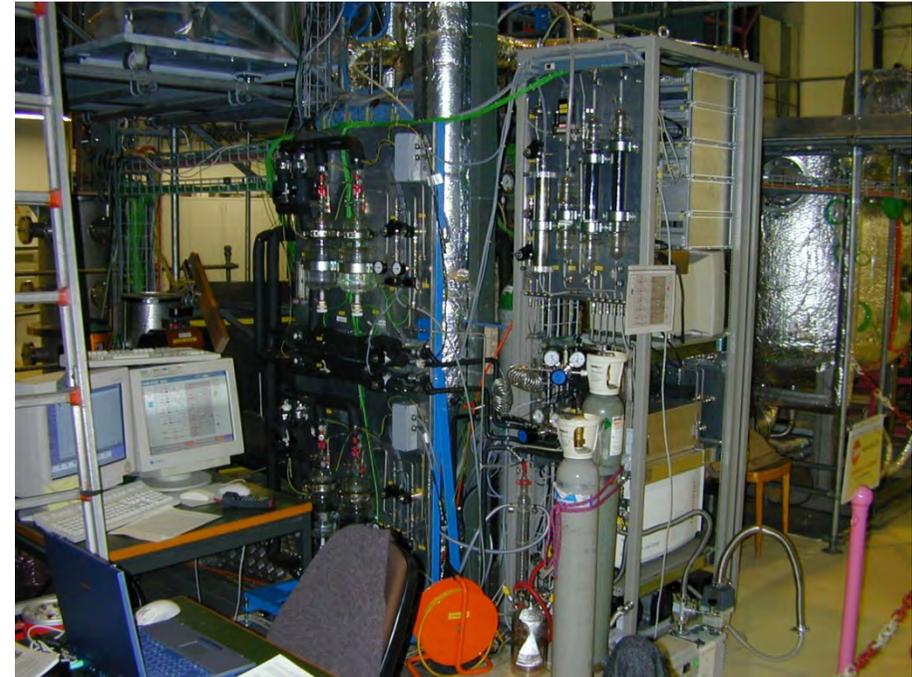
A representative module of FCVS filter used for aerosol tests

Experimental data base – Iodine retention tests

Qualification test for gaseous iodine species retention (2000 – 2002)



Iodine species generation and feed system



Iodine species on-line/grab sampling measurement system

No high retention of methyl iodide and I₂ obtained but finally...

Experimental data base – Iodine retention tests

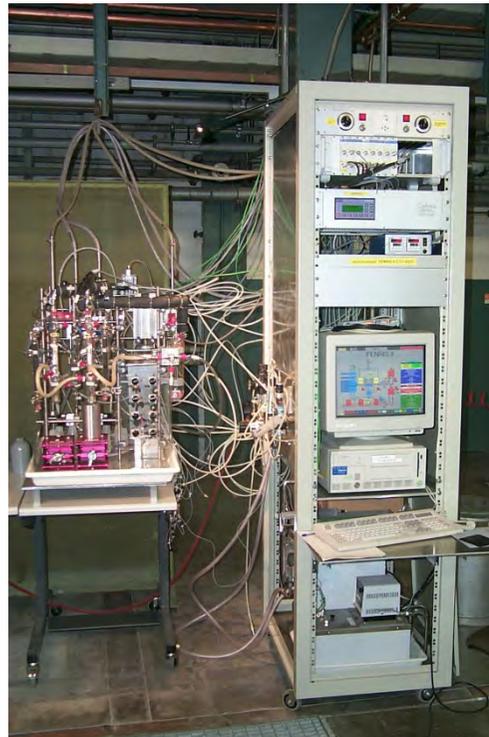
..the way to success with mastering iodine retention chemistry (2002 – 2008)

- Mastering iodine chemistry in aqueous phase to
 - Obtain fast and efficient destruction of volatile iodine species to iodide ions (methyl iodide representing all high volatile organic iodide species and I₂ for all other gaseous species)
 - Fix iodide ions to suppress their radiolytic and thermal oxidation
- Over 1000 tests conducted using I₂ and CH₃I covering:
 - Very acidic to strong basic solutions
 - Room to high solution temperature
 - A large range of initial CH₃I concentrations
 - A large range of individual and coupled usage of both additives
 - Effect of other impurities (irradiation products, fission products, etc.)
 - Small to large dose
 - Effect of in situ β-irradiation and external γ-irradiation
 - Static and dynamic systems
 - Effect of additives on the aerosol scrubbing

...with specially developed measurement techniques to follow chemical reaction products

Experimental data base – Iodine retention tests

Influence of radiation on iodine retention



Reaction vessel, apparatus for distillation and activity control systems as well as the remote control units are ready for the transfer to the hot cell for in-situ β irradiations



Reaction vessel in the γ -irradiation chamber and gamma-cell



Experimental data base – Conclusions of the tests (I)

- **Activity retention**, overall **minimum** decontamination factors (DF):

for the **2nd generation FCVS**:

in comparison with **1st generation FCVS requirements**:

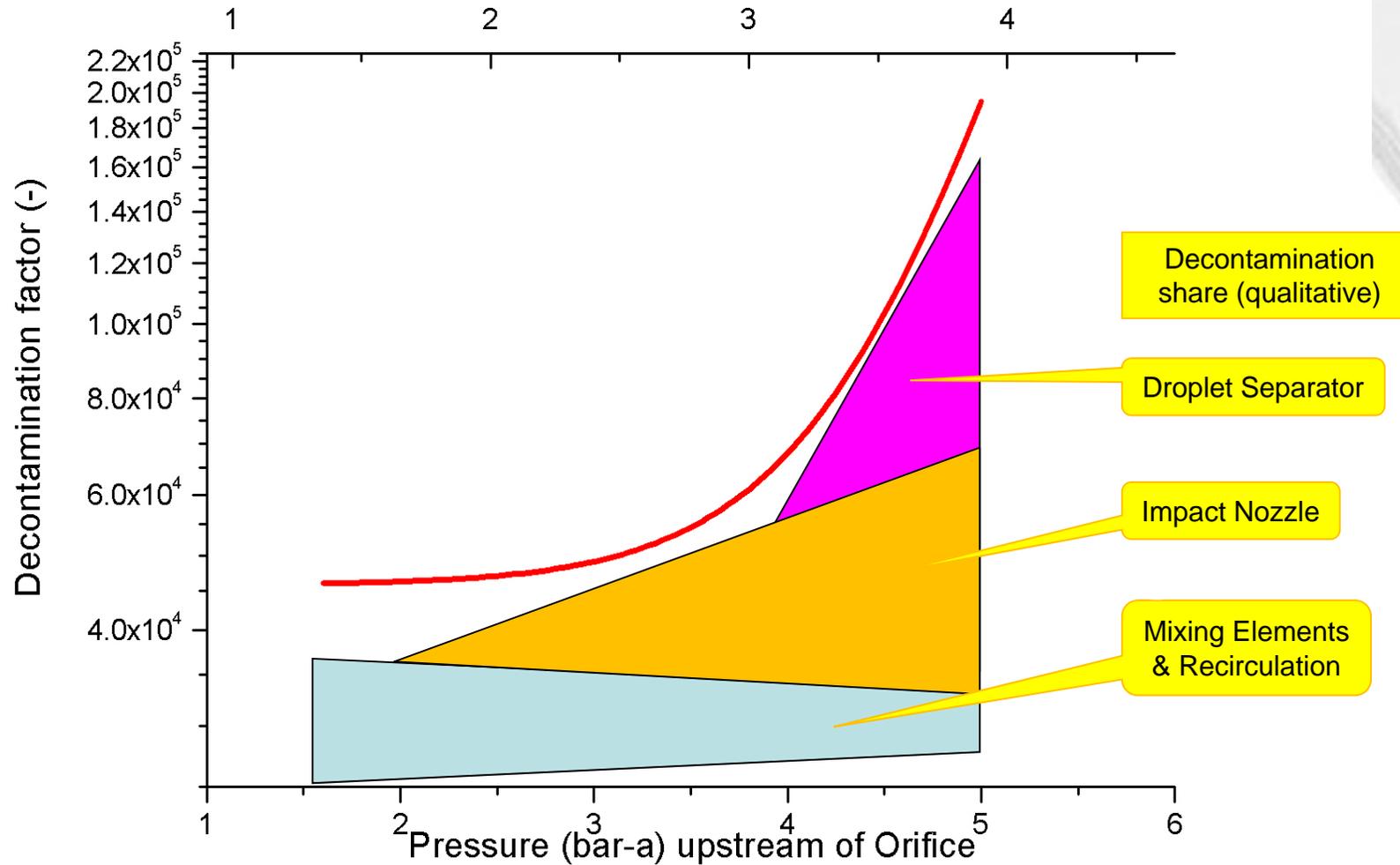
👍	Aerosols	» 10'000	> 1'000
👍	Elemental iodine (I₂)	> 1'000	> 100
👍	Organic iodide (CH₃I)	> 1'000	none!

In the following operational conditions:

- **Flow rate ratio of larger than 10**
- **Multiple venting** possible – no release of fission products (desorption, re-vaporization) because FP trapped in filter water only
- **Post venting** – no long term release of fission products **including iodine(s) bound** in filter water (re-volatilization) because of chemical binding
- No filter **clogging and hot spot** risk
- DF valid with low pH (3), all temperatures including boiling conditions, sub-micron to micron particle size, highest filter load

Experimental data base – Results

Pressure ratio across the filter



➤ Permanent sink for iodide ions enabling absolute iodine retention

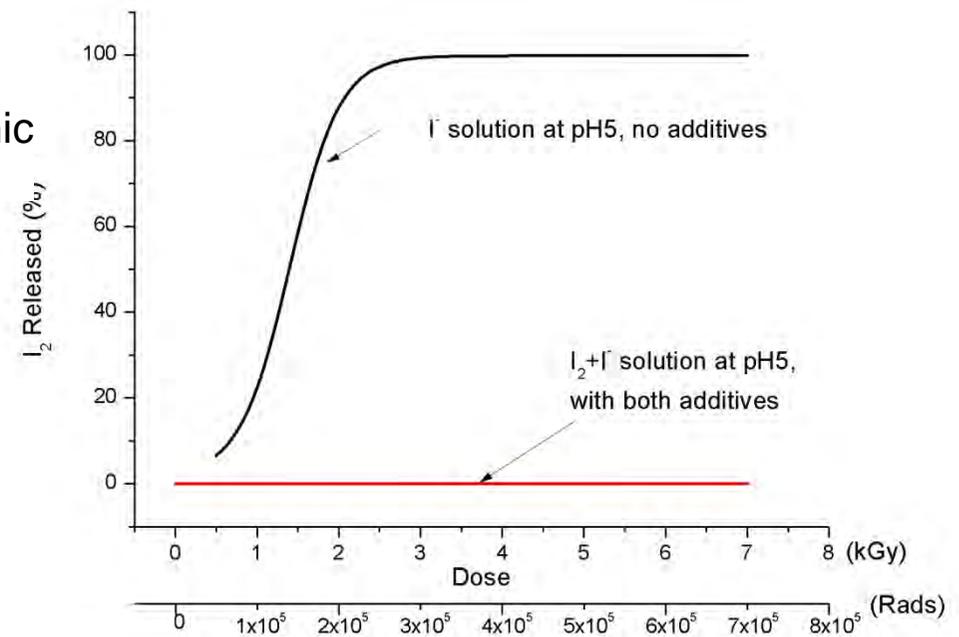
Source of iodide ions in FCVS:

- aerosols: scrubbed metallic iodides (CsI)
- gaseous: scrubbed elemental iodine and organic iodide

Test data shows no free iodide ions available in the water due to effective fixation reaction by the co-agent ...

...therefore, thermal and radiolytic oxidation of iodide ions to volatile I₂ does not occur

➔ **Re-volatilization of iodines does not occur**



Experimental data base – Conclusion of the tests (II)

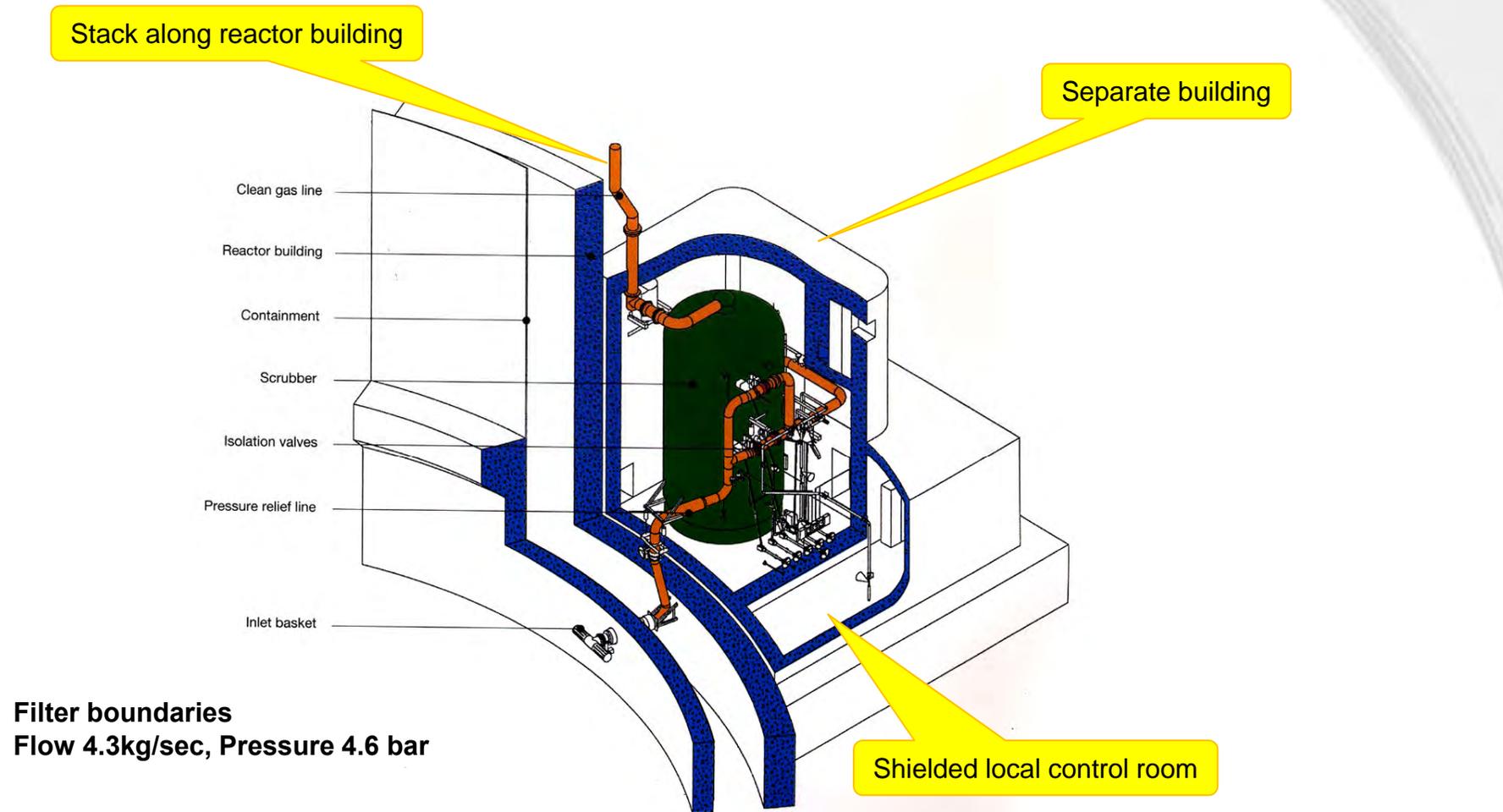


Improvements of filtration from 1st to 2nd generation

Accident Phase	Relevant, volatile Nuclids	Spec. Retainment Factor for FCVS Gen. 1		Spec. Retainment Factor for FCVS Gen. 2	
		conservative	best estimate	conservative	best estimate
Phase 1: short term retainment capacity after first ventings of scrubber /filter containers	Cs 134/137- aerosols	Min .1'000	>200'000	Min. 10'000	>200'000
	I-131 organic	1	<5	Min. 1'000	>1'000
	I-131 elementary	100	100	Min. 1'000	>1'000
	I-131- aerosols	Min .1'000	>200'000	Min. 10'000	>200'000
Phase 2: long term retainment capacity after several ventings of scrubber /filter containers NEW CONSIDERATION! FROM R&D	Cs 134/137 – aerosols	Min. 1'000	>200'000	Min. 10'000	>200'000
	I-131 organic	1	<5	Min. 1'000	>1'000
	I-131 elementary	1	<5	Min. 1'000	>1'000
	I-131- aerosols	1	<5	Min. 10'000	>200'000

Installed IMI FCVS

Beznau Nuclear Power Plant – Layout for Westinghouse 2 loops PWR



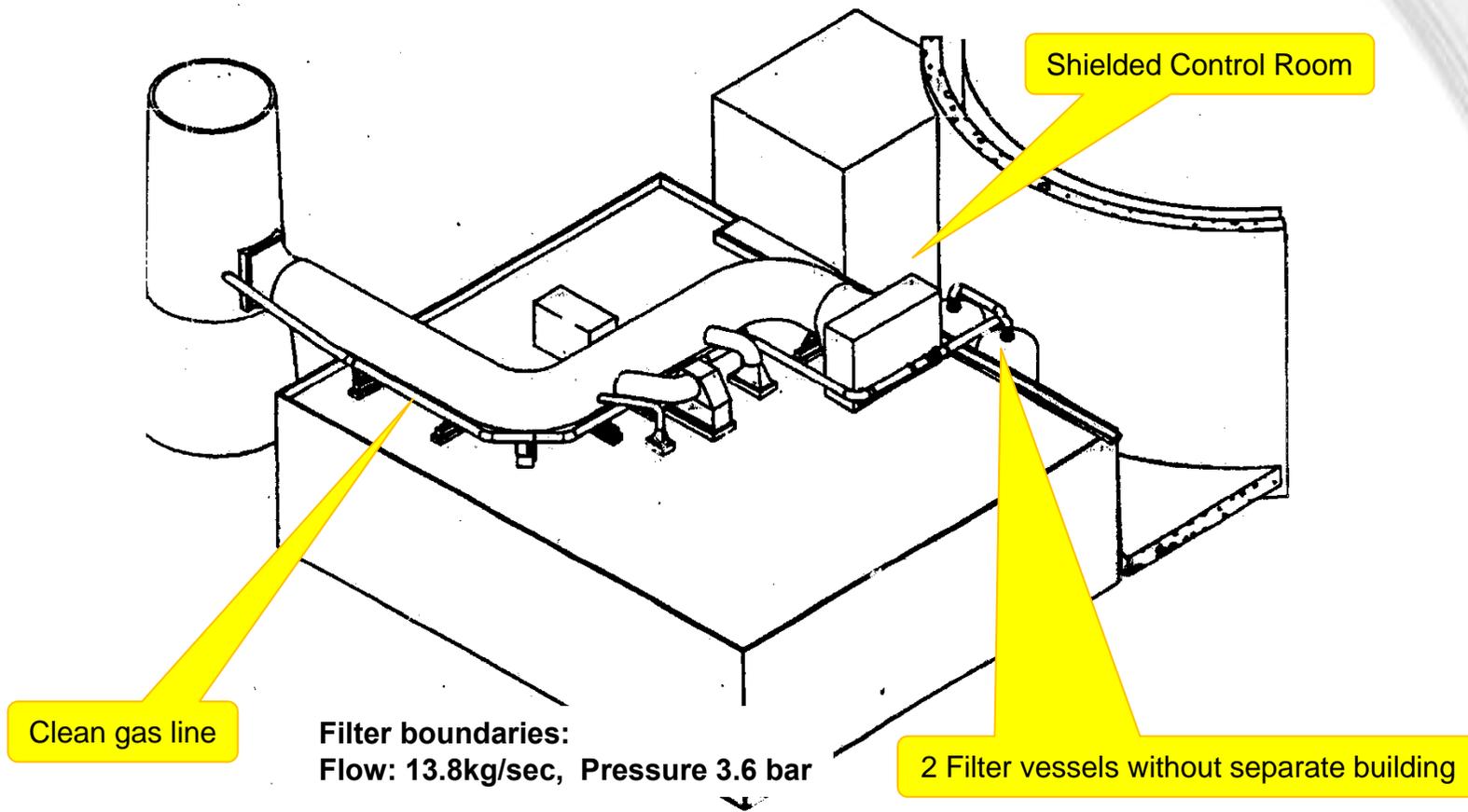
Installed FCVS – Beznau Nuclear Power Plant



Local control room with manual control valves and instrumentation

Installed FCVS – Leibstadt Nuclear Power Plant

Layout for General Electric BWR6

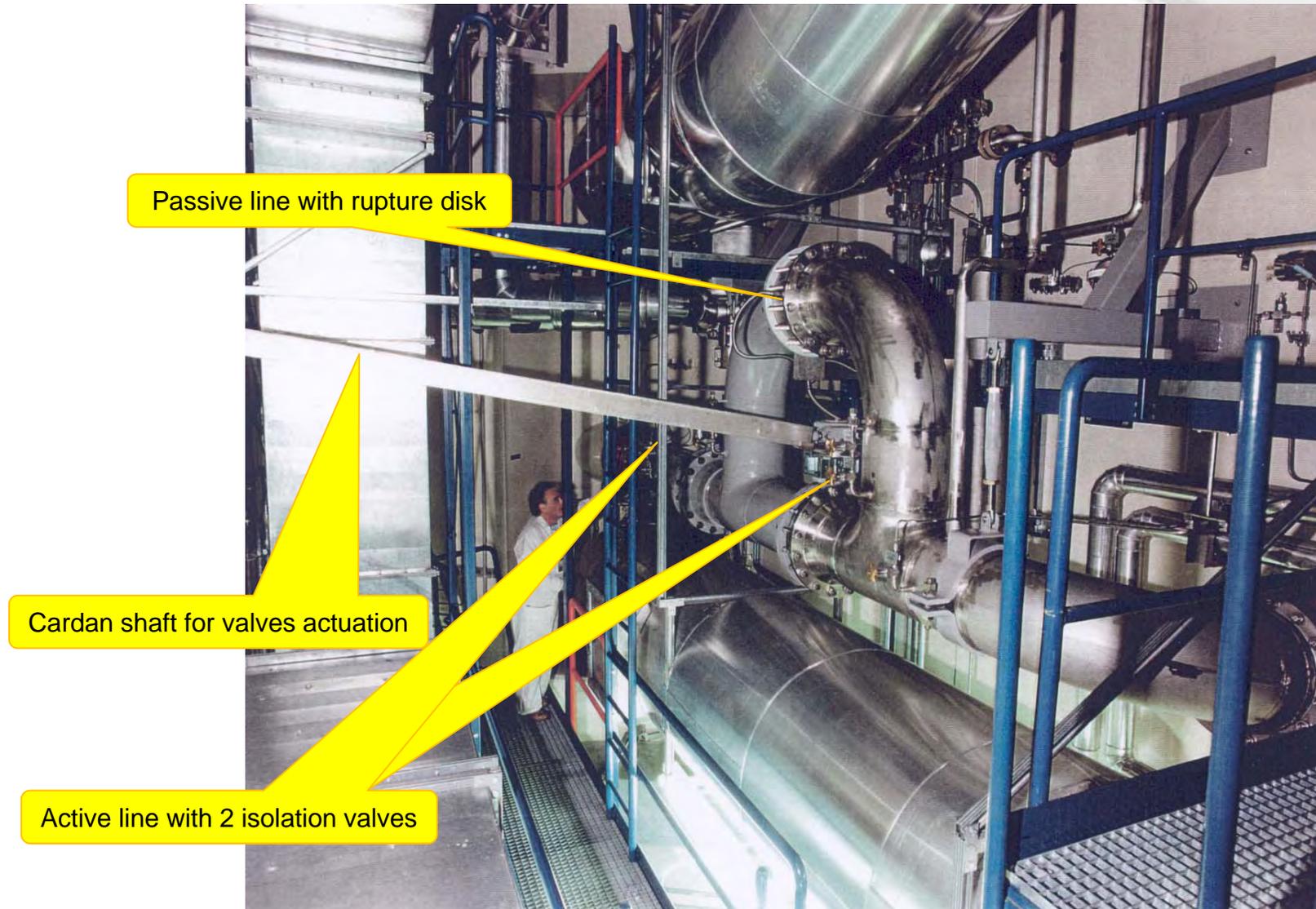


Installed FCVS – Leibstadt Nuclear Power Plant

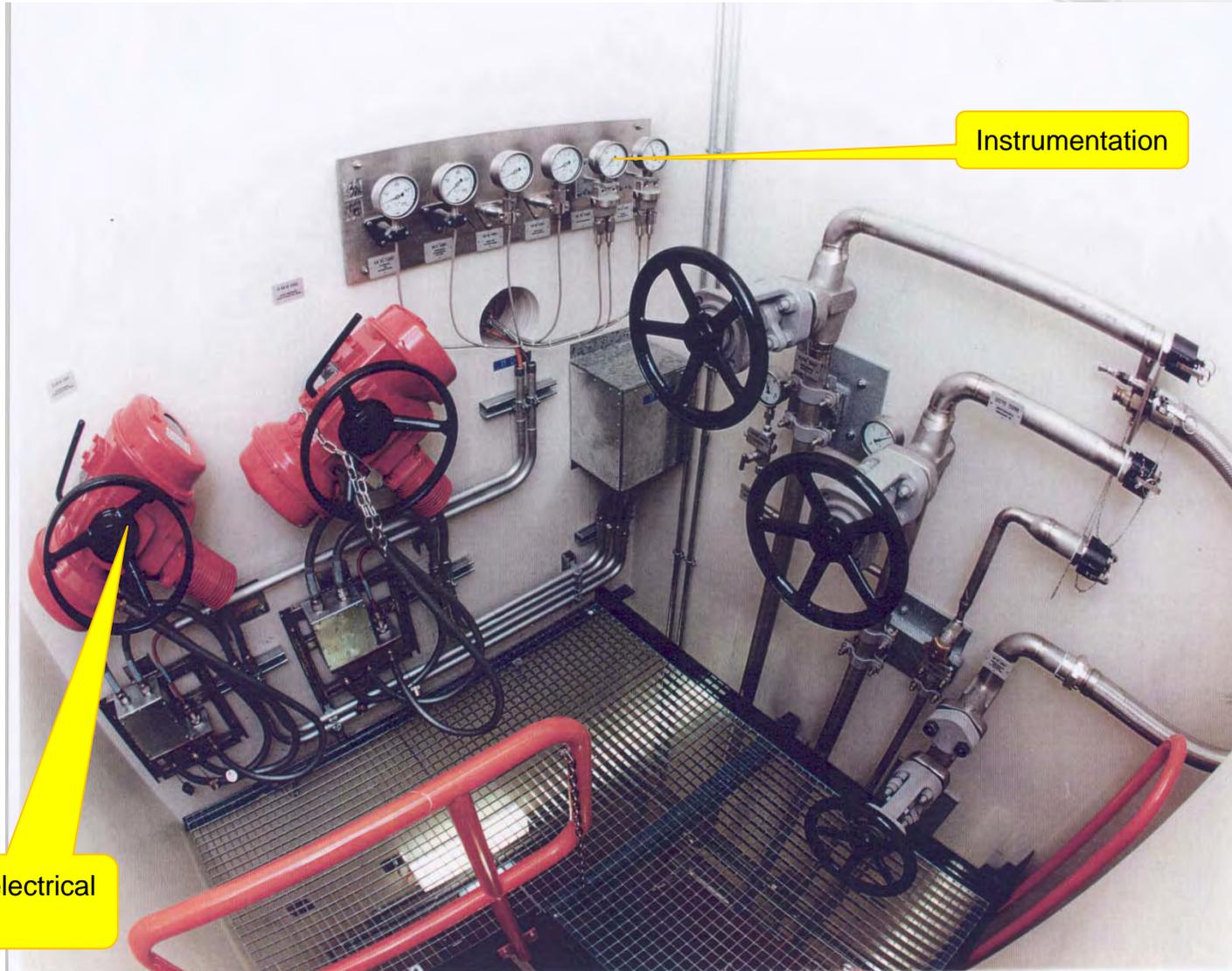


Delivery of two filter vessels to the NPP Leibstadt

Installed FCVS – Leibstadt Nuclear Power Plant



Installed FCVS – Leibstadt Nuclear Power Plant



Manual / electrical actuators

Instrumentation

Sizing

➤ Specified by Customer:

- Filtration: Required min. decontamination factors (DF) for aerosols, elementary iodine and organic iodine and boundary conditions accordingly, e.g. flow, gas composition, temp., pressures, cycling, aerosols size and concentration etc. Required Filtration behavior for mid and long term (re-volatilization, re-vaporization, re-suspension)
- Thermodynamics: Max. vent flow rate at given containment pressure, containment volume, gas composition in containment at venting initiation, total decay heat of aerosol and iodine to be scrubbed, steam and non condensable gas generation rates after venting initiation, reactor decay heat evolution at venting initiation and afterwards*
- Fission product: Total aerosol (active/inactive) mass to be scrubbed, total iodine species (metallic, elemental iodine and organic iodide) to be scrubbed, time frame for about the full activity to be scrubbed, acidification potential
- Operation: Time without any operator intervention (autarky), passivity without power, full passivity without power and rupture disk venting opening
- Layout (walkdown mandatory): Control room, filter room, penetration, existing in- and outlet piping

Note: Mandatory for quote

Sizing

➤ Specified by Customer:

- Filtration: Required min. decontamination factors (DF) for aerosols, elementary iodine and organic iodine and boundary conditions accordingly, e.g. flow, gas composition, temp., pressures, cycling, aerosols size and concentration etc.
- Thermodynamics: Max. vent flow rate at given containment pressure, containment volume, gas composition in containment at venting initiation, total decay heat of aerosol and iodine to be scrubbed, steam and non condensable gas generation rates after venting initiation, reactor decay heat evolution at venting initiation and afterwards*
- Fission product: Total aerosol (active/inactive) mass to be scrubbed, total iodine species (metallic, elemental iodine and organic iodide) to be scrubbed, time frame for about the full activity to be scrubbed, acidification potential
- Operation: Time without any operator intervention (autarky), passivity without power, full passivity without power and rupture disk venting opening
- Layout (walkdown mandatory): Control room, filter room, penetration, existing in- and outlet piping

Note: Mandatory for quote

- **Given in CCI test base:** Specific test results (aerosols, iodines) with variation of nozzles sizes, pressure ratios and volumetric flows in the 1 nozzle-full scale test bench:
- 1.6 to 5 bar (1.5 to about 4 pressure ratio) filter inlet pressure
 - Subcooled to saturated pools, pure steam to non-condensable gas to steam mixture flows
 - Submicron (0.3 μm to 2.5 μm –geometric-) particles, different materials for aerosols
 - Very small to very high iodine concentrations for iodine retention (iodine concentration, absorbed dose)
 - Iodine removal at low (pH 2) to high (pH14) pH and cold to hot water temperature
 - Complementary test data base: Iodine and aerosol pool scrubbing and aerosol removal in water pools with submerged structures, droplet entrainment by bubble burst

➤ Calculated by CCI:

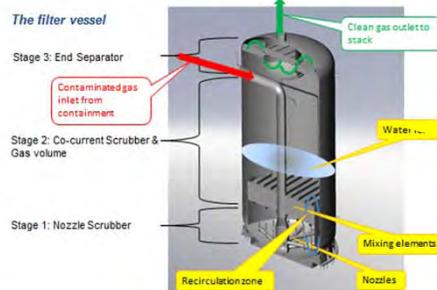
- **Select orifice size and number** to match desired max. vent flow rate and simultaneously check the filter pressure ratio for the lowest flow with regard to decontamination
- Check **Depressurization** behaviour
- **Determine Vessel size**
 - Desired autarky (consider simultaneously: steam condensation, water evaporation, water drainage back to filter)
 - Allocate space for aerosol mass remaining below sparger area (no return of contaminants in the containment necessary)
 - Remain in the experimental data base for iodine retention (Iodine concentration, absorbed dose)
- Filter **hydrogen** concentration calc. and decision on **mitigation**

➤ Designed by CCI:

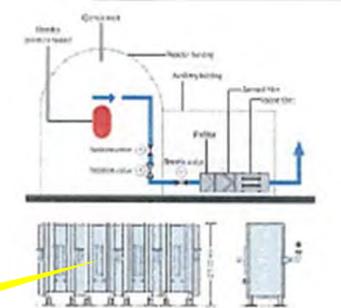
- P & ID
- Layout draft including control and filter rooms, piping inlet and outlet lines, penetration
- Fittings and instrumentation
- Installation – Operation - Maintenance
- Shielding
-

Why choosing the IMI filter?

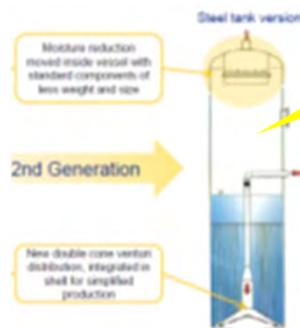
Available filtering technologies:



- Impact Nozzle
- Chemistry
- Mixing elements
- Recirculation zone

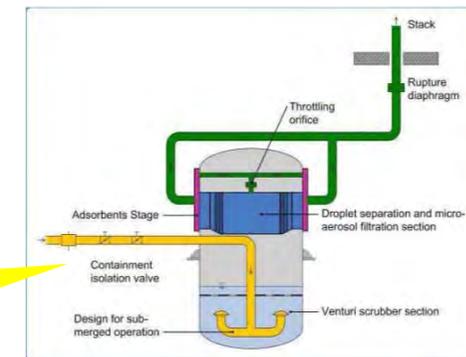


- Metal fiber filter
- Molecular sieve



- Venturi Nozzle
- Chemistry
- Metal fiber filter

- Venturi Nozzle
- Chemistry
- Metal fiber filter
- Molecular sieve



Why choosing the IMI filter? – Critical issues

Venturi Nozzle:

Sharp drop in decontamination factors of Venturies (20!) when out of narrow flow range and filter water level causes large aerosol transport to metal fiber filtration stage

Narrow volumetric flow range leads to low depressurization rate (long depressurization time) and thus hinders fast operation of low pressure injection pumps

Outlet throttling leads to high vessel pressure = high energy - H2 risk!

Why choosing the IMI filter? – Critical issues

Metal fiber filter:

High risk of **clogging**
with high aerosol load
and high temperature

Decay heat of fission
products leads to **re-
vaporization** of
aerosols (hot spots)

Corrosion and high
temp. damage to
metal fibers

Multiple venting leads to
re-suspension of
deposited fission products

Why choosing the IMI filter? – Critical issues

Molecular Sieve:

Pre-heating with active N₂ gas and pre-conditioning with H₂

Poisoning of zeolite through halogens, sulfur compounds, acid fumes and other fission products

High temperature sharply reduces absorption, i.e. by steam absorption and catalytic H₂-O₂ / silver reaction

High temperature by Decay heat (including absorbed nobles gases) leads to **Re-vaporization** of aerosols and iodine

Multiple venting leads to **re-entrainment** of fission products

Why choosing the IMI filter? – Summary Critical Issues



- ❖ **Venturi nozzles** have a **narrow flow range decontamination efficiency** and thus allow the **transfer of the filtration function to the next filtration stages** (fine mesh stage, molecular sieve)
- ❖ **The Venturi nozzles and Dry filter technologies** (fine mesh, molecular sieve) **do not allow for fast depressurization rate** (or sudden pressurization) **due to flow limitation**
- ❖ **Metal fiber filter** have a **high clogging risk with uncontrollable** (radioactive) materials and liquid/solid particules mixtures
- ❖ **Molecular sieve** need **pre-heating and pre – conditioning**. They are subject to **uncontrollable poisoning**
- ❖ **Dry only Filtering technologies solution**, i.e. fine mesh or/and molecular sieve, have to cope with the **the total amount of fission product heat: re-vaporization and filter damage** is expected
- ❖ **The ACE tests** late eightys are from today's view **not representative for high aerosol load, large flow range and irradiation influence** on filtration. The **re-volatilization, re-vaporization and re-suspension** are not adressed

Why choosing the IMI filter? – The reasons are:



- ❖ **Highest decontamination factors for aerosols** from high to low flows allows **wide operation flexibility**, e.g. fast depressurization without compromise on filtration
- ❖ **Highest decontamination factors for iodines** *by adequate chemistry*
- ❖ **Re-volatilization of iodines – issue solved** under all possible conditions *by adequate chemistry*
- ❖ **Re-vaporization of aerosols and iodines - issue solved**, i.e. *all fission products kept in filter water*. The same reason **excludes Re-entrainment** when multiple venting cycles venting
- ❖ **Best laboratory** worldwide ready to answer specific Utilities request **ready to test**

Conclusions

- IMI - PSI have developed a 2nd generation of Filtered Containment Venting System with a **unique, highly efficient filter system**
- For the first time in the nuclear power industry, a technology to **prevent the release of active aerosols AND iodines** species to the environment is available
- The installed approximately 120 FCVS, mainly in Europe have deficiencies in filtering aerosols and iodines. Other reactors worldwide do not have any filtering capabilities despite the fact that approximately half of the core damages scenarios might require containment venting
- Nuclear Safety Authorities and Utilities may consider the installation of a 2nd generation Filtered Containment Venting System to better protect public health and safety and preclude the possibility of land contamination due to the recent events

Disclaimer

The information presented here is not considered to be a commercial evaluation and or interpretation of performances of the available containment venting filter systems.

The receiving organization/person is alone responsible for the use of the information presented for any application if the use causes any damage in any kind. IMI/CCI reserves all rights thereto.

