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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

October 2, 2007

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

SUB-COMMITTEE ON ESBWR DESIGN CERTIFICATION

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TUESDAY,

OCTOBER 2, 2007

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The meeting was convened in Room T-2B3 of Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 1:00 p.m., Dr. Michael Corradini, Chairman, presiding.

MEMBERS PRESENT:

MICHAEL CORRADINI	Chairman
JOHN D. SIEBER	ACRS Member
MARIO V. BONACA	ACRS Member
GEORGE APOSTOLAKIS	ACRS Member
OTTO L. MAYNARD	ACRS Member
DENNIS C. BLEY	ACRS Member
JOHN W. STETKAR	ACRS Member
WILLIAM J. SHACK	ACRS Member
SAID ABDEL-KHALIK	ACRS Member
DANA A. POWERS	ACRS Member

NRC STAFF PRESENT:

DAVID MATTHEWS

AMY CUBBAGE

MOHAMMED SHUAUBI

ALSO PRESENT:

JIM KINSEY

DAVID HINDS

ALAN BEARD

RICK WACKOWIAK

IRA POPPEL

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

1:00 p.m.

CHAIR CORRADINI: Dana Powers, Jack Sieber, Bill Shack and John Stetkar. Tom Kress is also attending as a consultant to the Subcommittee, and Gary Hammer of the ACRS staff is the Designated Federal Officer for this meeting.

The purpose of the meeting is to review and discuss the Safety Evaluation Report with open items for several chapters of the ESBWR design certification. We will hear presentations from the NRC Office of New Reactors, and GE-Hitachi Nuclear Energy Americas, LLC. Is GEH an appropriate way of -- good.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the Full Committee.

The rules for participation in today's meeting have been announced as part of the notice of this meeting, previously published in the Federal Register. Portions of the meeting may be closed for the discussion of unclassified safeguards and proprietary information.

We have received no written comments or

requests for time to make oral statements from members of the public regarding today's meeting.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice. Therefore, we request that participants in this meeting use the microphones located throughout the meeting room when addressing the Subcommittee, and identify yourselves. The participants should identify and speak with sufficient clarity and volume so that they may be readily heard.

We'll proceed, and I'll call upon Mr. David Matthews of the Office of New Reactors to start us off.

MR. MATTHEWS: Thank you very much, Mr. Corradini.

My name is David Matthews, I'm the Director of New Reactor Licensing in the Office of New Reactors. We are very pleased today to be able to make the first presentation to the ACRS Subcommittee on the ESBWR design certification activities.

I'm particularly pleased today, for those of you who may have had me be in front of you before, two previous jobs ago I was the Director of the division responsible for de-commissioning of the NRC, and then I moved to being Director of the division responsible for license renewal at the NRC, and then on to Director for the division responsible for new reactor licensing. I don't know whether you call that reverse progress or not, I'm certainly enjoying it, but it's been evolutionary.

The presentations you'll hear this week, and in the coming months, represent a very significant effort on the part of both the NRC staff and GE-Hitachi. This review has been ongoing for two years. Amy reminded me that it had begun in August of 2005.

Just by way of numbers, and our numbers don't always agree statistically with GE's numbers, because we count different, but in general the number of requests for additional information that the staff has generated since the onset of this review is on the order of about 3,100, and GE has responded at this point to approximately 2,000 of those requests for additional information.

And, we view those 2,000 to have been satisfactorily addressed, and now considered resolved. So, at this juncture, I think there is certainly a sufficient amount of substantive information to warrant the ACRS' beginning to -- the Subcommittee and the Full Committee -- to begin their review of the GE effort and the NRC staff's review of that effort.

There is still a lot of work ahead. The staff's approach is to engage the ACRS at the SER with open items stage, but a little differently for this than maybe previous instances, we are going to do this on a chapter-by-chapter basis, and we are very pleased that the staff and the ACRS Subcommittee, and Full Committee, have agreed to provide this mechanism to us so that we can get early feedback from the committee, rather than waiting til some large juncture, such as the issuance of an SER with open items, to begin this review.

So, we have been providing you, as you know, on a regular basis, those SER chapters with open items that we have been generating.

At this point in time, we believe that that's the form in which you will see the SER with open items, it will come on a chapter-by-chapter basis.

At the juncture last year, GE proposed, and we agreed, that the idea of driving towards an SER with open item, I believe it was to be October of this year, was not an efficient and effective way to move forward, because of the level of review, both in terms of what they had supplied us and what we had completed at that juncture. That document might not have been a worthwhile document for the staff to invest in, in terms of a consolidated SER with open items, because of the number of open items and the areas in the design that had yet to be completed by GE.

So, we appreciate this unique approach. Our goal would be to work through these on a chapter-by-chapter basis, and at a juncture down the road we will be issuing an SER and, hopefully, at that point in time it will reflect resolution of a majority of the issues that we'll be discussing today.

Amy will get into the details associated with that review and its timing when I turn the microphone over to her.

We'd like to get your feedback now, so we can address any issues as part of our continuing review that the Subcommittee and the Full Committee may want to raise. We want to establish a level of finality on areas that we all agree are adequately addressed and, therefore, we are requesting a letter from the Committee on each of the chapters that we had offered to you, and we'll be offering in the future.

CHAIR CORRADINI: Just to make sure that our first attempt at that will probably be the November meeting.

MR. MATTHEWS: That's in agreement with

our schedule.

When we come back to the Committee, hopefully, in 2009, with that completed final safety evaluation report I just referred to, we intend to focus on the resolution of any remaining open items and any changes that have occurred that we weren't able to cover on this chapter-by-chapter basis.

We look forward to these future interactions with the Committee regarding design certification, and with regard to the COL applications referencing the ESBWR design.

The ESBWR-COL applications are expected shortly. We expect them to be submitted in November of 2007, February, 2008 and May of 2008, for the, respectively, North Anna, Grand Gulf and River Bend sites.

At this point in time, I'd like to point out that with us today is Mohammed Shuaubi. Mohammed is the Branch Chief responsible for the ESBWR and ABWR design centers. You are aware that the New Reactor Office has in effect a project management activity centered in the Division of New Reactor Licensing, and it's organized around these design centers, and that's the basis upon which the interactions with this committee and others will be done. So, Mohammed is responsible for the ESBWR and ABWR design centers at this point.

As we find ourselves faced with additional work that justifies replication of those design center branches, we will do that. Okay. We already now have two Westinghouse AP 1000 design center branches.

At this point in time, I'd like to introduce Amy Cubbage, who is the Senior Project Manager, who has been overseeing the NRC's review of the ESBWR design certification since its introduction into our process in 2005, and then following that GE-Hitachi will be making a presentation.

So, with that, I'll turn it over to Amy.

CHAIR CORRADINI: Thank you.

MR. MATTHEWS: And, I'm going to resort to the side table at this juncture.

CHAIR CORRADINI: Thank you, thank you very much.

MS. CUBBAGE: Again, as Dave said, I'm the Lead Project Manager for the ESBWR design certification review. I'm also supported by an army of additional project managers, who are sitting in the wings here. I won't introduce all of them, but they've been putting in a lot of effort, and you'll be hearing from them when their chapters come up tomorrow and in coming meetings.

And also as Dave mentioned, of course, GE-Hitachi will be making a presentation on the design this afternoon. For some of you, that may be a refresher, and for other newer members of the Committee this may be the first time that you are hearing their presentation.

And also tomorrow, we'll be presenting our evaluation of Chapters 2, 8 and 17.

For my presentation, I'm going to focus on giving you some of the history of the previous briefings that the Committee has had on ESBWR, an overview of the status of the ESBWR review, the design control document, and other submittals, review guidance that we are using for this review, and also touch on our plans for future briefings.

Beginning during the pre-application review, there were several interactions with the Committee, specifically, the Thermal-Hydraulic Subcommittee and then the Full Committee, and the Committee looked at the staff's review of the track *** code for application to ESBWR loss of coolant accidents, and also for thermal-hydraulic stability, so there were a number of meetings at that time, and it culminated ultimately with the staff issuance of safety evaluations accepting those methods for ESBWR.

And, the PRA Subcommittee has also had a few informational briefings, and we expect that to continue as well.

Review status, we actually began our pre-application interactions in 2002, and the application was submitted in August, 2005, and was later docketed in December, 2005.

Since that time, the staff has reviewed the materials provided and have completed our major milestones for issuance of RAIs, and there were four dates where those were issued, with a total of over 3,100 RAIs that have been issued.

The design control document Revision 3 was submitted in February, 2007, and that forms the basis of the safety evaluation reports that we have provided to the Committee and we'll be discussing during the month of October.

In addition, we have looked at numerous RAI responses and other more supporting submittals, such as topical reports.

DCD Revision 4 was submitted on Friday, and we're going to be getting you copies of that as soon as we receive the bulk copies from GE-Hitachi, so we expect those this week.

The primary purpose of DCD Rev 4 was to provide a reference for the COL applications that will be submitted starting in November. So, there's a lot of effort on the consolidation and clarification of the COL action items in the DCD, which the COL applicants will be required to meet in their applications, and there's a significant effort to upgrade both the content and format of tier one.

Lastly, many of the RAI responses have been incorporated into DCD Revision 4, and remaining RAI responses will be incorporated into DCD Revision 5 in March, 2008.

One other major deliverable that --

MEMBER SHACK: What's the scope of the remaining RAIs?

MS. CUBBAGE: There are about 1,000 of them, and you'll be hearing, when we come to the meeting starting tomorrow, you'll hear what the open items are that remain in the review, and those will be getting incorporated into Rev 5.

CHAIR CORRADINI: And so, in the Rev 4 we are going to get we'll see the differences between 3 and 4?

MS. CUBBAGE: Right, there will be a list of changes for every chapter, and I, perhaps, could let GE in their presentation give you more information about what changed and how it will be presented.

CHAIR CORRADINI: Okay, thank you.

MS. CUBBAGE: Another significant deliverable that was received last week was the complete Revision 2 of the PRA, that had been submitted in pieces beginning in the spring, but now we have the last part of that in a consolidated version, and again, we'll get you copies of that.

MEMBER APOSTOLAKIS: About Level 1 and Level 2.

MS. CUBBAGE: That's right.

MEMBER APOSTOLAKIS: The uncertainty analysis that we requested for the Level 2 phenomena is there?

MS. CUBBAGE: I'd have to ask GE-Hitachi to give us a status on that. Perhaps, they could do it in their presentation, or --

MEMBER APOSTOLAKIS: Fine.

MS. CUBBAGE: Okay, so topical reports, there are numerous topical reports that support the design control document. I've listed some of the topical areas. As you can see, there are quite a few of them. You'll hear more about these topical reports when we present the chapters that are associated with those topical reports. The bulk of them are affiliated with Chapters 3, 4, 6, 7, 15, 18 and 21, so we won't be hearing about topical reports tomorrow, but at future meetings, and we'll make sure that the Committee has the latest revision of all those topical reports leading up to those meetings.

MEMBER SIEBER: Will that list show which ones are reviewed and approved and which ones have yet to be approved?

MS. CUBBAGE: These are all under review.

MEMBER SIEBER: Okay, so there's none approved.

MS. CUBBAGE: None approved, that's right.

MEMBER APOSTOLAKIS: Will we have the I&C reports?

MS. CUBBAGE: One of them was just received on Friday.

MEMBER APOSTOLAKIS: Oh, okay.

MS. CUBBAGE: Others have been submitted previously, and we certainly can get copies of those to you.

MEMBER APOSTOLAKIS: Yes, let's make sure, because I'd like to have that. Mr. Sieber also would.

And, I want the three I&C and the human factors.

CHAIR CORRADINI: So, we'll just get a CD of all of them.

MS. CUBBAGE: Yes, I'd be happy to provide all of that.

MEMBER APOSTOLAKIS: A CD with everything.

MS. CUBBAGE: I can do that.

CHAIR CORRADINI: And, you can go through it at your own leisure.

MEMBER APOSTOLAKIS: Whatever you want to -- thank you, Michael, I didn't know what to do, but now I know.

Yes, if you would do that, put everything on a CD.

MS. CUBBAGE: For example, the human factors area there are about a dozen topical reports in that area.

MEMBER APOSTOLAKIS: A dozen reports on human factors?

MS. CUBBAGE: Right, one corresponds to each of the elements of the Human Factors Program, so there's a lot of information there.

MEMBER MAYNARD: Are these proprietary, or --

MS. CUBBAGE: Some of them are proprietary, and for those that are proprietary, of course, we have non-proprietary groups as well.

MR. KRESS: This Suppression Products Removal Module, is that a suppression pool model?

MS. CUBBAGE: It's more than just a suppression pool, it involves the PCCS, et cetera. I'd have to look to GE to give us a little more depth on what that contains, but this is an issue that's been in the works for about two years. It's the overall justification models for the PCCS product removal.

MEMBER APOSTOLAKIS: So this -- and maybe you mentioned it, but this Committee, or the review committee, will have to comment on each one of these at some point?

MS. CUBBAGE: They, in some cases, are supplemental information that supports the analysis results that are presented in the new DCD.

CHAIR CORRADINI: I think he's worked backwards from the --

MS. CUBBAGE: They work backwards from the DCD in many cases, right.

MEMBER APOSTOLAKIS: So, the letter addresses the DCD?

CHAIR CORRADINI: Well, it addresses the staff's evaluation.

MS. CUBBAGE: Staff's evaluation.

MEMBER APOSTOLAKIS: The staff's evaluation, that's correct.

MS. CUBBAGE: Right, and in some of these cases in limited areas we are going to prepare separate first evaluation reports, for example, the fuel design will receive a separate evaluation, because it is possible that at a later date the COL applicant or licensee can select a different tool design, and then at that point they would need to do a review. So, we are keeping that safety evaluation report separate, and will be referenced in the certification.

MEMBER APOSTOLAKIS: Okay, thank you.

MS. CUBBAGE: And so, in addition to what you saw in the last page, there are some more topical reports that have yet to be submitted, some of them related to security, some of them related to spent fuel rack design, the steam dryer acoustic load analysis for the center, and for all the topical reports there are revisions that are planned when necessary to incorporate requests for additional information.

We are expecting that GE-Hitachi will come and brief the Committee at the appropriate times when these new submittals are received, so that we can engage early and get the Committee's feedback on those, rather than waiting til the final SER.

And also, we are going to do acceptance reviews when we receive those topical reports.

So, as part of our review effort, we've conducted many audits. Some examples are listed there, where we've gone to the GE-Hitachi offices and looked at the detailed calculations and design records.

We also planned some additional audits. We are also doing confirmatory analyses in many areas, and those are ongoing and will continue.

The snapshot of our RAI status, I think Dave and I have already touched on this, but at this point we've got about 2,200 RAIs considered resolved, and 900 or 1,000 that are considered open at this time. However, we do expect that additional RAIs will be issued in response to the staff's review of DCD Revision 4, Revision 2 of the PRA, and the topical report reviews.

MEMBER SHACK: Sorry, Amy, just for a second.

MS. CUBBAGE: Sure.

MEMBER SHACK: In the ABWR the piping was largely an IPEC kind of thing. Is this going to be a more complete design, because it just happens to be, perhaps, a little closer to a COL?

MS. CUBBAGE: They are working on finalizing the design as part of their detailed design phase. However, there will be piping back as part of the certification. There will also be DAC in the original I&C area and the control room design area.

MEMBER SHACK: DAC.

MS. CUBBAGE: DAC, Design Acceptance Criteria.

MEMBER SHACK: Oh, okay.

MS. CUBBAGE: So, that's in lieu of design detail we have ITAAC so that we can verify the design in accordance with the design acceptance test.

CHAIR CORRADINI: So, some of it will still be in that mode where the criteria is specified, ITAAC will check it.

MS. CUBBAGE: Okay, so the status of our safety evaluation reports, you've received seven of our safety evaluation reports. We are going to discuss three of those tomorrow. The ones with the asterisks are those for any members of the public who are interested, are available publicly as of today, and the accession numbers are provided. We are going to be providing additional safety evaluation reports in the coming weeks and months to support future interactions. We expect the next that you'll receive will be Chapters 9, 13 and 16 support in November Subcommittee meeting. We need to work on a schedule for that meeting.

I'll touch on our review guidance. This has been a point of a little bit of confusion with the issuance of the March, 2007 Safety Review Plan while this review is ongoing. The ESBWR application provides evaluation of the design against the SRP that was in effect six months prior to the docket date. In most cases, the official version was the 1981 version of the SRP. There were some versions that had never been officially issued prior to '07, and those were issued in draft in 1996, and there were also some sections, for example, digital I&C, that had been updated in the late '90s and early 2000 time frame.

So, that was the SRP version that was addressed in the design control document, in Revision 0, and still to this day.

Certification, however, is based on compliance with the regulations in effect at the time of certification, so we need to assure that any regulations that came out after the SRP that GE-

Hitachi has referenced have been addressed acceptably and also any regulations that have yet to be promulgated, but would be in effect before the date of certification.

So, we are going to do a comparison of the March, 2007 SRP against previous versions. We are going to address any impacts, to ensure that the ESBWR complies with the current regulations. In some cases, additional RAIs may need to be asked, so that we can get enough information to ensure that the regulations have been met, and we'll revise our safety evaluation report with open items as necessary prior to issuance of the final SER.

In some cases, the staff has already looked at the acceptance criteria in the March, 2007 SRP, and you may hear tomorrow and in other meetings that that has been done, but in cases where it has not we are going to do that.

So, for future subcommittee meetings, the next one that's scheduled is October 25th. We are going to be covering Chapters 5, 10, 11 and 12. We are planning to have a full committee meeting on November 1st or 2nd to cover the chapters that are going to be discussed tomorrow and also on the 25th, so we're going to combine that. So, we'd be looking for a letter from the November full committee meeting on all of these chapters.

And then in November, we also want to have a subcommittee meeting to address Chapters 9, 13, 16 and, hopefully, GE-Hitachi will be prepared to come in and give an overview of the new topical reports that would have recently been submitted at that time.

And then, to cover those chapters at a December -- early December full committee meeting.

Remaining chapters --

MEMBER APOSTOLAKIS: Excuse me, let me display my ignorance here.

One of these chapters will address the PRA?

MS. CUBBAGE: Chapter 19.

CHAIR CORRADINI: We're not there yet.

MS. CUBBAGE: That will address PRA, and we are not there yet.

CHAIR CORRADINI: We've chosen to bundle, George, 5 and 10, Amy, is that it?

MS. CUBBAGE: 5, 10, 11 and 12.

CHAIR CORRADINI: Because that's a large part of the reactor coolant system, so we've bundled them with topics, but I think 19 won't be up this year.

MS. CUBBAGE: Right, and in light of the fact that the Revision 2 of the PRA was just submitted, we're waiting until we are further along with that review and have fewer open items.

The chapters that you are going to be seeing tomorrow and also on October 25th have fewer open items.

MEMBER APOSTOLAKIS: Well, there is already subcommittee --

MS. CUBBAGE: There is a subcommittee, and we are determining if GE-Hitachi has provided the information that you need to support that meeting.

If possible, we may need to defer that.

MEMBER APOSTOLAKIS: Okay.

CHAIR CORRADINI: The November meeting.

MS. CUBBAGE: The November 15-16 PRA site meeting.

CHAIR CORRADINI: Not to get into schedule, but just so we are clear, so if that gets delayed then likely I assume that you'd want to substitute it with looking at these chapters, which you might be further along with?

MS. CUBBAGE: We could try that, or we might prefer to do something later in November, just -- it depends on when we issue our SERs.

MEMBER APOSTOLAKIS: Do you have any idea when this Chapter 19 will come to us?

MS. CUBBAGE: At this juncture, no, but we'll keep --

MEMBER APOSTOLAKIS: Some time in the spring.

MS. CUBBAGE: -- spring, right.

MEMBER APOSTOLAKIS: Flowers.

CHAIR CORRADINI: With the flowers.

MEMBER APOSTOLAKIS: With the flowers.

MS. CUBBAGE: So, we are trying to get as many of those chapters to you to support committee meetings in the first quarter, and we may schedule topic specific discussions as needed, for example, on the fuel design or other topical reports that warrant their own meeting.

And then, we are planning our interactions on the final SER at this point in early calendar '09. When we receive the topical reports, they are going to be coming in this fall, we are going to assess their impact on the overall review schedule, so this at this point is a planning window, and we'll be speaking with you about the details later.

And, at that time you'll be receiving the consolidated safety evaluation report, rather than chapter by chapter, and our focus will be on the open item issue resolution, and changes from the SER with open items.

My last slide, anymore questions?

MEMBER APOSTOLAKIS: October 25th is a firm date?

MS. CUBBAGE: Yes, it is.

MEMBER SIEBER: For what?

MS. CUBBAGE: Next subcommittee meeting.

CHAIR CORRADINI: Subcommittee on a Thursday.

Any other questions?

Okay.

MS. CUBBAGE: Thank you.

CHAIR CORRADINI: We'll have the next.

MR. KINSEY: Good afternoon. We appreciate your time this afternoon. My name is Jim Kinsey, I'm the Vice President of ESBWR Licensing for GE-Hitachi, and again, we appreciate your time this afternoon.

I guess I would echo Mr. Matthews and Ms. Cubbage's input, we have spent a lot of time working with the staff back in the spring, and established a process for moving forward, which we think will be most efficient for all organizations as we work through the certification process and the remainder of the technical review. So, we appreciate the subcommittee accommodating our path forward with presenting topics on a per chapter basis, but there again, that will work through the closure of open issues on a much more efficient basis, it's a more efficient effort.

We are planning an overview today to, basically, provide everybody the same general basis of repeated line features of the ESBWR key safety aspects, and we'll provide some summary details of the incites that we've gained through the completion of our Vision 2 of the PRA.

In Amy's session, I understand that the Committee was asking a lot of questions and was very curious about the differences between DCD Rev 3 and Rev 4, and I guess what I would propose to do, in order to make that also an efficient discussion, is we'll include that as part of each of the individual chapter discussions that we're having starting tomorrow morning, so we can highlight the deltas that we have for that.

The presentation that we have planned to start now will take us just over an hour, we want to leave plenty of time for questions, and the presenters are David Hinds, who is our Vice President of New Units Engineering, Alan Beard, who is a principal engineer in the New Units Group, and Rick Wachowiak, who I think some of you -- Rick is our Technical Lead in the PRA area.

CHAIR CORRADINI: He looks familiar.

MR. KINSEY: And, with that as an introduction, I'd like to turn it over to the presentation team to move through the overview of the ESBWR design.

Thank you.

MR. HINDS: If you don't mind me standing up?

CHAIR CORRADINI: Actually, it's better.

MR. HINDS: I move around.

CHAIR CORRADINI: Because you need to be wired.

MR. HINDS: Oh, okay. Okay, we'll get some logistics going here.

Okay, good afternoon, again, I'm David Hinds, Manager of New Units Engineering for GEH.

We're glad to be here at this juncture in the review and have an opportunity to present to you the ESBWR, many, many aspects for us to talk about. What we've got prepared here today is, basically, a short overview to really lead into the individual chapter presentations. So, we've got a short overview here, I'll show you what we've got here on the agenda.

On the agenda we've got just a short discussion of the evolution of the design of the ESBWR, some discussion about some of the design features, and improvements, and some of the characteristics of the ESBWR.

A period to focus on our passive safety system, to discuss how the safety systems perform and interact with each other, and then a short summary of the PRA. We have, as Amy had mentioned, we have gone through with the PRA Subcommittee, some early introductory discussions, and we'll have -- I prepared here just a short summary of the PRA results.

Okay, this is just a pictorial, just to -- just to tell you a little bit about the evolution. Many of you are aware of the evolution of the boiling water reactors that GE has been developing, and to let you know that ESBWR is part of the evolution, there's new aspects to the design, but there are many aspects of that that have evolved over this design evolution we are presenting here, beginning with the early Dresden, the steam drum, and steam generators, going on to external steam engine riders without a steam drum, external recirculation loops and recirculation loops supplemented by jet pumps. Then on to the advanced coolant water reactor with the internal -- reactor internal pumps. Then the next stage of the evolution was to go into the natural circulation, which is the SBWR, which evolved to the ESBWR. So, it's just a little quick overview of letting you know that we've been evolving, and in many of the aspects you'll see in some of the hardware aspects they are very similar to some of the past designs and have evolved, and then we added new features to support the passive safety and natural circulation.

Okay, here's a cut-away view of the ESBWR, and just to get you oriented on the layout here, okay, over here starting on the left, on your left, we have the fuel building. You can see the spent fuel pool. The spent fuel pool is here below grade, with the incline fill transfer to get the fuel to the fuel building.

Then here in the center we have the reactor building, with, of course, the reactor vessel and the RCCD, reinforced concrete containment vessel.

You can see the pools up here, and during Alan's portion of the presentation he'll be talking to some detail about the heat sink, the passive safety systems, and that is the heat sink for those passive safety systems. The pools of water here would, basically, boil off.

And again, Alan will go through those systems in the safety system discussion that we've got in this presentation today.

Here in the foreground we've got the control building, and the control room operators. The actual control room is below grade here, and then the turbine building.

Now, this is a busy chart here, but it shows quite a lot of the systems and system interactions on the one sheet of paper. So, I just point out some features here, just to get you indoctrinated on the ESBWR and the operation of the ESBWR and the system interactions, just with a short pictorial. And again, we'll go through some of the systems in more detail in the individual chapters. We'll also, today, go through with a focus on the safety systems.

So, over here on the left is, basically, indicating the containment, and then above containment area here were the pools that I pointed out, the heat sink. So, we've got the passive containment cooler indicated here, and the isolation condenser indicated here. Gravity-driven cooling system pools here, just to get you oriented, and suppression pools here.

Some of the other things to point out, so again, you see the lack of pumps, and, therefore, passive safety systems, more gravity driven systems.

Also, other things to point out, the stand-by liquid control system still exists on this plant, but it's driven by a pressurized tank here with a nitrogen over pressure, but, basically, similar to the past designs, although not pumped.

Other changes in this evolution, you see down here on the lower portion is a reactor water clean-up/shutdown cooling system. Past designs had both reactor water clean-up and shutdown cooling was one of the functions of the residual heat removal system. We've combined those functions into one system here, and it's a high-pressure rated system.

Over here on the left is also another system where we've combined some functions together, where it's called the FAPCS system, or fuel and auxiliary pool cooling system, and combined some features there as well. So, it does water transfer, cooling, clean-up, it also has a low-pressure injection mode, and spray mode.

The other systems over here is, basically, indicative of the power cycle systems and the turbine building systems, very similar to past designs, but we continue to evolve and improve those systems as well.

Indication of the turbine, three low-pressure turbines, high-pressure turbine, condensate coming back through the feedwater heater system, seven stages of feedwater heating, and the associated feed pumps.

There's a lot of information there on that slide, just to kind of whet your appetite to get into some of these systems, and again, more of the details to follow will be primarily focused on these safety systems here.

MEMBER APOSTOLAKIS: Can I ask, you said the containment there, could you trace the containments?

MR. HINDS: Okay, the containment, the question was the containment, it is, let's see --

MEMBER APOSTOLAKIS: Okay, okay.

MR. HINDS: -- around that PCCS heat exchanger, oh, yes, let me state one thing, this PCCS heat exchanger is a portion of the containment boundary.

CHAIR CORRADINI: Which one, I'm sorry?

MR. HINDS: The PCCS heat exchanger,

you'll see it ties in with the containment boundary here.

CHAIR CORRADINI: Oh.

MR. HINDS: Okay?

CHAIR CORRADINI: The isolation condenser is part of the containment boundary, too, am I right?

MR. HINDS: No, the isolation condenser is not. The isolation condenser is tied in with the reactor vessel, and it does have isolation features there, and so it's, basically, a heat removal system that's tied in with the reactor cooler system.

MEMBER APOSTOLAKIS: Is the PCCS part of the -- inside the containment?

MR. HINDS: The PCCS here is the -- here's where the steam enters in, and we'll have some detailed slides that show it a little better, but here's where the steam enters in and condensate returns, and that physical boundary there is an extension or portion of the containment.

MEMBER BLEY: Inside the piping system.

MR. HINDS: That's correct.

Okay, here's some just high level basic parameters. The ESBWR is a 4,500 megawatt thermal plant, and approximately 1,575 to 1,600 megawatts electric gross, and, of course, the megawatts generated would vary based upon parameters such as cooling water. So, that's a nominal summer rating.

As I stated before, the ESBWR and the evolution, we have evolved to a natural circulation plant. We had been previously to the Committee and discussed stability, but it's fully natural circulation, no recirculation pumps. In order to accommodate that, and I've got a cut-away of the reactor vessel here, but we've changed some of the dimensions on the reactor vessel, basically, to provide that driving head.

It is a passive plant, passive safety systems, and those safety systems are designed for 72 hours passive capability, and then minimal action is needed beyond 72 hours.

CHAIR CORRADINI: So, if I might just ask a question, because it's just a little bit of history here so I'm on the same page, so SBWR to ESBWR, the power-to-volume was maintained. You went up from 2,000 to 4,000 megawatts thermal, and the size of the machine went up proportionally, is that approximately right?

MR. HINDS: Can you help me out with that, Alan?

MR. BEARD: That's approximately correct.

MR. HINDS: I think that's correct, yes.

CHAIR CORRADINI: Okay, and now you are at 4,500, what changed? You went up another 10 plus percent, what changed in the physical size of the machine?

MR. HINDS: From the 4,000 to 4,500, there were some changes in the core dimensions, the number of fuel bundles, we have a larger core.

CHAIR CORRADINI: And bigger, right?

MR. HINDS: It's the short core for differential pressure concerns, and that's actually shown in one of the coming slides, but it's a 3 meter core versus the nominal core now on the BWRs is about 3.7 meters. So, the core is shorter to minimize differential pressure in the natural circulating plant, and the core -- the number of fuel bundles was increase to get to 4,500 megawatts.

CHAIR CORRADINI: So, this is a side issue we could take up later, but just again for learning purposes, so long ago I was forced to remember that L/D equals 1 is the most reactive configuration for a criticality. So now, if I make it a shorter and flatter, it's in its most reactive configuration?

We can talk about it later.

MR. HINDS: Yes, I might have to think on that one a little bit. If any of my cohorts want to jump in on that one, or we can --

MEMBER BLEY: Before you go on --

MR. HINDS: Yes.

MEMBER BLEY: -- what kind of recirculation ratios do you get with the natural system?

MR. HINDS: Let's see --

MR. BEARD: Alan Beard, it's roughly 10,000 kilograms per hour per bundle.

MR. HINDS: We do have a chart in here that shows just the flow characteristic.

MEMBER ABDEL-KHALIK: He's asking about circulation ratio.

CHAIR CORRADINI: Yes, steam out versus spinning about.

MR. HINDS: Oh, oh --

MR. BEARD: It's 4-1/2 to 5, something like that.

CHAIR CORRADINI: What's the quality in the chimney?

MR. HINDS: The total volume?

CHAIR CORRADINI: The equality.

MR. HINDS: Oh, I'm sorry, the equality?

CHAIR CORRADINI: That would tell you what the circulation ratio is.

MR. HINDS: Okay.

MEMBER STETKAR: When you increased the core thermal power, did you change the dimensions to the -- vessel, the height of it?

MR. WACKOWIAK: The first question was talking about equality in the chimney?

MEMBER ABDEL-KHALIK: Right, because he's asking about circulation ratio.

MR. WACKOWIAK: In the chimney area it's about 85 percent steam.

MEMBER ABDEL-KHALIK: Oh, that's great. That's enough, we can get it from there.

MR. WACKOWIAK: I wanted to answer it in the units that I knew.

MEMBER ABDEL-KHALIK: That's fine, I'm happy.

MR. BEARD: And, Dr. Sieber, to your question, the physical dimensions of the ESBWR did not change for the 500 megawatt thermal increase.

MR. HINDS: The physical dimensions of the reactor pressure vessel, correct.

MEMBER SIEBER: What drives the natural circulation, also your safety, how high it is?

MR. HINDS: Yes.

Okay, so we were talking some differences here, now this is differences of ABWR to ESBWR, so we've already talked about natural circulation, it's, basically, natural circulation, we removed the recirculation systems.

The safety systems high pressure and low pressure active safety systems in the ABWR were removed and replaced with the passive safety systems.

The containment, heat removal function is performed as opposed to an active system, to conform with the passive containment cooler system.

The safety grade diesel generators are no longer, and now we have two non-safety diesel generators, the safety electrical power, and we have electrical discussion tomorrow, but the safety electrical power comes from a DC battery source.

RCIC system was replaced with the isolation condensers for a heat removal and isolation event.

Stand-by liquid control I'd mentioned previously, but it's replaced with accumulators, and shutdown cooling we had mentioned before, I had mentioned before, combined with the reactor water clean-up function and a high pressure system, and the service water, cooling water systems were made non-safety.

Here are some other design changes and improvements to point out. We have an island mode of operation, such that if we were to have a loss of the grid transient that takes away the grid, the plant has the capability of in excess of 100 percent steam bypass, and, therefore, can operate in the island mode of operation, and reduce power and continue reactor operation in the island mode of operation.

The fine motion control rod drives --

MEMBER STETKAR: Just for clarity, when you say island mode, you mean plant generating house loads from the output of your generator, so you've got a full turbine generator running back to 15 percent or whatever?

MR. HINDS: That's correct, so the reactor would remain on line, the turbine and the generator would remain on line, and the output of the generator would go to generate house loads, and then the excess steam would be dumped to the condenser through the bypass valves, and then the plant response would be to lower power in order to get closer to the actual power need.

CHAIR CORRADINI: So again, just for understanding purposes I think, John, to explain it, so any sort of transient that looks like I'm getting an off-site loss of power or blackout mode, it would pass through this to try to go to bypass? I'm trying to understand the logic that would take me there.

MR. HINDS: Yes, it would be a grid disturbance, something, say there's a storm or something that takes out off-site power in the switch yard and trips open the switch yard breakers, and so, therefore, there would be no outlet for the power to go out to the gird, this would be a means to keep the reactor on line, and again, the power would go to -- the steam, excess steam to the condenser, and the power going to house loads.

But, it would be, basically, driven primarily by a grid disturbance or a switch yard type activity, breakers tripping open, for instance.

CHAIR CORRADINI: Thank you.

MEMBER SIEBER: Now, when you reduce power that much on anybody's reactor, you run into sometimes stability problems, because of fine tuning of flow control valves and so forth, that changes the risk of a trip. And, I'm wondering if you evaluated the change in risk at running at just house loads and bypass.

MR. HINDS: Well again, the reactor would not immediately be -- the power chain to the reactor would occur over some time, and the immediate would be to take the excess steam to the condenser. But, as far as control systems, yes, we'll need to tune control systems to accommodate that type of transient.

MEMBER SIEBER: Do you envision having dual sets of -- I take it your feedwater control is by controlling the steam flow to feedwater pump turbines?

MR. HINDS: No, that's -- the feedwater pumps are motor drive, so it's not steam driven, and I didn't point that out on the flow schematic there, but the reactor feed pumps are motor drive. So, no, it's not steam driven reactors.

MEMBER SIEBER: You are relying for control on the control valves?

MR. HINDS: The actually adjustable speed drive, motor drive adjustable speed drive, for the reactor feed pumps, so change in the speed of the reactor feed pumps.

MEMBER SIEBER: Okay.

MEMBER BLEY: And, you must have 100 percent steam dump capability.

MR. HINDS: Yes, that's correct, in excess of 100 percent, approximately, 110 percent

MEMBER MAYNARD: Your electrical load,

your house load, do they come directly off your output, or are they coming back from the switch yard? I'm just trying to figure out whether you had a loss in the switch yard, is there an electrical reconfiguration that has to occur, or is it --

MR. HINDS: Well, there's reconfiguration of, say, switch yard breakers, but it does not have to -- the power does not have to transit through the switch yard.

MEMBER MAYNARD: That's fine.

MR. HINDS: Okay.

MEMBER STETKAR: You can go on.

MR. BEARD: We're going to cover that question in more detail, though, tomorrow.

MR. HINDS: Yes, tomorrow we'll actually trace out the electrical path tomorrow.

MEMBER STETKAR: Because I think that would be important.

MR. HINDS: We have some of our electrical experts here that they'll share tomorrow with you the detailed electric plant.

Okay, we have fine motion control, you know, the older BWRs have a locking piston type hydraulic control rod drives. These are fine motion control rod drives, which are in use now on the ABWR, and so, therefore, they have a motor-driven fine movement, and then a hydraulic scram.

So, for the safety function, they would receive a hydraulic scram, backed up by a run-in of the motor, but for normal power changes it's a fine movement with a motor-driven control rod.

I mentioned the systems that were combined, reactor water clean-up/shutdown cooling, and FAPCS, that's fuel and auxiliary pump pooling system.

Some of the others, the import instrumentation, we have a fixed SRNM, we call them, start up range nuclear -- neutron monitors, and fixed gamut thermometers. We expect to go into more detail on them in some of our future presentations, but the gamut thermometers for calibration of the neutron monitors, which replaced the transversing import probes.

I already mentioned the combination systems, this just shows you just some of the written words about the combination of these systems.

Some other improvements, some of these get into the maintainability arena, so not so much in the safety aspects, but in the maintainability arena, such as the ability to remove and replace, or rebuild control rod drives under vessel. There's a shoot-out steel on previous versions, we do not have shoot-out steel, which gets into a maintainability issue.

Head vent piping was reconfigured, such that it goes through the flange area, such that removal of the reactor head, breaks also the head vent piping, so it's, basically, a one flange type situation.

And then, some stainless steel lining on the suppression pool to improve water quality.

CHAIR CORRADINI: Again, just for my understanding, remind so, because I don't remember what shoot-out steel is?

MR. HINDS: It's a steel structure underneath the reactor pressure vessel, and in the older BWR design it's there for the event of a potential for a control rod drive mechanism rejection.

We designed the control rod drive such that that's, basically, impossible. The core plate, the internal core structure would prevent that.

MEMBER SHACK: Now, is your top guide, your core shroud, still welded in, or is that a replaceable component now?

MR. HINDS: I believe bolted in place, Alan can back me up on that. I believe they are both bolted in place, and some of those -- yes, the top guide and core plate is -- my memory is bolted in place, and certainly can look that up to confirm that.

MR. BEARD: Alan Beard, yes, both the core plate and the top guide are bolted in, and in addition to that the top guide is now actually manufactured out of a solid piece of stainless steel. The top guide and plate is notched --

MR. HINDS: Yes, the top guide begins with a forging, and then they are drilled, rough drilled, and then machined.

So, this just shows a cut-away of the reactor pressure vessel. So, I mentioned evolution, many of the components have evolved from the past designs, and the only basic new component added here is -- well, one is, I mentioned the dimension of the reactor vessel, we've added about 6 meters of height to the reactor vessel, which adds to the driving head, which helps for the natural circulation.

We have, basically, the water head external to the shroud, and external to the chimney. So, the chimney is a new component for the ESBWR, and I think you'll recognize from past BWRs the other components. They are listed out here with the designators. But, the chimney and chimney -- the chimney is like a barrel structure, the chimney partitions provide a channel for the steam to flow, basically, a 16 -- 4x4 16 fuel bundle configuration within each chimney cell.

And, for those of you all who participated in the stability sessions, we talked quite extensively about the chimney. But again, that's really the only additional component there, and again, the added height there is the drive on the natural circulation flow.

CHAIR CORRADINI: So, the chimney, though, was opened up to again reduce pressure drive in this design, right?

MR. HINDS: Well, this -- the ESBWR, or the SBWR, the ESBWR is the first introduction --

CHAIR CORRADINI: Right, I should have said it that way, I understand. Okay.

MR. HINDS: So, and it allows, you know, basically, the barrel, such that the chimney barrel allows for water, sub cooled water to be on the external of it, to be the head coming down and drive flow, and then the inside of it is steam being driven out of the core, so steam leaving the core, and which is what Rick was talking about there, as far as you were asking about quality. So, steam exiting the core comes through the chimney, and so, therefore, you've got a difference in density and, therefore, a difference in head to drive the flow through the core.

CHAIR CORRADINI: You are operating at the same pressure as the SBWR?

MR. HINDS: Yes.

CHAIR CORRADINI: So, that's 1,000?

MR. HINDS: It's roughly -- it's like 1,040 pounds.

MEMBER APOSTOLAKIS: So, what's the total height?

MR. HINDS: It's approximately 27 meters.

CHAIR CORRADINI: It's a big thing.

MR. HINDS: It takes quite a bit of height to drop that natural circulation flow.

And again, the components here are very similar, you know, there's the core down in this region, chimney in this region, there's the core plate, the top guide, chimney, chimney partitions, steam separator and the steam dryer.

MEMBER APOSTOLAKIS: So, the chimney is about 6 meters you said?

MR. HINDS: I think that's correct, yes.

Okay, so this just shows a pictorial of the flow path that I was mentioning before. So, the sub cooled water is on the exterior, exterior of the shroud and exterior of the chimney, flow goes in this direction, and then up through the core where boiling begins ,and then you've got the steam exiting through the dryer -- or separators and dryers, and out the steam line.

CHAIR CORRADINI: So, I'm sorry to get back to the scaling again, I apologize, but so from a power to flow standpoint, if I looked at the ABWR and the ESBWR, the ABWR is 4,000?

MR. HINDS: 3,926.

CHAIR CORRADINI: Okay, i was going to say 3,900 something, 4,000, this is 4,500.

MR. HINDS: Okay.

CHAIR CORRADINI: So, did you -- is the -- and I wasn't here for the thermal hydraulic part so I apologize again, is the opening in the downcomer larger, given the same -- essentially, the same power to flow?

MR. HINDS: Larger than?

CHAIR CORRADINI: Larger than the ABWR, more area?

MR. HINDS: No.

MR. BEARD: With the ABWR you had constrictions at each of the internal pumps.

CHAIR CORRADINI: Right, down at the

bottom.

MS. CUBBAGE: Down at the bottom. So, the overall cross sectional flow area available in the ESBWR is much larger than it is in the ABWR.

The actual gap, though, between the shroud and the vessel is smaller.

CHAIR CORRADINI: We are going to get back to recirculation again later, but I would guess that the recirculation ratio here is lower than the ABWR.

MR. HINDS: I can't answer that one off the cuff, unless some of my cohorts can. We'll have to look that one up.

MR. WACKOWIAK: We can find that out.

CHAIR CORRADINI: Higher quality recirculation, that's what I was getting at.

MR. HINDS: We'll confirm that one, look that one up for you.

MEMBER BLEY: Excuse me.

MR. HINDS: Yes. sir.

MEMBER BLEY: The material you are showing, is this design -- is this the design scale up of the previous designs, or are there some experimental or scale models where you've actually run experiments on these?

MR. HINDS: Well, we have -- there is

quite a number of experiments done to improve the natural circulation and stability.

And then, it's also some of the --

MEMBER BLEY: Scale models of --

MEMBER BLEY: -- some of the test basis comes from a Dodewaard plant in Holland ,and some test basis, we have quite -- we submitted quite a test -- test and development program basis for the natural circulation for the core flow for the safety systems, and so, basically, test basis.

And, as well as the Dodewaard was an actual operating reactor, if you can expand -- can you expand on the Dodewaard capacitor size -- I mean, the Dodewaard is 200 megawatts, so an operating reactor plant, which we used a lot of experience based from that, from a Holland operating plant, as well as the test bases, altogether, and then many of the components here, as I mentioned previously, were used in the ABWR, so there are pressure drop characteristics and flow characteristics that are known from past designs.

So, for instance, the core plate is a similar design, where we've got fuel testing data, we've got top guide similar design, and we've done testing for chimney, chimney flow characteristics, and then we've got an operating plant basis as well as test basis for separators and dryers.

MEMBER STETKAR: Some of that was full-scale testing, right?

MR. HINDS: As far as the -- full scale, we had full height testing, for instance.

MEMBER STETKAR: Right.

MR. HINDS: On some.

MEMBER STETKAR: So, you don't have to scale --

MEMBER SHACK: But, that was full height for the SWBR, wasn't it?

MR. HINDS: As far as -- I think that's right, yes.

MS. CUBBAGE: Additional capacity was added without changing the height in the ESBWR.

CHAIR CORRADINI: Well, that's why -- just so we are back to where -- back to asking the power flow question, right, you doubled the thermal power, then you had to double the machine size, double the machine size, but then you also then upped it another 10 plus percent, and I'm trying to understand how you -- we'll get to the answer, but how you did the testing to, essentially, get the scaling, because the high-end stability, I'm just curious about how the scaling goes for a pressure drop of any significant amount.

MR. HINDS: Yes, we've done detailed scaling studies, and actually under -- then submitted the detailed scaling study submitted as part of -- well, the testing development program, and then there was an RAI exchange that we went through, as far as scaling studies to address the details of the scaling.

I mentioned the shorter core previously, to minimize pressure drop, and Alan had mentioned there are no restrictions in the downcomer area, where past plants either had jet pumps or reactor internal pumps in the downcomer area, there is, basically, nothing in there restricting flow.

This shows the flow -- this is natural circulation flow curve here, this is average power per bundle, or average -- with average flow, so this is, again, the natural circulation flow for the ESBWR as compared to natural circulation through a pooling water BWR/6, or an ABWR.

So, the reduction of those pressure drops, as well as the extended height of the vessel, calls for increased natural circulation flow.

Okay, we are up to an overview of the passive safety systems. Alan Beard will be going through a passive safety system overview.

MR. BEARD: Okay, good afternoon. My name is Alan Beard. It's a pleasure to be back again. I was up here when we did this 13 years ago for the ABWR, and actually some of the faces are still the ones that were around the table then, lot of new ones.

CHAIR CORRADINI: Just more grey hair.

MR. BEARD: As David said, I'm going to try and cover the passive systems, this will probably take 30 to 45 minutes, depending on the interaction we have.

But, the chief passive systems we are employing in this plant, the isolation and -- system is depicted on the right-hand side up there at the top, passive containment cooling system depicted here, the emergency corer cooling system, which consists of a gravity-driven cooling system in conjunction with our automatic depressurization system, and then the final element is our standby electric control system, which would look very much like a PWR accumulator when all is said and done.

We are not afraid to borrow from other technologies, when it suits our means.

Just a quick cut-away of the reactor building. One thing to look at here is, here is the grade elevation, and you've got a sense of where these large bodies of water are contained within our design, and we have the GDCS pools in the upper part of our containment, what we call the upper drywell. It's about 1,800 cubic meters worth of water in those three pools. We have an elevated suppression pool, which is different from most of our previous designs. Previous designs the pressure pool actually sat down on the base map area, and as you can see we moved it substantially up in the building.

And then, the green bodies of water are the bodies of water that we use for cooling of our isolation condenser and our passive containment cooling and heating storages.

One other view, this is if you lift the refuel floor up and look right underneath of it, this is what you'd see. You'd see the 6 PCCs, three of them located here on this side, three of them located here, and then the four isolation condensers out on the four corners, large bodies of water here and here, and then some additional bodies of water available at our cleaning pool, as well as our reactor cavity, and then this is our new fuel storage area that we pre-stage all our fuel prior to the start of an outage, and then the -- fuel transfer system is here that allows to refuel up and down from the fuel building down below.

Something else to point out here, the isolation condensers and the PCCs operate by actually boiling the water that's in the pools. As that steam comes off of the bodies of water they exhaust out through these connection cores, flows over the top of the water body, and then exits out through a motion separator assembly, just a simple chevron type of arrangement, where we wring out any excess moisture and collect it and allow it to drain back into the pools, and then the resulting steam is allowed to exhaust out through some duct work that's mounted on the outside of the reactor building. Steam is allowed to escape directly to the atmosphere or to the environment.

One key point to make on that is, we are insensitive to wet pool temperatures as far as the heat removal system works on this. We can have 100 percent humidity and it doesn't matter to these things, unless we get into a sauna-type situation.

So, I'll spend a little bit of time talking about the isolation condenser system. It does limit the reactor pressure, and it also prevents the SRV operation, and that's a key point. We've made it before, I want to make it again. One of the great things about this design is, in response to isolation transients we no longer have our safety relief valves lift. Previous BWRs, if we had the MSIVs closed, or your -- flow valves with a bypass failure happens, the safety relief valves will then pop open in a three to five-second time frame. In this design, and you'll see it on an upcoming chart, we never come close to lifting the safety relief valves. We keep our reactor cooling pressure cavity in tact throughout that transient.

They do provide a passive means of removing decay heat. They are sort of failure proof, and they are designed to operate in all design phases and conditions. Now when you get into the larger break LOCAs, the capabilities are greatly diminished, and we actually don't credit them as far as the heat removal that's provided in our analyses.

There are four of them, as I said. Another key point to make is, when these folks are operating, we are actually removing the decay directly out of the -- containment and allowing it to exhaust out to the atmosphere. We don't have an intermediate exchange boiling water inside a containment and then condensing that water back. So, we are not creating a steaming environment in the containment and the isolation condensers are in operation.

They are great heat removal devices. In fact, if we have all four operating, the operators will have to intervene and actually start to close down on the capability of some of these. If we don't do that, we will exceed 100 degrees Fahrenheit cool down limit rate.

Having said that, we do advertise a 72-hours hands-off capability. If we have an excessive cool down, it's an analyzed condition, we have many of those built into our factory and design in the plant, and so we don't expect that the operator has to do that, but we do feel that they should go ahead and do that.

We do have redundant diverse active components, I'll talk a little bit more on that when we get to the PNIV.

Key characteristics of the isolation condenser, they are safety related, that is a change from the SBWR. In SBWR they were a non-safe -- IC was considered a non-safe-related system. A number of reasons for that, just suffice it to say we've gone ahead and thought it made sense to make safety related.

They are independent of AC power, and Dr. Rick Wackowiak, our PRA expert here, always coming up with new-based scenarios, well, he identified, and I don't want to steal all of his thunder, but some of the design improvements that we've made as a result of this section of the PRA I think probably most significantly, at least in my mind is, not only are we station blackout capable with the isolation condensers, Rick coined a phrase, we are super station blackout capable. And, what we mean by that is, we can suffer the loss of all AC and all DC and the isolation condensers will still operate and remove the decay heat and we are in a safe condition.

There are four high-pressure heat exchanger units. Each unit is -- yes?

MEMBER STETKAR: Not immediate loss of all DC.

MR. BEARD: Immediate loss of all DC.

MEMBER STETKAR: You have to open the --

MR. BEARD: Loss of all DC, if you wait for my PNIV I'll tell you how we do it.

MEMBER STETKAR: Okay. I'll reserve the question.

MR. BEARD: Each of the heat exchangers actually have two identical modules, and the following chart we did do full-scale testing of an individual module over in Switzerland, we have a lot of test data from that.

CHAIR CORRADINI: This is on the PANDA facility?

MR. BEARD: No, it was actually a test prior to the PANDA test, same facility, but it was not part of the PANDA test.

With three of the four units operating we have about 2-1/4 percent negative boiler rate of heat movement capability, and the water stored in those isolation PCC pools that I discussed is enough to sustain operation of those heat exchangers for at least 72 hours, without external refill being required.

The isolation advancers are maintained in what we call a hot standby condition. What we mean by that is, they are fully exposed to --

MEMBER ABDEL-KHALIK: 72 hours, assuming that the water actually totally boils off.

MR. BEARD: No, we qualified the isolation condensers down to 1/2 tube pipe water, down to the 1/2 tube pipe, for the -- capability -- and so we have enough water in there such that after 72 hours we still have at least 1/2 the tubes covered with water to remove the heat.

CHAIR CORRADINI: So, the 72 comes from the batteries, not from the pool capacity, I guess is another way of asking the question.

MR. BEARD: No, they are about the same. With the amount of water we have up there, we will boil off down to 1/2 tube pipe the total volume of water up there in 72 hours, or thereabouts.

MR. KRESS: Can these handle ADWS conditions?

MR. BEARD: The question was can these handle ATWS conditions? Yes, we do assume that they come on in response to an ATWS event. They are not going to handle the --

MR. KRESS: You don't have 72 hours on the ADWS side.

MR. BEARD: No, but as soon as we have the liquid poison in there, it will drop rapidly back down.

MR. KRESS: Okay, you need to poison it to shut it down.

MR. BEARD: Yes, we need to poison it to shut it down.

So, it is a live standby, what we mean by that is, we have live steam being introduced up there, and then the only thing preventing it from operating are these two valves being closed right here, so the steam comes up, we have a high point invert from this point back, and this is all insulated piping, so from that point down they are filled with sub cooled fluid that's been collected in the heat exchange and the connected piping. And then, from that point back towards the RPV we have a constant pitch, so that any one that any water that does condense on those hot surfaces drains back to the RPV.

Now, another thing we have is, because it's an elevated -- non-condensable gases are definitely going to have a preference to go ahead and locate up to that high point. To take care of that issue, we have a vet line, or a purge line, located here, and how this works is, it will go through the nozzles of the main steam lines we have, a restricting orifice, 12-inch diameter restricting orifice. We use that for measuring our main steam flow. The other advantage to that is, if we have a main steam line break it helps to limit the differential pressure across the core structure.

The final advantage of that is, it gives us about 40 pounds differential pressure drop from the internal vessel to the down stream side of that restricting orifice, and so we bring that purge line back in down stream in that restricting orifice, so I now have about 40 pounds differential pressure of steam sweeping up through here and then coming back down through that purge line, helping purge those non-condensements out of the system.

CHAIR CORRADINI: Can you say that one more time, just so I understand. So, where -- what line are you pointing to? I was looking and I --

MR. BEARD: The purge line is this little one right here.

CHAIR CORRADINI: Yes.

MR. BEARD: It goes up to the top header up here, and so we have steam coming through here, and then because there's a 40 pound difference between the outlet pressure here and the outlet pressure here, we have that 40 pound difference getting steam flowing through that 3/4 inch line continuously during standby operations.

CHAIR CORRADINI: Okay. So, you are leaking it out and then purging the non-condensates with that leakage.

MR. BEARD: Correct.

Okay, the IC, as I said, are maintained in standby mode. They are initiated by opening one or both condensate return valves, and we are going to get to your question.

The initiators include, if we have a high reactor pressure for greater than 10 seconds, whether we -- if we have closure of MSIVs on two or more steam lines, less than 92 percent open, or less than full open, with the reactor mode switching run that is also an initiating condition.

If the reactor water level drops to level 2 with the time delay, that is an automatic initiation of isolation condensers, if it's gets to level 1 it's an instantaneous initiation of isolation condensers, and then the loss of power generation buses, we are looking at a loss of feedwater, we are going to preemptively initiate the isolation of that just to get additional water volume into the reactor pressure vessel at that time.

But, obviously, like most systems, we have manual initiation as well.

Okay, the steamless generator on the full side of the ICs, we already talked about --

MEMBER ABDEL-KHALIK: I'm sorry, would you go back, please?

MR. BEARD: Yes.

MEMBER ABDEL-KHALIK: You said when you

lose feedwater you automatically start this, to bring more water into the reactor?

MR. BEARD: There is a volume of water stored within -- a very significant volume of water stored within the heat exchanger, in this return pipe and the semi vessel, that we'd want to go ahead and get that volume of water into the RPB.

MEMBER ABDEL-KHALIK: And, how much water is that?

MR. BEARD: Each system has 15 cubic meters of water.

MR. WACKOWIAK: Heat exchanger and tank, yes.

MR. BEARD: Yes. So, with the four of them, we'll have 60 cubic meters, 264 -- to a cubic meter. I'll let you do the math.

So, it's not insignificant, it's probably several feet of water level within the RPV when it's all done together.

We do have 72 hours worth of water stored in the ICPCC pools. After 72 hours, the only thing we need to do to maintain that continuous heat removal is, we don't need the batteries recharged, because I'm going to explain this in a minute, all we have to do is get additional water up in those PCC pools and we can continue to remove heat from the reactor pressure vessel.

During normal operation, once the vessel is isolated I no longer have that 40 pound differential to keep purging the non-condensables out of there, so I have to have another means to do that. We've got additional vent lines with solenoid operated valves on those that we periodically pop open to allow the non-condensable gases that might be accumulated in the isolation condenser to be brought in at suppression.

MEMBER STETKAR: DC-operated solenoid valves?

MR. BEARD: They are powered by the -- power derived from the batteries.

MEMBER STETKAR: That's what I mean.

MR. BEARD: We ask the question, are they AC solenoids or DC solenoids?

MEMBER STETKAR: They are DC solenoids derived --

MR. POPPEL: Ira Poppel.

MEMBER STETKAR: -- I'm sorry, Ira Poppel General Electric.

MR. POPPEL: Can I make a statement?

MR. BEARD: Sure.

MR. POPPEL: Ira Poppel, GE-Hitachi.

The DCIS, if you will, makes all the DC power needed for the squibs and solenoids redundantly per division, and it's derived from AC going to the DCIS, and in turn the AC is derived from the plant batteries, which are sized for the 72 hours.

MR. BEARD: Okay, so the vent lines that I was talking about are these over here. There's one that goes up to the upper header assembly, and then there's one that comes off the bottom header, and there's parallel flow paths here.

But, as the operator would assess a degradation in the heat removal, probably showing up as my pressure is no longer dropping, I'm hitting this steady state, he can go in and cause these valves to open up.

We now have 700 pounds of steam pressure open, very strong loaded force, and take the non-condensable gases and steam flow down through this line and that line is submerged into the suppression pool, and it will go ahead and push the non-condensables over to the suppression pool, close those valves, and we are back into removing the isolation condenser.

Now, to answer the question that was asked before. We have two parallel valves here, both of them are pneumatically operated. One of those valves is designated to be a fail open valve on loss of either pneumatic pressure or electrical signal to the solenoid.

MEMBER STETKAR: Thank you, equal size valves?

MR. BEARD: Yes. Either one of those two valves opening will give you full capability for the isolation of the actual cell.

CHAIR CORRADINI: this is the NMO valve?

MR. BEARD: Yes, NMO is nitrogen motor -- I'm sorry, no --

CHAIR CORRADINI: No, no, no, those are isolation.

MR. BEARD: Those are the isolation valves.

CHAIR CORRADINI: So, these valves aren't shown.

MR. BEARD: Yes, they are, right here.

MEMBER BLEY: I can't find your pointer.

MR. BEARD: Right here.

MEMBER BLEY: Oh, okay, thank you.

MEMBER STETKAR: One of those fails by loss --

MR. BEARD: Loss of pneumatic pressure or an electrical power to the controls.

Okay, we mentioned -- or I mentioned at the top, we've held varying isolation events. We've never come near lifting the safety relief valves. Here's our safety relief valve set point way up here at 8.7 -- you see the various pressures, you know, this would be the steam line pressure, and this is the bottom head pressure, but you can see we've got substantial margin between the set point and that.

And, the other interesting thing to keep in mind here is, the first 30 seconds here the isolation condensers really are doing nothing, because one of the things we found during our test program was, we actually have to slow down the initiation of the isolation condensers, or we get a tremendous steam hammer event going on, as we expose -- rapidly expose to those cold tube surfaces. So, we've got to meter that water level drop down in the tube surfaces to mitigate that steam handling event.

As a result we don't fully drain the isolation condensers for the first 30 seconds after initiating an operation. So, you ask, what's going on here? Well, what's happening is, all that sub cooled water we had out in the annulus is now swept into the core, helping to collapse the steam and bring the pressure down. That's what's really driving all this along.

Now, the other point to make here is, if the isolation condensers fail to operate, correct me if I get this wrong, Rick, but it's about five minutes before our pressure would actually come back up to a point we'd have to lift the relief valve.

And, I should say that we lift the safety valve because we have no relief function in this design.

Just to point out, we did do full-scale testing, and this is a picture from the test we did for the SBWR, and it is a full module unit. We did -- we extended the length of these just slightly to give us a little bit of additional capacity. The basic configuration is the same, and you get a sense of just how large these heat exchangers are by the man standing there.

MEMBER STETKAR: Let me ask one more question, since we are changing topics.

So, this is more for Rick, and I have to apologize, I'm one of the new members, so I don't have the benefit of previous briefings, or any of the other presentations, so I'm trying to come up to speed quickly here.

In the risk assessment, or the design analyses, have you evaluated -- my first reaction looking at these things is, you put steam generators on a boiler, so have you looked at the equivalent of isolation condenser to rupture events, or failures of the steam side of the isolation condenser, in the accident analyses and in the risk assessment?

MR. WACKOWIAK: Yes, those are included in the initiating events, and then also in the failure modes of the isolation condenser.

MR. BEARD: And, just to expand on that, we do have the containment isolation valves, two here on the steam supply, two on the condensate return, and what we are monitoring for that is leakage in the system. We are looking at, we've got some radiation elements up here, if we get radioactive steam coming up, and all for high flow conditions, You would want condensate for steam flow and --

Any other questions on isolation condensers?

MR. WACKOWIAK: But, it's really not like a steam generator tube, it's not a real -- it's like --

MEMBER STETKAR: No, I understand, it's

just the concept.

MR. BEARD: Dr. Corradini, we have a break scheduled at 3:00, correct? Okay, continue to move then?

CHAIR CORRADINI: Oh, yes.

MR. BEARD: Okay.

CHAIR CORRADINI: You are doing great.

MR. BEARD: Thank you.

Passive containment cooling system, heat exchangers look very similar to the ICs, just a little bit difference in the scheduled thickness of the piping.

They do operate in medium and large break LOCAs. They also provide a back-up to our isolation condenser system if, for whatever reason, the ICs don't work. But, to do that we are going to have to depressurize the vessel, that's part of our emergency core cooling system, which I'll explain in a little bit more detail in the following slides.

The PCCs, unlike the ICs, are entirely passive. There's no active component on that system that needs to reposition in order for the flow path to be created.

CHAIR CORRADINI: Can I go back to the topic? Something just -- I get a little bit of history -- so, was Oyster Creek the plant that had an isolation condenser for a large capacitor, or am I getting that confused?

MR. BEARD: Oyster Creek, Dresden 2 and 3 --

CHAIR CORRADINI: That's what I thought.

MR. BEARD: -- all had isolation condensers. However, they were horizontal tube and shell, not vertical tube within a bathtub. And, Nine Mile 1, yes.

CHAIR CORRADINI: So, that leads me, I guess, to my next question, which is, I was going to ask how different are these isolation condensers. So, the previous ones were horizontal.

MR. BEARD: They were horizontal tube and shell configuration, yes.

CHAIR CORRADINI: And, had they ever been exercised in their lives?

MR. BEARD: Oh, yes.

CHAIR CORRADINI: Okay, so -- so then, I guess back to my question, which is, the change in design was initiated because of performance of those? Why vertical now versus horizontal? I'm trying to understand the design change from the isolation condenser design that you previously had.

MR. BEARD: I don't know the full answer to that. I think part of it is we wanted to get the 72 hour capability. The other ones, I believe, are only about 30 minute capability for water they have stored in a head tank, as well as what's in the shell itself.

MR. HINDS: It improves venting capabilities, the purging, non-condensable purging capabilities?

CHAIR CORRADINI: That's lines, I mean, just to push the point, those are all lines. I'm curious about the vertical versus the horizontal configuration. You've got some -- was there some performance issue, was there something?

MR. BEARD: I don't know.

CHAIR CORRADINI: Okay.

MR. BEARD: I'm sorry, I can't answer that. We can try and find out from the people who make the decisions. I was not part of that.

MR. HINDS: Yes, I thought some of it gets into the purging capability, you know, the orientation and the collection of non-condensables, but we can further tap into that.

But, part of the purging capability is aligned with, you know, the nature of it to collect non-condensables.

MR. BEARD: Okay, so the PCCS, passive containment cooling system thermal hydraulics, instead of having steam being directly piped from the reactor coolant pressure boundary, main steam lines, we are now going to actually have the steam go out through the drywell first, and then --

MR. MATTHEWS: I'm sorry, I've been sitting here with my head spinning trying to remember, the old ones had some operational events where they opened when you didn't want them to, as I recall. What happens if these open while you are at full power?

MR. BEARD: The first thing the -- is probably going to see is decrease in electrical output of the pump.

MR. WACKOWIAK: And, steam on the outside of the building.

MEMBER BLEY: Any more significant than that?

MR. BEARD: Well, the steam, as Rick says, it's probably going to create a pool, but, no, other than indication that the valve has gone open, the only other indicators would be you have lost a little bit of electrical output, because, I mean, if you fall about 1 percent --

MR. WACKOWIAK: We'd want to be analyzing it.

MEMBER STETKAR: The turbine is controlling how much it wants to go, and you'll probably go out on high power.

MR. HINDS: And, analyze the cold water, you need cold water effects to analyze them as well. So, the condensate, when it injects, that's part of the analyzed event.

CHAIR CORRADINI: You'd have an over power, I think John's point is you'd have an over power event, you try to compensate with your turbine valve, and then the turbine is going to be seen two ways in the parallel path then.

MR. BEARD: Well, no, because the control mounts are maintain constant reactor pressure.

MEMBER BLEY: But, it depends on the turbine control.

MR. BEARD: Yes.

MEMBER BLEY: And, how it is hooked to the grid and how it is set up to respond.

MR. BEARD: So, there would be some amount of effects of the cold water and the turbine needs to be analyzed then. But, we have looked at it anyway.

Go on?

CHAIR CORRADINI: Sure.

MR. BEARD: Okay, so the steam is now being introduced into the drywell. We have a large ten-inch diameter pipe that penetrates through the top slab of the primary containment for each one of these six PCCs, the steam goes up that 10-inch pipe and enters into the upper header, and again, functions exactly like the isolation of that, your steam comes from the contact of the cold tube surfaces, the steam is condensed, collected in the lower drum, but in this case, instead of returning directly back to the reactor pressure vessel, where you will turn it back to one of the three GDCS pools, from the GDCS pool then we allow the water to flow into the RPV.

MEMBER ABDEL-KHALIK: Now, this whole heat exchanger is full of gas, essentially, before it's called --

MR. BEARD: Correct.

MEMBER ABDEL-KHALIK: -- how do you clear the gas?

MR. BEARD: Rick, do you want to answer this? Okay, Rick can tell you that.

MR. WACKOWIAK: For example, in a depressurization event --

MEMBER BLEY: It doesn't matter what happens on the reactor side.

MR. WACKOWIAK: Well, on the reactor side. well, suddenly I have steam in the containment.

CHAIR CORRADINI: You have to get steam on the containment.

MR. WACKOWIAK: Right, and, you pressurize the containment.

Now normally, when you think of the pressure suppression containment, where we are pushing gas through the vertical vents into the suppression pool, there's also a vent line from the PCCS down into the suppression pool. So, initially, as the containment pressurizes, the containment pressure drives all the gas out of the PCCSI into the suppression pools.

CHAIR CORRADINI: Because you are porting that steam up to the top of the --

MR. WACKOWIAK: It goes into the drywell.

CHAIR CORRADINI: -- you are porting the mixture in, whatever the pressurized width is going to go up and through.

MR. WACKOWIAK: So, it's going to start going through here preferentially, and it will follow the path and until this heat exchanger is filled mostly with steam, the function is just to get non-condensables cleared through here.

And, if you look at the short-term response of this system, the heat transfer capability of this system doesn't start until some long number of seconds, until all of that non-condensable has been purged out by the containment pressurization.

MEMBER ABDEL-KHALIK: But, you indicate here that some of it will remain at least in the lower plenum.

MR. WACKOWIAK: A little bit.

MEMBER ABDEL-KHALIK: Why there rather than the top?

MR. WACKOWIAK: That's what the experiment showed.

MEMBER BLEY: Do you understand the experiments?

MR. BEARD: The answer to that is, we are venting the non-condensables from the lower part, and we are going to vent enough non-condensables from the upper part of these tubes until we restore enough heat and lubricate the building, and that's the decay heat curve.

MR. WACKOWIAK: I'm sorry, the non-condensables that may stay in the upper portion don't affect the heat transfer characteristics. The tubes are down toward the bottom.

Venting it off the bottom was shown in the experiments to be the most effective way of clearing the heat exchanger.

CHAIR CORRADINI: And, just to repeat what you said to Dennis, where is it remaining? I didn't --

MR. WACKOWIAK: Lower plenum.

CHAIR CORRADINI: Lower plenum.

MR. BEARD: Down in this area right here.

CHAIR CORRADINI: In the top of that lower -- that surprises you?

MR. BEARD: It doesn't surprise me, no.

CHAIR CORRADINI: Okay. So then, the explanation is?

MR. BEARD: The explanation is, all the condensing is being done up in tubes here, non-condensable gas is here and not affecting my -- capability, because they are located down in that lower plenum.

CHAIR CORRADINI: This was -- which test showed the remainder in the lower plenum?

MR. BEARD: That was PANDA.

CHAIR CORRADINI: A PANDA test. And, the

experimenter runners, have they an opinion on this, as to why the lower plenum non-condensable gas remained high -- remained higher?

MR. BEARD: Well, I think it's -- you know, we have about a one-meter submergence here, and -- this sparger right here, but the purge line sparger is about one meter submerged, so as the heat limiting capability of the PCCs is degraded, and pressure to the drywell is going to go out, it's going to start to depress this water column, and at some point I'm now going to depress the water column past that sparger. I now open up this flow path, I start purging non-condensable gases out of there, and I'm going to purge enough non-condensable gases out until I start to remove more decay heat out of here than I'm generating, pressure is going to start to go down on the drywell, we come back and recover.

So, it's constantly -- it's burping, is what it's doing.

MR. HINDS: And, in Chapter 6, we have some trends, charts, some charts showing the performance, and so you can see some of the non-condensable clearing charts.

And, when our Chapter 6 team comes in, they'll come -- go into more detail as well.

But, yes, you can see the clearing, periodic clearing of non-condensables on the performance charts of the PCCs.

MEMBER ABDEL-KHALIK: So, what's the distance between the top of the pool and the bottom of the venting line? The normal water level in the pool is the bottom of the venting line.

MR. BEARD: This right here?

MEMBER ABDEL-KHALIK: Right.

MR. BEARD: It's about one meter submergence, versus three meters of submersion.

Because what we are trying to do is, we want the heat not being absorbed in the suppression pool long term, we want it being transferred out of the containment and sent out to the atmosphere.

And so, we've got two meters differential here, and we take advantage of that to go ahead and purge that system, and as long as we don't ever press the DMS bar, because that puts additional heat in that suppression pool, other than what's coming through during the purge operation.

And, this next bullet goes to exactly what we talked about, the PCCs only work as hard as they need to, and they do that, and they just have this continuous, constant purge, and you see it in kind of a sinusoidal wave in the pressure of the drywell, and that's what's going on.

And, there's some heat exchangers, as we said there's a moving boundary in the fluid rich in steam, the fluid rich in non-condensables, and we move that boundary up and down to get the heat removal capability that we need.

And, we also have done full-scale testing on these. We did the integral testing as part of PANDA, but we also did some full-scale testing in addition various combinations in non-condensables and steam flow rates into these to demonstrate that they actually do work as expected.

Any questions on PCC?

Okay, the next system is the emergency cooling core system, and really the ECC consists of the automatic depressurization system, as well as our gravity-driven cooling system.

There are some secondary supportive systems, the isolation condenser and the standby electric control system in the ECC large break LOCA response for the aspect of dividing some water that are contained in those systems, we do assume that they are injected into the RPV as part of our overall inventory control.

MEMBER SHACK: Now, what class of accidents do I need this for, versus --

MR. BEARD: This would be medium or large break LOCAs.

MEMBER SHACK: Okay.

MR. BEARD: Who are beyond design basis accident -- isolation condenser --

MEMBER SHACK: How large is a large break LOCA?

MR. BEARD: It's a medium break LOCA. If you go on the line of the main steam line, that would be what we've characterized as a large break LOCA, medium would be a GDCS line.

MEMBER SHACK: I'm looking for a hole size just so the line doesn't break.

MR. WACKOWIAK: Now, in the Chapter 6 analyses, they looked at each individual line break to determine a limiting size, so the categorizing it into large, medium and small is a semantic sort of thing. In the PRA, we did it by a different method, by looking at what the effects on the plant were.

A large break was a hole that's large enough to allow GDCS to inject without any further depressurization using relief valves. So, if it's in a steam line, a large break is one size, versus in a liquid line a large break would be a much different size.

And, what we found is that, down low connected to the reactor, if you remember the chart from earlier on, the GDCS and the standby liquid control lines, all those that are down mid plane on the vessel and lower, there are pipes -- there are no pipes large enough to have a large LOCA, they are all in the medium range.

The shutdown cooling suction line is a borderline large break LOCA, because it initially starts out as a liquid break, and then eventually turns into a steam break. And so, what we've shown in the analysis that we did for the thermal hydraulic uncertainty is that it actually falls into the side of the large LOCA capability. We do depressurize when steam starts coming out of that line, before we heat up the core to the point where we'd have core damage.

So, in terms of lines there, that's about a 12-inch line, but that's only because it's initially covered with water.

MR. HINDS: So, the steam in the feedlines are large breaks, so not -- unlike the past plants with their recirc suction, there's no re -- you know, of course, no recirc suction break, and no large lines down below.

The bottom drain line is, of course, down at the bottom, but other nozzles are up above core level, and the bottom drain line is a series of four pipes tied together into two -- one in one look and two going to another, so it's four 2-inch pipes, approximately, 2-inch pipes.

So, any large break would be up in the upper elevation feeder steam.

MR. BEARD: Okay, a key point that we have not made yet is, for the ESBWR, for all design basis accidents, our core never uncovers. In fact, the worst case we are ever going to have is at least one meter of water over top of it, most cases show that we have at least three meters water coverage over top of active fuel at the low level point, correct, Rick?

MR. WACKOWIAK: It's, approximately, one meter, it depends on --

MR. BEARD: Some of the assumptions that go into the single failures or whatever, but minimal case we have at least one meter with low fuel coverage, obviously, very little if any for heat up.

MEMBER SIEBER: You have an RWCU on that vessel, right?

MR. BEARD: Correct, yes.

MEMBER SIEBER: If that breaks, how long will it take to -- what change will that make in the vessel water level?

MR. BEARD: Well, the RWCU, as David said, it's a combined system reactor clean-up and shutdown cooling. Higher up, above top of active fuel we have two 8 or 10-inch pipe penetrations to provide the flow we need for shutdown cooling, lowered down for the bottom header for the thermal stratification and to get all the junk that accumulates down there.

We've got four 2-inch lines. The difference here, though, is -- and we didn't talk about this before -- those 2-inch lines come in from the periphery of the head, and then there's actually tubes that follow the contour of the head down to the lower invert point at the RPV, such that we don't have problem with debris being dropped into the vessel going down and clogging up the bottom head nozzle.

Also, from a severe accident standpoint, we no longer have that port as a potential melt-through port.

MEMBER SIEBER: That penetration is what, about two inches?

MR. BEARD: Those nozzles are two inches, the flow lines that come in are two inches.

MR. WACKOWIAK: They are very small nozzles, and that's one of the analyzed LOCAs in Chapter 6, and we show where the water level gets to in that particular case, and it's still above the core.

MEMBER SIEBER: Well, they are small compared to the amount of water in the vessel. I was curious about that.

MR. HINDS: And, just for the reference in your slide chart, on No. 10, Slide 10, shows the nozzle elevations if you need to see them.

MR. BEARD: Okay, so in order for the gravity-driven cooling system to work we've got to depressurize the vessel, because we are taking advantage of pretty low driving head, just the elevation in the pools.

So, to do that we've got a two-stage automatic depressurization system. The first stage of that we are going to take ten of our safety relief valves, we are going to open them in a relief type function, and we are going to allow the steam from those ten valves to blow out through collectors that are located at the bottom of the suppression pool, and we can do the initial part of the blow down using that.

Later on, we've got eight depressurization valves. These are squib-actuated valves that open up and vent directly to the drywell, and we fire those off in sequence to go ahead and bring the RPV pressure down to the same point that it equals the drywell pressure, such that we don't have that back pressure from the submergence of the collectors in the suppression cooling.

So, ten of our 18 SRVs have got the additional external actuators on them to provide an ADS, and then we've got the eight DPVs, four of those are mounted on the main steam lines, and then four are on stub tubes that we also use to route the steam to the isolation condensers, and each of the DPVs is twice the capacity of an SRV.

Again, the bottom line is, we wanted to show that the pressure in the RPV is equal to the pressure in the drywell.

MEMBER SHACK: Now, is the depressurization you get from either system sufficient, or you need both systems to work?

MR. BEARD: You need the DPVs to open in order -- because if we had that back pressure, that 7 meters coverage over the collectors, we are not going to get down to the point that the gravity will flow it up.

But, we want to take the initial flow down, channel that energy into the suppression pool there before we let the rest of the energy out to the DPV.

CHAIR CORRADINI: So, you get down to -- you said it and I just didn't hear it, you get down to what pressure, just literally the water head is the differential that you are left with?

MR. BEARD: Right, once the DPVs are open, the pressure inside the RPV equals the pressure of the drywell.

MEMBER BLEY: Did you say all four of them need to operate?

MR. BEARD: There's eight DPVs.

MEMBER BLEY: Okay, four of them --

MR. BEARD: From our design basis accident standpoint, I can't remember if it's six or seven, Rick's analysis says, I think, we only need one or two.

MR. WACKOWIAK: The design basis analysis was done using single failure criteria, so we've analyzed it with seven of eight, so that's what's in Chapter 6, is seven of eight, and that works. We didn't analyze it with fewer than that.

In the PRA, we've looked at fewer numbers of DPVs being successful. In all cases, we can show that it works with four, in some cases we can show that it works with three.

MEMBER BLEY: And, that's only in the PRA.

MR. WACKOWIAK: In the PRA.

MR. BEARD: So, what do these depressurization valves look like? They are squib-actuated, there are pyrotechnic charges up here, and there is a tension bolt and piston assembly. The pyrotechnic charge is ignited, creates a high pressure gas, the pressure of that gas goes up to the point the tension shears off, breaks off, piston travels down very rapidly, strikes the nipple assembly, the shear assembly here, shearing that off, the cap falls off, it's retained by the retaining pin here, it falls out of the way and establishes the flow path.

So, we have two indications of firing at the depressurization valves, one during normal operation. We have a continuous tripper charge of electricity going through those booster assemblies, and so when the continuity signal is lost, as a result of firing those charges, we know we've at least initiated the squibs, and then we have an electromagnetic switch here that will pick up and indicate the shear assembly has relocated into the open position, it's out of the way to allow the steam path to flow.

MEMBER ABDEL-KHALIK: How high does the containment pressure go when you fully depressurize?

MR. BEARD: The design pressure containment is 42 pounds gauge.

MEMBER ABDEL-KHALIK: No, but how high does it actually go?

MR. BEARD: The actual pressure, I believe, goes to 37 pounds, 36 pounds.

MR. WACKOWIAK: I work in kpas.

MR. BEARD: Two and a half kil-pascals?

MR. WACKOWIAK: on the break I'll pull that up, those specific numbers.

MR. BEARD: But, it's in the mid 30 range, mid to upper 30 pounds gauge.

MEMBER ABDEL-KHALIK: All right, thank you.

MEMBER BLEY: Is there a particular reason you had to go to valves with the expensive boosters on them? I'm curious on that.

And, are these one -- do these exist somewhere else, or were these designed for this one?

MR. BEARD: These were designed for this

plant, and we did, again, when we are using new technology, we put them through a full test program, and here's an example of one of those.

the answer on that, part of it is when you look at the design of the electrical system, you either have to go with pneumatic valves controlled by solenoids, but you get into the issue where because you are opening so many valves in a simultaneous condition, it's not so much the total amount of energy consuming, but the very high peak average flow rates you are getting for average usage, really drives the electrical systems to non-optimizing.

The other one is, you know, these are non-reversible state, and it gives us some benefit for the accident scenarios and some other ones that I really can't talk about, at least not in open session.

MR. HINDS: Leak-tight integrity as well, their leak-tight integrity, you know, prior to actuation as well, they are very leak-tight.

MEMBER APOSTOLAKIS: Are they used anywhere else?

MR. BEARD: This particular design, no, but we do use squib-valves on both our standby electrical control system as well as our -- port flow.

MEMBER BLEY: I have one question on your design basis accident. You said you went to seven out of eight because you used single failure criteria. I don't think you probably need to do that, you need to show you can survive single failure, but is there a reason, thinking about it, essentially, what you are doing is making the people who built one of these eventually run assurance to prove that they'll have seven out of eight, instead of four out of eight or something like that, which is a hell of a lot more reliable.

MR. BEARD: Well, two points, the point I haven't made is, there are actually two booster assemblies on each one of these. So, firing either one of those booster assemblies will result in the opening of that.

MEMBER BLEY: Makes them more reliable.

MR. BEARD: More reliable, and then those two booster assemblies, for other reasons, can be fired by any one of three safety-related divisions or our diverse protection system.

MEMBER BLEY: So, you think they are reliable enough it's not a burden to have to show that seven out of eight.

MR. BEARD: We think so, yes.

MEMBER ABDEL-KHALIK: And, these will

never be tested, if they are never called upon?

MR. BEARD: They will be tested as part of an initial qualification program, and then periodically as it's necessary to replace the booster charges. We'll go in, replace the booster charges, and then take the booster charge that we just took out of there to a test facility and initiate it and make sure that it did fire.

Not absolutely defined yet, but it's going to be somewhere about a seven-year time frame, and we'll set it up so that it's a staggering rotation, with probably almost 50 booster assemblies within the design. So, depending on what kind of refuel cycle they are on, we may be doing 10, 15, 20 percent replacement of booster assemblies on every outage.

MEMBER STETKAR: But, there will never be an actual test where you fire one to blow it open, thinking about mechanical interferences, and things that happen like that.

MR. BEARD: We are taking --

MEMBER STETKAR: Booster assemblies work pretty well.

MR. BEARD: -- we are taking the position that, yes, knowing we wouldn't need to do that, however, you will note that it is a bolted flange assembly, so if we have to we can go in and put in a new booster assembly.

MEMBER STETKAR: Check valves occasionally fail, too.

MEMBER SIEBER: It can't corrode enough to cause it to stick or anything like that, because you are actually breaking it.

MR. BEARD: Okay, so we have done full test program on these, and that is the full-scale size that we need under various inlet steam conditions.

MEMBER SIEBER: The trick is going to be to get the explosive in there past security.

MR. BEARD: Finally, the gravity-driven cooling system, we have three pools of water that are located in the upper drywell. There are four safety-related divisions, so there's four divisions of plumbing that tap into those three pools.

Two smaller pools, one larger pool, each of the smaller pools is only connected to one division, and the larger pool is connected to two divisions.

In our analysis, as part of the single failure criteria, we assume that we can drain one of those pools and we still have sufficient water to fulfill the mission.

A couple of different modes of operation for the gravity-driven cooling system, versus what we call short-term cooling, that's where we are injecting water into the reactor pressure vessel.

Long-term cooling, some debate whether we even actually need it, but originally it was thought that in the long term that you might have a net transfer of water over from the drywell side into the suppression pool, that at some point you get to the point that the water height in the suppression pool is actually higher than what was in the drywell, and so we have flow paths that we can open up to re-equalize those water levels if that becomes necessary.

And then, as part of our severe accident strategy that Rick is leading, we have a deluge capability, and that's predicated on the fact that, well, if we got core damage it probably means we didn't get the water into the reactor pressure vessel, so we've still got all that water sitting up in those GDCS, go ahead and use it for other purposes.

CHAIR CORRADINI: And, where are they directed?

MR. BEARD: Where --

CHAIR CORRADINI: Where do they go?

MR. BEARD: The deluge lines --

CHAIR CORRADINI: You've got all that water, and now you are in a situation where you want to put it somewhere, does it automatically drain into the core, yes? No where else?

MR. BEARD: No.

MR. WACKOWIAK: It goes in to the BIMAC core catcher.

MR. BEARD: The first place we'll want to put it is in the core.

CHAIR CORRADINI: Oh, but you actually have a separate path that you can put it in the BIMAC?

MR. BEARD: Yes, right here.

CHAIR CORRADINI: And, those are normally closed, and they are opened how, to send it one place versus another?

MR. WACKOWIAK: Two separate control systems that actuate that, the ECCS control system actuates the valves that put the water into the vessel.

CHAIR CORRADINI: That's the two that we've seen here.

MR. WACKOWIAK: That's the two on the side, and the three that go down toward the lower drywell part of that cartoon are actuated by a separate set of controls, a logic controller that's part of the BIMAC device, that actually detects the temperature of the drywell floor, and when the drywell floor is elevated to where we think that the core is down there, then those open and flood the lower drywell.

CHAIR CORRADINI: Without any operator action.

MR. WACKOWIAK: Without any operator actions.

CHAIR CORRADINI: So, kind of like sprinklers.

MR. WACKOWIAK: kind of like the sprinklers, but there are other safeguards in there to prevent inadvertent actuation, which we'll talk about a little bit.

CHAIR CORRADINI: later.

MR. WACKOWIAK: later on.

CHAIR CORRADINI: I guess I'm struck by the path, that you can accidentally put at the wrong place. That kind of gets me wondering.

Later is fine. Later is fine.

MEMBER ABDEL-KHALIK: If you go back to the schematic that you just showed, Mike, okay, now how do you prevent uncondensable gas from accumulating between the check valves and the squib-valves on those gravity-driven lines?

MR. BEARD: There are vents and drain lines, manual vent drain lines that are inside the system.

CHAIR CORRADINI: Where is that?

MR. BEARD: Well, we are no showing them on a --

CHAIR CORRADINI: Vent lines on the gravity-driven supply lines?

MR. BEARD: Standard configuration like you'd have on any significant large bore pipe, you have a vent and drain line to make sure that when you fill the system initially that you fill it solid, and you've got all the non-condensable gas.

MEMBER ABDEL-KHALIK: I thought I read someplace that those check valves are actually partially open, is that correct?

MR. WACKOWIAK: They are mounted vertically in the pipe, is the latest configuration that we have in Rev 4, they are mounted vertically in the pipe, and they are in an open condition.

MEMBER SIEBER: They are not sealed shut.

MEMBER ABDEL-KHALIK: So, these lines that you are indicating here that have both the squib-valves and the check valves, they are vertically oriented?

MR. WACKOWIAK: The squib-valves I'm not sure, but check valves, we've talked to the engineer about this several times, and they are mounting them vertically in the pipes, so that they are open during normal operation.

MR. HINDS: To help minimize the potential of what you are referring to.

MR. WACKOWIAK: Right.

MR. HINDS: As far as any blocking.

MEMBER SIEBER: It doesn't make any difference for the squib valve, does it?

MR. WACKOWIAK: No, it shouldn't make any difference for the squib valve.

MEMBER ABDEL-KHALIK: No, I was just concerned about the space between the two.

MR. WACKOWIAK: Right.

MEMBER ABDEL-KHALIK: Well, how long is that line, between the two valves?

MR. HINDS: Don't know right off hand. I haven't seen the final arrangement.

MEMBER ABDEL-KHALIK: Those are what, 8-inch lines?

MR. BEARD: Eight or seven.

MR. WACKOWIAK: By the time they are at

the check valve I think they are 6-inch lines. I think it's eight coming out of the pool, and then it splits into two six inch.

MR. BEARD: Okay, what initiates the ECC, water level persisting for ten seconds or greater. Also, before the ECC squib-valves will fire we need to complete the depressurization, and this is just the time delay on the ADS. Five of our ADS valves are going to immediately open, followed by the remaining five ADS SRV valves ten seconds later, we are going to initiate three of the eight DPV 50 seconds after that, and then sequence the rest of these out, and that's just to help minimize the loading on the containment and also to not blow all the water out right away, while we are waiting for all our other systems to get into operation.

I did mention earlier that the water inventory, the liquid inventory above the standby liquid control system, the isolation electricity is credited, and our LOCA analyses SLC is going to operate a coincident with the DPVs being said that they are open.

The need for the equalization lines, like I said, a lot of our studies show that we never need to open them, we never transfer enough water over the suppression pools, but they are there just in case, and they would open up to maintain water level equal between the suppression pool and the drywell.

And then, the containment heat removal and inventory conservation is via the passive containment cooling system.

So, these three bodies of water located here, 1,800 cubic meters of water, are sufficient such that we can fill both the reactor pressure vessel, as well as the entire portion of the lower drywell if we have a low, you know, bottom head drain line break, we can fill all that volume up to at least one meter above the top of active fuel. There's enough water up in these three pools to do that.

So, the schematic, this is just one of the four trains that we show here, so each of the four trains has two flow paths for the short-term cooling, the vessel injection, come out with an 8-inch line and then it goes to two 6-inch lines, with the check valves and squib valves. The equalization line over here from the suppression pool is going back into the RPV, should we ever need to use that.

And then, the daily response and Rick will talk about more as part of BIMAC, maybe.

MR. WACKOWIAK: Yes, I'll talk about it.

MR. BEARD: GDCS squib valves, a little bit more conventional design, as to what's been used previously. It's got a shear assembly that flops out of the way, it's actually a concentric ring that we drive across into a recessed area here. Same basic principle, and we do have electromagnetic switches to indicate that the valve has opened.

LOCA water level response, we have a long-term water valve, BWR 4 through 6s, the best we could ever assure was two-third core height, based on the jet pump flood line. With the ABWR, with the active systems coming rapidly into operation, we are able to show that we never uncovered the core, and we maintained at least one foot of water coverage over top of active fuel flowing in the design basis accidents.

For the ESBWR, we continue that trend, we never uncover the core, and for most cases the low water mark when we begin is about 10 feet over top of active fuel.

CHAIR CORRADINI: Before we do the LOCA I have a question. We are okay on time.

So, I'm still back with this parallel flow path with the GDCS. So, if the valves fail to open, how much water is in the lower -- in the cavity region without that opening to the pedestal region, or whatever you want to call that area.

MR. WACKOWIAK: If the valves -- if which valves fail to open?

CHAIR CORRADINI: Those three pointing down.

MR. WACKOWIAK: Okay, that's one of four divisions, so there's a total of 12 in the plant, so just remember that. So, we've got 12 valves to get water down into the BIMAC.

So, if those three did not open, how do we get water into the lower drywells?

CHAIR CORRADINI: I would assume there's going to be some condensate run-off already there. That's another way of asking the question. In the absence of having the GDCS water directly get there, what sort of water inventory are you expecting below the reactor vessel?

MR. WACKOWIAK: If it's a LOCA, we'll have lots of water down there, which poses other problems associated with things like steam explosions.

If it's not a LOCA, if it's a steam-line break, or if it's a transient that ultimately results in a depressurization of the plant, the steam that would be in the drywell, most of it is condensed in the PCCS, put back into the GDCS pools, and the overflow from the GDCS pools goes to the suppression pool, it doesn't go to the lower drywell.

So --

CHAIR CORRADINI: So, in theory, it's dry?

MR. WACKOWIAK: -- in theory, in most of our core damage sequences, we have less than 70 centimeters of water in the lower drywell at the time of the vessel failure.

So, it's just a little bit of water down on the floor, and we want it that way because then there's no potential for any type of fuel coolant interaction as the fuel comes out of the vessel. We want to put the water out down there after the initial melt. That's the design of the BIMAC.

CHAIR CORRADINI: And then, if you are going to talk about this later we can wait, are you going to talk about this later?

MR. WACKOWIAK: It depends on what you are going to ask?

CHAIR CORRADINI: So, the three valves go to the top of the thing, or flowing through the BIMAC underneath the piping? I'm still struggling as to where this stuff goes.

MR. WACKOWIAK: Do you have your back-up

slides? Can you get the schematic of the BIMAC? It should be the last slide in your packet.

Okay. The way that the BIMAC is set up, we have the tubes underneath the floor, and these lines that we were talking about are one on this side and then conceptually there's one on the opposite side. And, six of those lines are directed so that they pour into the downcomer of the BIMAC.

So, the BIMAC downcomer is sitting there on the floor, it's a big open pipe, and these deluge lines dump down directed into it. So, it's not actually forced in, like it's a complete pipe connection, it pours down directed to be like a drain sitting there on the floor, where it's going to go into.

And, what we are --

CHAIR CORRADINI: So, just -- we'll stop it here, I don't want to waste too much time, so the six lines come in -- I'm sorry, there's 12 --

MR. WACKOWIAK: Right.

CHAIR CORRADINI: -- four sets of three, and six of the 12 are aimed at the sump drains, which is the BIMAC, and the other six are just aimed any old place, and it fills the whole damn thing up.

MR. WACKOWIAK: We haven't gotten the

total detail on that, but some of them are directed to these downcomers, probably most of them. Some may be directed to the sump, because we'd like to have the sump itself filled with water, so that if there's any corium that goes toward that way the water in the sump helps protect the sub wall, and then others might just go directly into the floor. That's all part of the final optimization of this, and we'll detail that in detail design.

We've come up with flow rates necessary to fill the BIMAC and get it to start working, and it's a fraction of the 12 valves, small fraction of the 12 valves that we need.

CHAIR CORRADINI: Right, and then in the absence of operation it's 70 centimeters, that's good enough, I'll remember that.

MEMBER ABDEL-KHALIK: Now, you just told us that the core will always be covered, so why the core catcher? Do you have a scenario in mind in which this will be called upon?

MR. WACKOWIAK: When things fail, defense-in-depth.

MR. KRESS: The cover is just for design basis accidents. You can visualize severe accidents, very low probability.

MEMBER MAYNARD: It's beyond design basis accident, isn't it?

MR. KRESS: There's very little probability.

MR. WACKOWIAK: I will talk about that.

MR. BEARD: So, Dr. Corradini, we do have the video clip. We are at the scheduled break time.

CHAIR CORRADINI: Right, what it is, ten minutes, five minutes?

MR. BEARD: Four minutes.

CHAIR CORRADINI: Why not.

MR. BEARD: Okay. Just let me set the stage for this. This is an animation we've had put together that shows how the plant responds to a LOCA. You will see a clock in the bottom left-hand corner, and you -- all the water levels you see, IC/PCC pools, you see them boiled down, you'll see the water level in the RPV, you'll see the GDCS pools all changing. It's all modeled basically on what our analysis shows, and with that as a lead in --

(Whereupon, video showed.)

CHAIR CORRADINI: Okay, with that we'll take a break until 3:25.

(Whereupon, at 3:10 p.m., a recess until 3:28 p.m.)

CHAIR CORRADINI: If you want to get wired up.

MR. WACKOWIAK: Yes, I'll get wired up while everybody gets settled down.

Okay, since coming back from the break I'll introduce myself again. I'm Rick Wackowiak from General Electric-Hitachi, and I'm the Tech Lead for the ESBWR PRA part of the project.

So, what I want to cover first, and then we can get into some of the more questions and technical details, is what is it that we were trying to accomplish when we undertook this doing a PRA before we had a plant to do a PRA on.

So, what we want to make sure that we did was, we combined our knowledge on designing reactors and evaluating the risk of reactors from the existing operating fleet. So, in the new reactor we want to use a PRA to help up front determine what our risk management strategies are. We want to look at all aspects of the design, so that we can address core damage events, severe accidents, make sure that we've got the gamut of everything covered, internal and external events.

We want to bring that operating experience from doing other plant PRAs to the design process.

So, what we are trying to do here in this particular case is provide a bounding estimate of risk so that we can make the safety case for the plant.

We do this in various parts and various phases. When we were still conceptual, coming up with a conceptual design of the ESBWR, we used all data and PRA arguments. We know that if you do things this way, you should design for things this way. Later on, as we started to have some more system descriptions and simplified diagrams of systems, we put together risk models and started to calculate some the risk, so it's a progression through all of our design process to come to the point where we have a PRA.

Where are right now is, we are trying to make the safety case to show that we meet all the goals for risk, and that the way we meet it is robust, and that we've addressed pretty much all the issues that have come before.

One of the things that we did to do this, and I'll elaborate on this a little bit later, is making the risk assessment an integral part of the overall design process, and in about another slide or so I'll talk about that a little bit more.

We have to remember now, when we do everything that people have been doing before with

PRAs, have been trying to get the detail and fidelity of the model, honed like a Ginsu knife here, more, and more, and more detail, and we'll get to that in the process with the new plants. We are just not there yet.

And, I guess it's Part 50 now, 57.2, 57.1, wherever that is in the new rulemaking, the updated detailed PRA model will need to be in place by the COL holder prior to fuel load. So, that part comes later. Right now, we are trying to make the safety case for the plant design.

So, when we were trying to do this whole project, one of the things that we recognized is that there are different ways that you can effect risk or effect the calculation of risk, which later allows you effect risk, and usually where we've been playing in the existing plant world is in this area of procedures and getting more refined data to try to focus our risk attention. And, we don't play too much with the design part of it.

But, in my estimation, the benefit that you can get from these different things are -- it's diminishing. Design changes, you can get the most bang for your buck when you are incorporating risk insights. Procedures are great, they help out, but they are a little bit less effective. Data, I probably even drew that line too high, it's marginally effective, just messing with data doesn't necessarily get you places.

MEMBER APOSTOLAKIS: What data are these?

MR. WACKOWIAK: If you want to calculate a more refined way --

MEMBER APOSTOLAKIS: PRA data?

MR. WACKOWIAK: -- PRA data. Do we know what the actual failure rate of some feedwater control is, or can we come up with --

MEMBER APOSTOLAKIS: I think we are going to have a problem. I don't remember how you guys described it, but the I&C, because it's not just data, it's also models, and I haven't seen a model of bringing I&C into the PRA yet. Maybe you can tell us a few words about it at some point, you don't have to do it now.

MR. WACKOWIAK: Yes, I will tell you at some point.

Have you seen the revision?

MEMBER APOSTOLAKIS: 2, Rev 2?

MR. WACKOWIAK: Rev 2 of --

MEMBER APOSTOLAKIS: That was last Friday.

MR. WACKOWIAK: And, we said the chapter

that contained the new I&C model in April.

MEMBER APOSTOLAKIS: Okay, so it's there? Oh, in April?

MR. WACKOWIAK: Right, well, that was the end of April when Chapter 1 through 7 were initially submitted, so it was an advanced copy for them to start their review. The full thing is there now, so you can maybe look at that.

We talked about it a little bit in the meeting we had this spring, how we were going to implement that. We've added some additional failure modes to the I&C. We've done some sensitivities with models external to the whole PRA model, to look at the ways that the digital I&C systems could fail, and what type of dependence is needed to be brought forward from the power, and HVAC and those sorts of dependent systems into the reliability of the digital I&C, looked at different failure modes for software that are included in the model, and then some common cause of things like hardware and software.

So, those are included, and, Alan, you may want to talk about that.

MEMBER APOSTOLAKIS: Well, we are going to meet again on this.

So, in my view, this is one of the biggest problems we are going to have with new reactors that use I&C, digital I&C extensively.

I think the PRA value now becomes a little -- now, if you guys feel otherwise, I'll be happy to study what you've done and change my mind.

MR. WACKOWIAK: What we are trying --

MEMBER APOSTOLAKIS: It is so pervasive, and, okay, you looked at failure modes, I'm sure you did the best you could, but the truth of the matter is that as a community I'm not sure we understand all the possible modes, unless somebody in the world understands it and does let the rest of us know.

So anyway, I don't want to delay this presentation, but I'm just voicing my concern.

MR. WACKOWIAK: And, I want to make sure that everybody understands that we are trying to address this under the rules of an engagement here.

MEMBER APOSTOLAKIS: I understand.

MR. WACKOWIAK: The design PRA is supposed to do this. In the details of the I&C model, I think as long as we captured the failure modes and the dependencies, we can do -- we can do this without solving the whole issue of reliability of the I&C system.

It comes down to, what decisions we made in the design, given the PRA tools that we have right now, and I think where we are in our design is, we've decided that we have a digital instrument and control system that controls our ECCS, and we think we need to have a back-up system in case there are failure modes that fail that system.

And, whether or not we know the details of how that system is failing, as long as we know we have a diverse back-up system we can address that using defense-in-depth rather than detailed, quantitative principles. And, I think that's where we need to be for this particular application.

MEMBER APOSTOLAKIS: But, you also said that you demonstrated you met the safety goals, which means now that the number really counts. Defense-in-depth is a good idea, it's a great idea, but when it comes to meeting the goals I don't know how you do that if you don't quantify it.

MEMBER MAYNARD: Well, at some point it's going to have to be addressed, but it's part of the design reliability program, reliability assurance program, construction reliability, and the operational reliability assurance program, it requires that it be built, constructed and operated in a way to meet these numbers. So, at some point it's going to have to, it doesn't necessarily have to in the design certification.

MEMBER APOSTOLAKIS: No, no, no, I'm just voicing a general concern. It's not like human error, where there were problems with the models, and then I remember one applicant said, okay, put on the human error one to one, and the CDF increased by maybe a factor of ten, but it was still very low.

I suspect you can't do that here, and that's why I'm concerned. You can't say save the whole damn thing and see what happens to the CDF.

MEMBER BLEY: No, that other test was as much a test of focused models than a test of how important human actions were, by the way.

MEMBER APOSTOLAKIS: The different --

MEMBER BLEY: It's a test of how you built your model with human action setting all the way.

MEMBER APOSTOLAKIS: Yes, anyway, I mean, I don't want to make a big deal out of it today, but it really seems to me this is a major issue we are going to face, this Committee will face, I mean, when we have to write letters and say, yes, it's fine.

MEMBER SIEBER: Well, the technology is changing so fast that you can't model something now that you are going to install four or five years from now, because technology will be different. So, all you can do is set design parameters from your PRA.

MEMBER APOSTOLAKIS: So, we're going to have the problem of the COL.

CHAIR CORRADINI: Can we just divert back?

MEMBER APOSTOLAKIS: Yes. I just don't want you to think that --

CHAIR CORRADINI: No, no, I don't mean that, I think it's important.

MEMBER APOSTOLAKIS: I think it's a most important problem with any very important issue we have in front of us.

CHAIR CORRADINI: We'll return to it.

MR. WACKOWIAK: So, just to go through with this, we want to make sure that now when we have the opportunity to influence the design that we actually take that opportunity, because it's going to go away, and then we'll be left with things like procedures and other things like that. We want to use that to the greatest ability at this point in time. So, that's our focus.

MEMBER ABDEL-KHALIK: Just to go back to George's point, data here, you are talking about calculated risk versus actual risk? I mean, changing the data doesn't change the actual risk.

MR. WACKOWIAK: Yes, that's why I tried to caveat that, that that was the least effective. You can change -- you can get better data and then the decisions you make using that data can improve risk, but you really only are changing calculated risk. There's small potential to actually change risk with data. That was my point with the very low bar there, there's very limited ability to actually change risk by just changing data.

MEMBER APOSTOLAKIS: I think you are right.

MR. WACKOWIAK: So, when we use it as a design tool, the overall objective from the PRA point of view is to eliminate severe accident vulnerabilities. That's what we are looking at, we want to make sure that core damage frequency is low, hard release frequency is low.

So, using the PRA, depending on where we are in the different phases of the design, we set up a systematic means for finding vulnerabilities, figuring out what to do about them, and see if we can come up with some design method of addressing them.

We incorporated this into our design process. So, for example, typically you'd see in a design change process, it's got to be signed off by mechanical, electrical, I&C, well, PRA is a sign off on all of our design changes, and so we incorporate risk into all those -- into all the aspects of the design.

CHAIR CORRADINI: So, let me just make sure I understand, now that you've inserted yourself in the design process. Does that mean that if something looks different on how it might affect the PRA, you actually can effect back and effect the design?

MR. WACKOWIAK: Yes, and I have some examples of that, we'll have a slide here later.

CHAIR CORRADINI: Okay, fine.

MR. HINDS: And, Rick is an integral part of our design team, as an example, as opposed to being an after-the-fact portion, he and his team are an integral portion of the design team in process.

MEMBER APOSTOLAKIS: Now, the last sub bullet there, what does it mean, fire PRA --

MR. WACKOWIAK: Right, that gets back to where we are in the different phases of the design. If we've got something that's a conceptual design, that we don't really have something to physically make a model and manipulate, but we rely on our previous operating experience for how we've modeled this in other plants, what gave us problems, were there problems with spurious actuations of isolation condensers, how much redundancy should you build into something before the numbers get to be where you want to have them in that range.

And so, on the early end, we use very qualitative PRA methods to influence the design, as the design progresses further it gets more and more and more quantitative, to the point right now where we are able to use quantitative means, even in our fire PRAs, to identify the locations of some of -- locations of where some equipment should be in the plant.

MEMBER APOSTOLAKIS: So, qualitative means, primarily, event sequences, accident sequences.

MR. WACKOWIAK: Yes.

MEMBER APOSTOLAKIS: That kind of thing, without any quantification.

MR. WACKOWIAK: Right, or --

MEMBER APOSTOLAKIS: Or some minor --

MR. WACKOWIAK: -- things from your experience that you know that if you have some level of redundancy that that equates to a level of safety.

So, if you know you've got two redundant trains that probably gives you about a 10^{-3} for that type of, you know, those types of things that we use in things like STP and other areas.

MEMBER APOSTOLAKIS: The word any bothers me there, but that's okay.

MR. WACKOWIAK: Okay.

MEMBER ABDEL-KHALIK: How does cost enter into this iterative process?

MR. WACKOWIAK: Cost is another aspect of our design changes. It's not only engineers who come to the table to talk about design changes. The table is filled with lots of people, and they are in there, the accountants are there, the people representing the construction side are there.

MEMBER ABDEL-KHALIK: Multi-disciplined team.

MR. WACKOWIAK: It's a very multi-discipline team. So, I focus on the engineering end, but it's not -- it's not just engineering.

Okay, so what are we thinking about when we do -- when we are trying to influence the design?

What we found is, if we follow some pretty simple principles we can usually come out with a good result. In the ESBWR, we are looking at things like core damage, preventing core damage, what we typically have, or what we try to have, our target configuration is some passive means of performing a function, backed up by one or more active means of performing the same function, and then our support systems, we make sure that we have diverse support systems, like we have our ECCS safety related I&C that can control the passive, but we also have a diverse I&C system that's a back-up to it.

But, what I found is, as long as we follow this configuration, we can use historical data that tends to be high, historical initiating event frequencies that we think we are going to do better, but we haven't proven it yet, and we can still have low core damage frequencies.

We can minimize the reliance on operator actions. In fact, most operator actions, I think we only have a half a dozen of them modeled in the -- that we take credit for in the PRA, and we can still show a low core damage frequency. And, the things that we found that give us trouble is when we find a sequence where we can't find a function that's set up that way.

MEMBER APOSTOLAKIS: So, what's an example of an active asset protection system?

MR. WACKOWIAK: We have our control rod drive system, which can provide about a thousand gpm of high pressure make-up. If we have a transient in the passive system, which would be the ICS, if that happens to fail this high pressure injection system can keep the core covered without activating the DPV.

MEMBER APOSTOLAKIS: These are non-safety related?

MR. WACKOWIAK: Non-safety related.

MEMBER APOSTOLAKIS: With standby diesel generators.

MR. WACKOWIAK: Yes, all the things are powered by the standby diesel generators.

MEMBER APOSTOLAKIS: And, the PRA, you will not credit for those?

MR. WACKOWIAK: We do take credit for those in the PRA, but we have a sensitivity for the -- evaluation, the focused PRA, when we look at what happens if we pull those out.

MEMBER APOSTOLAKIS: Right.

MEMBER SIEBER: Do you penalize your reliability numbers when you move them from safety related to non-safety related?

MR. WACKOWIAK: I don't know that there's any data to support that.

MEMBER SIEBER: The data I've seen doesn't support it.

MR. WACKOWIAK: I'm glad you made that point. Typically, the non-safety things, you use, I guess, market forces help make those things more reliable. You have innovations from the vendors, and you have better practices that you can do. You are more flexible with maintenance on the non-safety related things versus the safety related. It's harder to go in and, you know --

MEMBER SIEBER: The biggest example is average times tend to be longer, because you don't need -- there's nothing driving it particularly, except the PRA guy.

MR. WACKOWIAK: And, that's why, you know, we have the -- program helps with that, the design reliability assurance program also helps with that.

MEMBER APOSTOLAKIS: Then still you have the whole modeling tomorrow and quality assurance. That was a touchy issue with Chairman Jackson.

MR. WACKOWIAK: Okay, just to give everybody a perspective, so you know what it was that we have in the current model. It's done using a detailed -- entry system or model, except for seismic, which I'll touch on in a second, covers level one, level two and the level three with an assumed world that came from the URD population and other things like that.

We cover both internal and external events, all modes, full power, shutdown, in this latest revision we've done a better coverage of all the intermediate modes, too, I think.

We did do a seismic margins analysis to demonstrate that we don't see any outliers and vulnerability in the seismic margins. We really -- we only looked at the seismic Cat 1 structures, so there are still other things that we can -- that can be looked at after the plant is designed and we can walk it down, and we can see when the seismic capabilities will be, but we have demonstrated that there really aren't any outliers.

MEMBER APOSTOLAKIS: So, this means that when the plant is ready to start operation, you have 11 to 3 PRA, with internal and external events, no markings, no bounding stuff, real PRA, is that what you mean by these bullets?

MR. WACKOWIAK: I'm saying this is what we did for the DCD PRA.

MEMBER APOSTOLAKIS: Yes, but you said that --

MR. WACKOWIAK: I said the seismic can be addressed after the plant is designed, and if a consensus standard for seismic PRA is one year prior to the first start-up than it will include that.

CHAIR CORRADINI: Is that a big -- I mean, since I'm not a PRA person --

MEMBER APOSTOLAKIS: That is a lot of controversy.

CHAIR CORRADINI: So, it's a big if, not a little if.

MR. WACKOWIAK: I guess if I point to that you guys can't see what I'm doing. I'll take out my green laser.

MEMBER APOSTOLAKIS: There is a standard that is being prepared by the ANS on external events, which has been -- John, are you involved in that, which has been out there being attacked by various forces.

MEMBER BLEY: I'm on the shutdown one, and that's the same situation.

MR. WACKOWIAK: All of them are being attacked by various forces.

So, if that's -- what we are doing with the design PRA is, we are setting up the starting point for doing those --

MEMBER APOSTOLAKIS: I understand, yes. No, as far as --

MEMBER STETKAR: Let me ask two questions quick, and we'll try to keep it quick.

MR. WACKOWIAK: Okay.

MEMBER STETKAR: You said it included all internal and external events, so that's the internal fires.

MR. WACKOWIAK: Yes.

MEMBER STETKAR: Because you do not have -- let me ask you, did you quantify the effects of things like fire induced spurious signals, hot shorts, that type of thing, or is this more of a five type analysis, without detailed quantification, for the fires?

MR. WACKOWIAK: When we did Rev 1, it was a five analysis. In Rev 2, we took it the next step and implemented the NUREG --

MEMBER STETKAR: CR-6850.

MR. WACKOWIAK: --CR-6850, to the extent we had the input available.

MEMBER STETKAR: Okay.

MR. WACKOWIAK: So, some things are not known right now, and you can't -- so we were unable to do any fire modeling, because we don't have initiators and target sets, so we had to make some bounding assumptions on those.

MEMBER STETKAR: Okay.

MR. WACKOWIAK: But, we did address spurious actuation also.

MEMBER STETKAR: Second question is, when you say all mode shutdown, one of the questions I had is, are the gravity-drain condensers supposed to be available throughout all shutdown modes? And, if not, how do you satisfy 72 hours of decay heat removal cooling with no AC power supplies for events that are initiated during shutdown?

MR. WACKOWIAK: The first part of the answer is that there really isn't a requirement to satisfy 72 hours without AC power during shutdown.

MEMBER STETKAR: Okay, that's enough.

MR. WACKOWIAK: But, the second part is, we looked at what we have in our tech specs, what we have in -- if we were going to implement like an outage management and a NUMARK 9106 program, what would be available, looked at what's in our availability control manual, and made decisions about how much credit we can take for GDCS pools, and it's not full credit, it's reduced to address maintenance that would have to occur during shutdown.

MR. BEARD: Alan Beard, just let me add to that. Another fundamental principle there is, we have an in-tact reactor coil pressure boundary for about 24 hours after shutdown, so the isolation condensers are still there through that if we depressurize.

So, we are well down the decay heat curve before we even get into the point that we pull the head off.

MR. WACKOWIAK: And, we've taken a look at those, you know, where things come into play, and so, I guess --

MEMBER STETKAR: We can talk about that, we need to get back on schedule. There's a subcommittee meeting on the PRA.

MR. KRESS: Just for my information, Level 2 is done with MAPP?

MR. WACKOWIAK: Level 2 is the assessment of the containment following a core damage event.

MR. KRESS: Is it done with the MAPP code?

MR. WACKOWIAK: Level is, the MAPP code helps you determine how the accident is going to progress, and what some things -- what we would expect to have happen. The Level 2 analysis itself was done using a combination of the roll methodology that Dr. Theofanous did, and some quantitative event tree, fall tree manipulations of the systematic aspects that weren't covered by the roll process.

So, MAPP is used as an input to the Level 2, but it's not the Level 2.

CHAIR CORRADINI: And, Level 3 was done with MACCS.

MR. WACKOWIAK: Level 3 was done with MACCS2, yes.

CHAIR CORRADINI: And, that part of the Level 2 we'll see in November, hopefully.

MR. WACKOWIAK: When the meeting is scheduled, that's what you'll see. That's well put.

MEMBER APOSTOLAKIS: But, there's talk of postponing, right?

CHAIR CORRADINI: Let's keep it that way.

MR. WACKOWIAK: It's well put.

Okay, we've included in our basic -- in our design PRA model generic data. Typically, it's from the utility requirements document, puts it out in equal footing with things that other plants that have already been evaluated, plus it also -- we are trying to not -- we are trying to not estimate improvements in reliability of components based on things that we maybe have a prototype of, but have not seen in operation. So, we are trying to keep our data within the known experience base.

Same thing with initiating event

frequencies, we are using historical initiating event frequencies in the PRA, even though we probably could start calculating some improved initiating event frequencies, we've chosen not to do that, mainly because we want to make sure we get as much as we can out of the design configuration and not do a data configuration sort of model.

The other thing about this, we talked about the -- somebody had a question about the island mode in the probability of that succeeding, or what happens with core damage frequencies in that.

Currently, the design PRA model assumes that any loss of power is going to result in a scram of the reactor. So, we are not trying to reduce the loss of off-site power, core damage frequency by taking credit for the island mode in the design PRA.

MEMBER STETKAR: So, you force everything over to the rats.

MR. WACKOWIAK: In our PRA, we've done several different uncertainty analyses and sensitivity analyses. We've addressed parametric uncertainty. We've also looked -- done a systematic search for modeling assumptions that result in uncertainty. That was in the upcoming scheduled ACRS subcommittee meeting. We'll be talking about some of these also, and we've got a more comprehensive set in the Rev 2 of the sensitivity analyses that we did.

So, here I want to give you a flavor of what our results are. In the internal events, full power, we come out with about 1 x 10^{08} core damage frequency, and we can see that it's balanced amongst all the initiating events.

Earlier revisions of the ESBWR design had some dominating-type sequences. We've recognized that influenced the design, and we've come up with a way to more balance the risk. We don't have large outliers like we did in the earlier revisions.

I want you to notice that most --

MEMBER POWERS: I mean, why do you do that? The bottom one is CDF is about the same, why not have an all-in-one sequence and then just watch that sequence really closely?

MR. KRESS: Training.

MR. WACKOWIAK: Yes, I think we don't -- I don't think we would ever want to try to tell the operators that they don't have to watch for different types of events. You know, you are only focused on one thing.

MEMBER POWERS: I didn't say that.

MR. WACKOWIAK: Okay.

MEMBER POWERS: Why get a balance between all these things, what drives you to do that?

MR. WACKOWIAK: Well, it's an interesting point, because if it were unbalanced it would make some things easier. DRAP would be simple, we would have the one thing that was unbalanced in the DRAP and not have to worry about it.

But, remember, we are still at -- we are still in a design phase here. We don't have any operating experience with this plant yet, and there still are things that we don't know about.

And, what I want to make sure that we are doing in the PRA is, we are looking at everything, and making sure that all types of scenarios have adequate coverage, and not try to just focus on one or two things, and I certainly don't want to focus on this thing only.

What we want to make sure that we do is, that we understand the kind of scenarios that we have, and we addressed all of those scenarios, and it really is -- is a --

MEMBER POWERS: If I can't get -- below the loss of preferred power, or the loss of normal heat removal, such that it makes no contribution, why not go ahead and do that, and suffer the consequence of the inadvertent opening of relief valve becomes, instead of 36 percent, becomes, what is that, 38 percent. Why not do that?

MR. WACKOWIAK: From this starting point, if we did that then I think we end up with an issue of cost maybe out being addressed, because if we try to do -- put more and more emphasis on this right now, then we may be spending money on something that is getting rid of a 1 x 10^{-9} sequence, and that doesn't make much sense.

MEMBER POWERS: I have no idea how you went from having a few outliers to get to this multiple slice party, but it was not done with zero cost, that I am assured.

MR. WACKOWIAK: Yes.

MEMBER POWERS: I just wondered why you did it?

MEMBER MAYNARD: I think another big factor is, you end up with just one big piece of pie, everybody is going to want to know why don't you do something to reduce that piece of pie.

MEMBER POWERS: At 1 x 2^{08} I'm not going to lose a lot of sleep.

MEMBER SIEBER: Make the pie smaller.

MR. WACKOWIAK: Right. So, that's a good

question, and there were many reasons why we wanted to address the asymmetries, if you will, that we had previous. Some of them were -- some of them were associated with the PRA, others were associated with the consequence of those scenarios that even though they may not have already gone all the way to core damage, if they were partially gone to core damage, and we save the core, they were still high economic recoveries.

MEMBER APOSTOLAKIS: But, if we follow this philosophy, let's say some brilliant mind comes back and reduces everything excepting the opening of a relief valve by a factor of 10, then you will feel obligated to reduce that contributor, too, even though the whole thing has gone now way down, because you don't want it to stick out. Is that a philosophy?

MR. WACKOWIAK: We can't do that anymore, because --

MEMBER APOSTOLAKIS: So, we better not find ways of reducing that. I never understood that either. I've seen it in English documents and other places that no individual initiator should dominate, in fact, earlier versions of the NRC technology-neutral framework had a suggestion the sequences should be at most 1/10 in frequency of the corresponding goal.

MEMBER POWERS: And, it still has that kind of flavor to it.

MEMBER APOSTOLAKIS: I don't understand it either. I mean, there must be some reason.

MEMBER POWERS: The seismic is going to be two orders of magnitude larger than this, and it's still a mystery to me.

MR. WACKOWIAK: Well, I agree with that, that seismic is going to be an issue, but I don't think it's an insurmountable issue, because, once again, many of the things that we did in here, to get this the way it is, also apply to the seismic area. So, when we do the detailed seismic model, I think we'll come up with a result that maybe isn't two orders of magnitude, maybe it's only -- you know, it certainly is not going to be nothing.

MEMBER POWERS: But, with respect -- my recollection of the uncertainty ranges for 10^{-6} earthquakes is that they are sufficiently large, very, very difficult for economic designs to get much below 10^{-6}.

And, the other problem you'll run into quickly is, you sent the material, and we'll sit here saying, okay, how come the seismic models don't agree with what happened in the Japan earthquake.

MR. WACKOWIAK: Okay.

MR. KRESS: The technology-neutral framework justified their thinking of having sequences not too much different, as they do -- to make sure that the design addresses those, just as if they were like design basis accidents, you address all the design basis accidents, and they don't contribute much to --

MEMBER POWERS: 10^{-6}, they've addressed them.

MR. KRESS: They have, they have, but --

MR. WACKOWIAK: In here, we are really left with the more bizarre common mode failures, all the rods just stick, that are hard to --

MEMBER APOSTOLAKIS: But, this is not your mean CDF, right? I remember --

MR. WACKOWIAK: This is the point estimate CDF.

MEMBER APOSTOLAKIS: Yes.

MR. WACKOWIAK: And, it's not much different.

MEMBER APOSTOLAKIS: Oh, it's a little different.

MR. WACKOWIAK: It's a little different,

but it's not much different.

CHAIR CORRADINI: Can we -- I want to -- there was a question over here, but I guess I want to not let you finish, I want to let you finish answering some of the members' questions, but are you going to describe the colors of the pie so we are clear as to what each of these little guys are?

MR. WACKOWIAK: Okay.

CHAIR CORRADINI: The loss of feedwater is -- the relief valve, the general transient, that's the one that I'm not sure what a general transient is.

MR. WACKOWIAK: General transient is the terminal grips.

CHAIR CORRADINI: So, it's a miscellaneous pile.

MR. WACKOWIAK: It's a miscellaneous pile. Everything else -- the key is for -- most of these larger pieces, this one, and this one, and to some degree this one, something is gone when we have that scenario, and that's why these pieces are bigger, inadvertent open relief valve, we conservatively assume that that's always going to fail the ICS, so that's going to be a big, big piece here.

Loss of feedwater takes away one of our high pressure injection sources, so that's a big thing here. Also off-site power still takes that away, but the initiator is lower than what we've assumed.

General transient stays in there mainly because we said it's going to happen every year, so it's a high frequency event, but lower --

MEMBER SIEBER: You still have cut-offs where you don't, you know, there's some risk level that's so low that you don't bother putting it in, right?

MR. WACKOWIAK: Yes, well, what we've done in the report is, we've truncated the model at 10^{-15}, so we'll need to get different CPUs if we want to do something else.

MEMBER STETKAR: I just wanted -- this can be, and I hope it is, a yes or no answer.

On an earlier version, some summary of the pie chart, I noticed that it wasn't moving.

MR. WACKOWIAK: Yes.

MEMBER STETKAR: It had about somewhere between 55 and 60 percent contribution from LLPP or LLSP, or whatever you want to call it.

MR. WACKOWIAK: Right.

MEMBER STETKAR: I don't know where that was in time, relative to this version. So, I don't know if it was the immediately preceding version of the analysis or not.

At the moment, I don't care.

The only question I had is, was a design change made to the electrical system to effect that difference?

MR. WACKOWIAK: No.

MEMBER STETKAR: Thank you.

MR. WACKOWIAK: The design change -- I have to --

MEMBER STETKAR: No, that's fine, no, that's fine.

MR. WACKOWIAK: -- was made to the isolation condenser system.

MEMBER BLEY: There was a design change.

MR. WACKOWIAK: There was a design change, yes.

MEMBER BLEY: The isolation condenser system.

MR. WACKOWIAK: The extra tanks that we had, the inlying tanks that provide the extra water --

CHAIR CORRADINI: Those are the little things that you put in.

MR. WACKOWIAK: Right, those were added, and by adding that additional volume of water to the vessel we were able to prevent many actuations of the

DPVs, which then if you actuate the DPVs that takes the isolation condensers out of the picture.

So, it puts them back into this range here.

So, we effected the risk of this by changing a mechanical system.

MR. KRESS: What defines your core damage frequency, when the water level gets halfway down below the core, or top of the core, or what?

MR. WACKOWIAK: The search for whether it's core damage or not begins when the water research the top of the core. Almost all the sequences that we call success have core coverage every time. There are one or two where we've gotten up to 1,000 degrees K in the core.

MR. KRESS: But, you actually calculate the temperature.

MR. WACKOWIAK: In a couple sequences we had to do that. For some of the uncertainty runs, we did that. For the base model, which is why we picked some of the success criteria we did, we don't see any heat up of the fuel, it's where the water dips below the top in the base model.

In the uncertainty analyses, though, we did look at heat up of the core.

MR. KRESS: So, this is conservative.

It's likely to be conservative, but not because of the reason that you are saying here. It's likely -- it's conservative because we think we have conservative numbers in for the common cause failure values.

MEMBER SIEBER: But, you can't tell.

MEMBER APOSTOLAKIS: You can't tell right now.

MR. WACKOWIAK: You can't tell now, until we get some information on digital I&C, common mode failures, software common mode failures, CRV common mode failures, things that have not been estimated in the past.

MEMBER APOSTOLAKIS: If you look at the first BSA conference, 1978, there wasn't a single paper that didn't have an analysis of safety system for LWRs that had an unavailability greater than 10^{-6}. It was a standard number that everybody was getting.

And then, as the years go by, that number starts shifting up.

MEMBER SIEBER: After events started.

MEMBER APOSTOLAKIS: Events and the maturity of analysis reviews and so on, and now it's 10^{-4}, thereabouts, right?

But, even if this goes to 10^{-6}, that's still a low number. I mean, that's really a low number.

The age of the earth's crust is 10^{-9}, they are almost there.

MR. WACKOWIAK: And, we're there because of the configuration, by setting things up so that now we are left with analyzing these previously unaddressed common mode failures.

MEMBER APOSTOLAKIS: And, this is still a low number, but whether we survive, I don't know.

MEMBER ABDEL-KHALIK: Whether there's DPV valve failures fall in this pie chart, which bin did you put them in?

MR. WACKOWIAK: It would be in probably all of them, there would be some aspect of DPV failure. I don't --

MEMBER ABDEL-KHALIK: Which is now failure as an initiator.

MR. WACKOWIAK: Oh, as an initiator, inadvertent actuation of DPVs?

MEMBER ABDEL-KHALIK: Yes.

MR. WACKOWIAK: Inadvertent actuation of DPVs is in the LOCA.

MEMBER ABDEL-KHALIK: Okay.

CHAIR CORRADINI: Okay, going forward. Do you have much more?

MR. WACKOWIAK: No, I have one slide, and then there's a wrap up.

CHAIR CORRADINI: Okay.

MR. WACKOWIAK: I want to give some examples of what kinds of things we've done with the PRA and how we put it in. We talked about -- Alan talked about our FABCS for low pressure -- reactive low-pressure injection system. One of the things we found is that if we had redundant flow paths for that we were more resistant to fires in the various areas of the plant. So, we put in redundant flow paths, and that helped out.

The definition of what's connected to the diverse protection system, and how it is connected, we've been involved with the I&C people to help make the most out of this system that we are now putting in as an additional back-up. It was decided to be there independent of the PRA, but now, however, we are going to use it, we are influencing that.

Improved digital I&C, and the thing that we are focused on here is trying to decrease the probability of an inadvertent actuation. So, the question came out about fires, you know, do you include that? Part of our design specification that we've set up is that you would have to have a fire -- even within one division, you'd still have to have a fire in two separate fire zones before it's possible to have an inadvertent actuation.

Main control room, the way we are connecting the main control room, we should not see any inadvertent actuations of anything except scram or MSIV closure from a fire in the control room.

MEMBER STETKAR: You had to mention it, so I have to ask, I understand the fire analysis, fires in the main control room, fires in the remote shutdown areas, do the signals go from the main control room, through the remote shutdown area, to the actuated device?

MR. WACKOWIAK: No, that's -- the remote shutdown area is just another node on the network.

MEMBER STETKAR: In parallel with.

MR. WACKOWIAK: In parallel, because it doesn't flow through anything, it's just there. So, fire in the remote shutdown panel shouldn't do anything else, shouldn't be any different.

MEMBER STETKAR: Just curious, older designs were not like that.

MR. WACKOWIAK: Alan talked about the

redundant internal, that is the next one down, redundant supply valves in the IC/PCC pool make-up, we added some additional valves there to give some redundancy for long-term cooling.

The redundant drain valves for the ICS, the PRA influence here wasn't actually to put those valves in, it was to keep them in after a design review recommended taking them out.

The rerouting of some of the fire protection line, we found flooding -- areas where flooding was a problem, and the flooding was due to fire pipes. So, if you install the piping and do it the way NFPA tells you just to go and do it, we ended up with flood vulnerabilities in some zones. And so, we rearranged how we installed those pipes, so we still met NFPA, but no longer had the flooding vulnerabilities.

Location of some of the I&C cabinets, our diverse protection system, we found that the initial place that we were planning on putting it was a fire vulnerability once again, and so we found a different location for that cabinet that eliminated that fire vulnerability.

And then finally, on this chart the examples here on the Basemat Internal Melt Coolability

Device, our BIMAC and core catcher, that was suggested by our -- management team as a way to address the long-term containment integrity issue. We could show, at least back in that time, we haven't tried to reshow that, but we could show that we could make 72 hours without breaching the containment, but the 73rd hour wasn't a good day.

So, we wanted to make sure that we weren't trying to do some kind of horse race, and then introduce operator actions and things, so we said, why not go ahead and just eliminate the problem. We put in a system that eliminated the problem.

MEMBER APOSTOLAKIS: I thought you said earlier that this was a purely defense-in-depth way, so how can it be dictated by the PRA when it's defense-in-depth?

MR. WACKOWIAK: I'll claim that I can do some defense-in-depth in the PRA. Part of the PRA is to look for defense-in-depth.

MEMBER APOSTOLAKIS: Defense-in-depth means that the PRA says that I don't really need it, but because I'm a cautious guy I put it in.

MR. WACKOWIAK: No, no. What we are saying --

MEMBER APOSTOLAKIS: What's defense-in-depth, what if I'm wrong? Anyway, it's not your problem, it's our problem.

MEMBER ABDEL-KHALIK: Can you give us an example of a design change that came out as a result of PRA that was rejected on economic basis?

MEMBER APOSTOLAKIS: Tricky question.

MR. WACKOWIAK: Okay, so far, and we are not done yet, so I don't want to say that they've all been rejected, I still haven't stopped on all these, but one of the issues is looking at reactor water clean-up drain lines. And, from the PRA point of view, we think that we could find a better way to configure that drain line, and so far that has been not acted on, because there's issues with room for where you put the things ,there's issues with the vessel, there's all sorts of issues with implementing it, but it's something that hasn't been accepted at this point.

MEMBER ABDEL-KHALIK: So, is there a cost assessment that goes along with these decisions that would allow you to make that determination? I mean, all of the things that you mentioned are just sort of matter of convenience, as far as how the design would change, or how you alter the configuration, or how big a space you need, or something like that.

But, is there an economic analysis that goes with all of these assessments, and you sort of rejected on a quantitative basis?

MR. WACKOWIAK: They were rejected on -- I don't think so. If we had a situation where there was a very high risk contributor, 10^{-6}, 10^{-5} type thing, I'm not sure that we wouldn't go forward with that with a very high cost.

But, if I'm going to say, you know, we are going to -- if you guys do this we are going to increase CDF from 1.2×10^{-8} to 1.3×10^{-8}, you better not do that. I don't really have much of a leg to stand on if that's stated.

CHAIR CORRADINI: So, let me just ask the last bullet, so the BIMAC doesn't involve CDF at all, unless it's negative by dumping the water where you don't want to dump it.

So, two questions, so let's say -- what?

MEMBER SHACK: Fixed containment integrity.

MR. WACKOWIAK: Yes, CDF is only half the answer. We have a large release frequency that we have to address also.

CHAIR CORRADINI: Right, but so my question first is, if you didn't have the BIMAC, and you put it in, or the inadvertent operation of that second path for the water, how did that affect the CDF?

If we -- we've eliminated, if you eliminated the water -- the chance of even a parallel path accidental discharge, how much would that change the CDF, any perceptible amount?

MR. WACKOWIAK: Very small amount.

CHAIR CORRADINI: Okay, so it's in one of the pie slices I can't see that are so many colors.

MR. WACKOWIAK: Yes, that inadvertent actuation in those lines is included.

CHAIR CORRADINI: And, in which of those pies?

MR. WACKOWIAK: In all of those pies, every place where we asked GDCS.

CHAIR CORRADINI: Oh, okay.

MR. WACKOWIAK: We know that, but you have to remember that inadvertent actuation of that line, with the exposure time there, is very short. GDCS, in all these scenarios, actuates within the first couple hours, so there's a very small exposure time to that inadvertent actuation.

What's more challenging with that is inadvertent actuation during operation, which is not a safety issue, but it's a messy issue.

CHAIR CORRADINI: Say that again, I apologize.

MR. WACKOWIAK: Inadvertent actuation of the deluge lines during operation of the plant, it wouldn't -- it doesn't directly affect safety, but it's not a --

MEMBER SHACK: You don't use the GDCS all that often.

MR. WACKOWIAK: You would not -- we would not expect to use GDCS.

MEMBER SHACK: I mean, an inadvertent actuation core damage would be --

CHAIR CORRADINI: So then, my second question is, take that away, now I'm in the world of containment failure. The presence of the BIMAC takes the chance of containment failure from one in ten to one in what? I mean, one out of infinity?

MR. WACKOWIAK: It eliminates that particular failure mode, so I'd have to look at the -- we've got that in the PRA. It takes it from -- it takes it from the realm of saying that we have to implement a difficult strategy to deal with the core on the floor event, because there's uncertainties in whether it's going to spread and be coolable, and even if it was going to be coolable, ABWR still has the deluge lines, so we wouldn't be able to get rid of that particular aspect of it.

There are all sorts of things that really become hard to make the definitive safety case, and that's what we've heard, if we don't have something that's going to prevent the core from continuing to ablate the concrete in the lower drywell.

CHAIR CORRADINI: So then, the final question is, on a large radioactivity release, how much is it changing?

MR. WACKOWIAK: The reason I'm not answering that is because we didn't look at it quite that way. What we did --

CHAIR CORRADINI: Because that goes back to George's question, defense-in-depth, it's a what if, you put it there, what if, but what I'm hearing is, you haven't quantitatively honed in on the number for the changed containment failure probability or honed in on the number on the change in the delta LRF.

MEMBER APOSTOLAKIS: But I think Rick is bringing up another point that is related to Said's comment, I mean, the design phase, I believe, I don't know whether your team did the same thing, but other things were done, the ease of convincing the NRC that you have made the case is a significant consideration, and I think that's what you just said, that you would have difficulty arguing, you know, this and that, and by putting that there it goes away. So, it's an important consideration, too.

MR. WACKOWIAK: So, if --

CHAIR CORRADINI: I'm sorry, are you saying we've satisfied perception? Is that what you just told me?

MEMBER APOSTOLAKIS: No, but you have to make the case before the stuff, and if you feel that this will eliminate a lot of the argument about controls and possible negatives, you say I'm going to do it. It's a multi-attribute decision, it's not just --

MEMBER BLEY: It dealt with what would have been a very large uncertainty.

MEMBER APOSTOLAKIS: That's another way of putting it, you increase the confidence in the safety case.

MR. WACKOWIAK: So, for example, with the core on the floor scenario, that's what we are trying to address with the BIMAC, is what happens when the core ends up in the lower drywell.

Everybody believes, everybody is a big

word, but I'll say everybody believes that if you pour a lot of water on top of that it's probably going to be coolable, but nobody can prove it.

There are scenarios that were done and experiments that show that there are non-coolable configurations when the core comes out of the vessel.

CHAIR CORRADINI: Pretty much every time Argonne tried it, that's what they found.

MR. WACKOWIAK: Well, but there were -- okay, but the thing is, once the probability of being in a coolable configuration versus a non-coolable configuration, how can you calculate that number? And, the answer is, nobody can calculate that number. You can make estimates of what you think, and what your level of belief is, but you can't quantify what the fraction of time it's going to be in a coolable geometry.

So, rather than try to play with numbers and calculate a fraction, so that we meet the goal, we put in a system that eliminates the question.

So, to get back to your original question, if the BIMAC fails, the containment is probably not going to fail, but we can't tell you what fraction of the time that is, because that question hasn't been answered.

MR. KRESS: I am interested in why you went to large release frequency. In the spanse we have now, the LERF sort of dominates all of these frequencies. I suspect you don't have any LERFs in your plant, is that true, with the LRF?

MR. WACKOWIAK: Well, we went to LRF because the Commission said we had to.

MR. KRESS: Oh, absolutely.

MR. WACKOWIAK: And, but also when we look at our release modes, we have some that are early, like these bypasses and steam explosion type failures, and we have some that are very late. So, it's a mix that's in there, and I think we meet the goals either way you analyze it.

CHAIR CORRADINI: All right, anymore questions before we roll out the table and see if others have questions?

MR. WACKOWIAK: Anymore?

MR. KRESS: That pretty well answered most of mine.

CHAIR CORRADINI: Dana?

MEMBER POWERS: A couple questions for you. One is, when do we do site business?

CHAIR CORRADINI: Site business tomorrow morning.

MEMBER POWERS: Tomorrow morning.

CHAIR CORRADINI: No. 2, then No. 8 and No. 17.

MR. SHUAUBI: I think the order is a little different than that, 17 we switched, remember?

MS. CUBBAGE: You have the agenda, I believe.

MR. SCHEAR: It's 17, then 8, then 2. Two is in the afternoon tomorrow. This is Mohammed Shuaubi from the staff.

CHAIR CORRADINI: That's how we get you to show up for 17.

And, what's your second question?

MEMBER POWERS: And, at what point do we discuss thermal stresses that arise in the sacrificial material on the BIMAC?

CHAIR CORRADINI: I assume in Chapter 19. I can't guess any other place. Not in Chapter 2, not in Chapter 5.

I'm sorry, it's been a long day.

MR. WACKOWIAK: Dr. Theofanous has some new information on that, that came out of our testing program that we just completed, and we'll be supplying a report that discusses some of the details, like what are the characteristics of the sacrificial material.

It's going to be a proprietary report.

MEMBER POWERS: And I understand the testing is step changes in heat flux but not step changes in temperature, is that correct?

MR. WACKOWIAK: I believe that that's correct.

MEMBER POWERS: And, consequently, they don't address the issue of thermal stress?

MR. WACKOWIAK: Didn't have any sacrificial material in the test either, so the test wasn't meant to address the sacrificial material. The test was meant to address the thermal hydraulic capabilities of the BIMAC, and from the results Theo was able to come up with some additional guidance on what to do with the sacrificial material, and that's in an upcoming report.

CHAIR CORRADINI: And, we will be able to see that, because that will be a connected report to Chapter 19, just so we are clear on the --

MR. WACKOWIAK: It will be connected, but at this time this is going to be a proprietary report, though, so it's whatever you guys have to do to receive proprietary stuff.

CHAIR CORRADINI: They lock us in a room and we have to fight each other to look at the one volume.

MEMBER SHACK: If you are submitting it as part of your licensing case it's not a problem.

MR. WACKOWIAK: Right, and we connect it to the PRA.

CHAIR CORRADINI: Dana, did you have other questions?

MEMBER POWERS: I have tons of other questions.

CHAIR CORRADINI: But, for the moment.

MEMBER POWERS: Oh, for the moment, no. I have for them, but not now.

CHAIR CORRADINI: Okay.

Thank you all very much and the meeting is closed.

(Whereupon, the above-entitled matter was concluded at 4:29 p.m.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Charles Morrison
Official Reporter
Neal R. Gross & Co., Inc.

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Presentation to the ACRS Subcommittee

ESBWR Design Certification Project Overview

Amy Cubbage, Senior Project Manager
NRO/DNRL/NGE1

October 2, 2007

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

Topics:

- Previous ESBWR Briefings
- ESBWR Review Status
- ESBWR DCD and Other Submittals
- Review Guidance
- Future ESBWR Briefings

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

Previous ACRS Briefings on ESBWR

- TRACG for ESBWR LOCA
  - July 2003, January 2004, and February 2004
- TRACG for ESBWR Stability
  - January 2006, March 2006, and April 2006
- PRA Subcommittee Meetings
  - April 2006 and December 2006

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

ESBWR Review Status

- Preapplication review
  - June 2002 → August 2005
- Application submitted - August 2005
- Application docketed - December 2005
- Major staff RAI milestones completed
  - October 2006
  - December 2006
  - January 2007
  - May 2007

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

Status of ESBWR DCD and Other Submittals

- DCD Rev. 3 submitted 2/28/2007
  - SER with open items to be presented is based on DCD Rev. 3 plus RAI responses and other supporting submittals
- DCD Rev. 4 submitted 9/28/07
  - Tier 1 upgrade (format and content)
  - COL action items reduced/remaining items clarified
  - Many RAI responses incorporated
  - North Anna and Grand Gulf COL applications will reference DCD Rev. 4
- Complete PRA Rev. 2 submitted 9/28/07
- DCD Rev. 5 expected March 2008
  - Remaining RAIs to be incorporated

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

Status of ESBWR DCD and Other Submittals

- Topical Reports under review include:
  - Fuel Design
  - Control Blade Design
  - Critical Power Correlation
  - Initial Core Design
  - TRACG for ATWS
  - I&C Software Development plans
  - I&C Defense-In-Depth and Diversity Report
  - Digital I&C Platforms
  - Human Factors Implementation plans
  - Fission Product Removal Model
  - Flow Induced Vibration
  - Containment Loads

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

Status of ESBWR DCD and Other Submittals

- Additional Topical Reports to be submitted
  - Cyber Security
  - Additional Security Related Reports
  - Feedwater Temperature Operating Domain
  - Initial Core Analyses
  - Spent Fuel Rack Design (Neutronics and Structural)
  - Steam Dryer Design, Analysis and Testing (acoustic load)
- Revisions to Topical Reports also planned to address RAIs

ESBWR Review Status

- Public meetings have been conducted on many topics
- Audits have been conducted
  - Piping, Structural, Seismic, Fuel, T/H analysis, PRA, I&C, Dose Assessment, Human Factors, QA inspections, etc.
  - Additional audits planned
- Confirmatory Analyses have been performed and continue in many areas

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

RAI status

- Staff has issued over 3100 RAIs to date
  - 900+ supplemental RAIs also issued
- GEH has responded to over 2900 RAIs
  - 600+ supplemental responses also submitted
  - Majority of remaining responses expected this Fall
- Approx. 2200 RAIs are now resolved
- Additional RAIs will be issued as needed
  - DCD Rev 4
  - PRA Rev 2
  - Topical Report Reviews

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

ESBWR SER Status

- SER with Open Items Issuance by Chapter
- Committee has been provided with SER with Open Items for Chapters 2*, 5*, 8*, 10, 11, 12 and 17*
  - SER with Open items for Chapters 9, 13 and 16 planed to support November Subcommittee meeting
  - Additional Chapters to follow

* Now Publicly available - Chapter 2 non-proprietary version (ML072550004), Chap 5 (MLML070780172), Chapter 8 (ML072120282), Chapter 17 (ML072140668)

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

Review Guidance

- ESBWR application provides evaluation of the design against the SRP revision in effect 6 months before the docket date of the application in accordance with 10 CFR 52.47
- March 2007 SRP was not available
- Certification will be based on compliance with the regulations in effect <u>at the time of certification.</u>
- Staff will perform comparison of March 2007 SRP to previous versions
- Staff will address impacts to ensure that ESBWR complies with all current regulations
- Additional RAIs may result - impact is expected to be limited
- SER/OI Chapters will be revised if necessary prior to issuance of Final SER

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

<u>Future ESBWR Meetings 2007</u>

- October 25, 2007 – Subcommittee
  - SER Chapters 5, 10, 11 and 12
- November 1/2, 2007– Full Committee
  - SER Chapters 2, 5, 8, 10, 11, 12 and 17
- November 2007 (Date TBD) – Subcommittee
  - SER Chapters 9, 13 and 16
  - GEH Overview of New Topical Reports
    - FW Temperature operating Domain, Digital I&C, Etc.
- December 6/7, 2007 – Full Committee
  - SER Chapters 9, 13 and 16

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

<u>Future ESBWR Meetings</u>

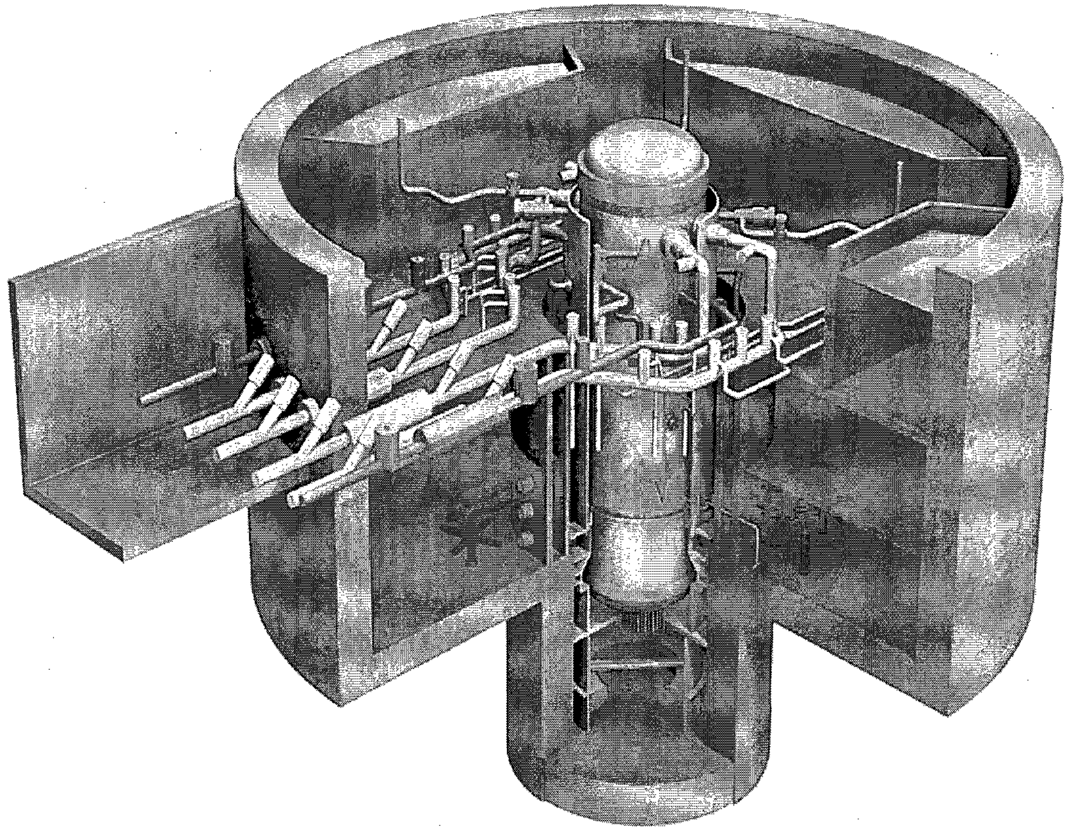
- Remaining SER with Open Items Chapters targeted for First Quarter
- Additional meetings may be scheduled on topic specific basis as needed (e.g., topical report reviews)
- The staff plans to brief the ACRS on the final Safety Evaluation Report in a Early CY 2009
  - Consolidated SER rather than the Chapter by Chapter approach taken for SER with open items
  - Briefings will focus on OI resolution and changes from SER with open items

ACRS Subcommittee Presentation
ESBWR Design Certification Overview

Questions?

ESBWR Overview

Advisory Committee on Reactor Safeguards



David Hinds
J. Alan Beard
Rick Wachowiak

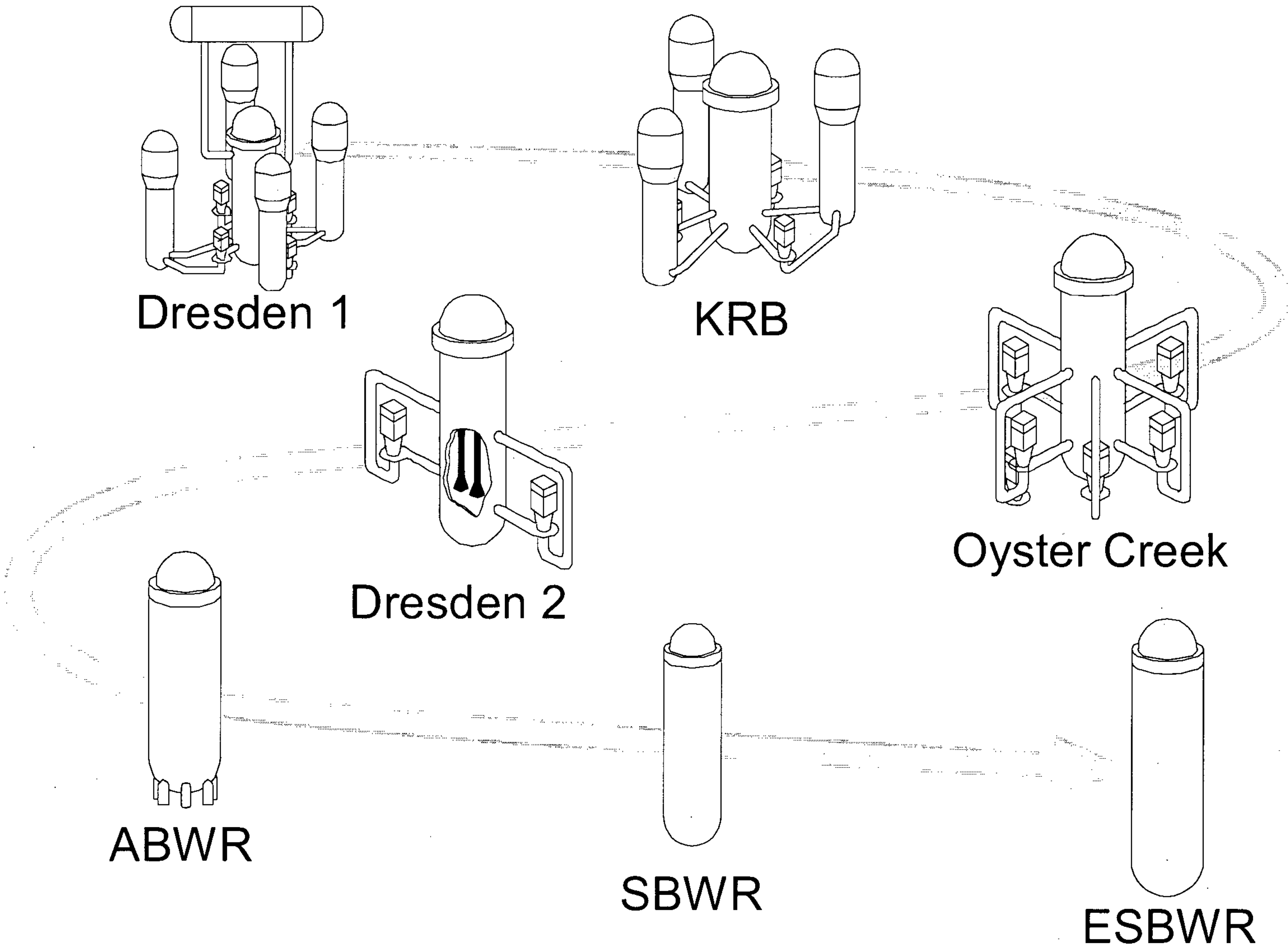
October 2, 2007

GE Hitachi Nuclear Energy

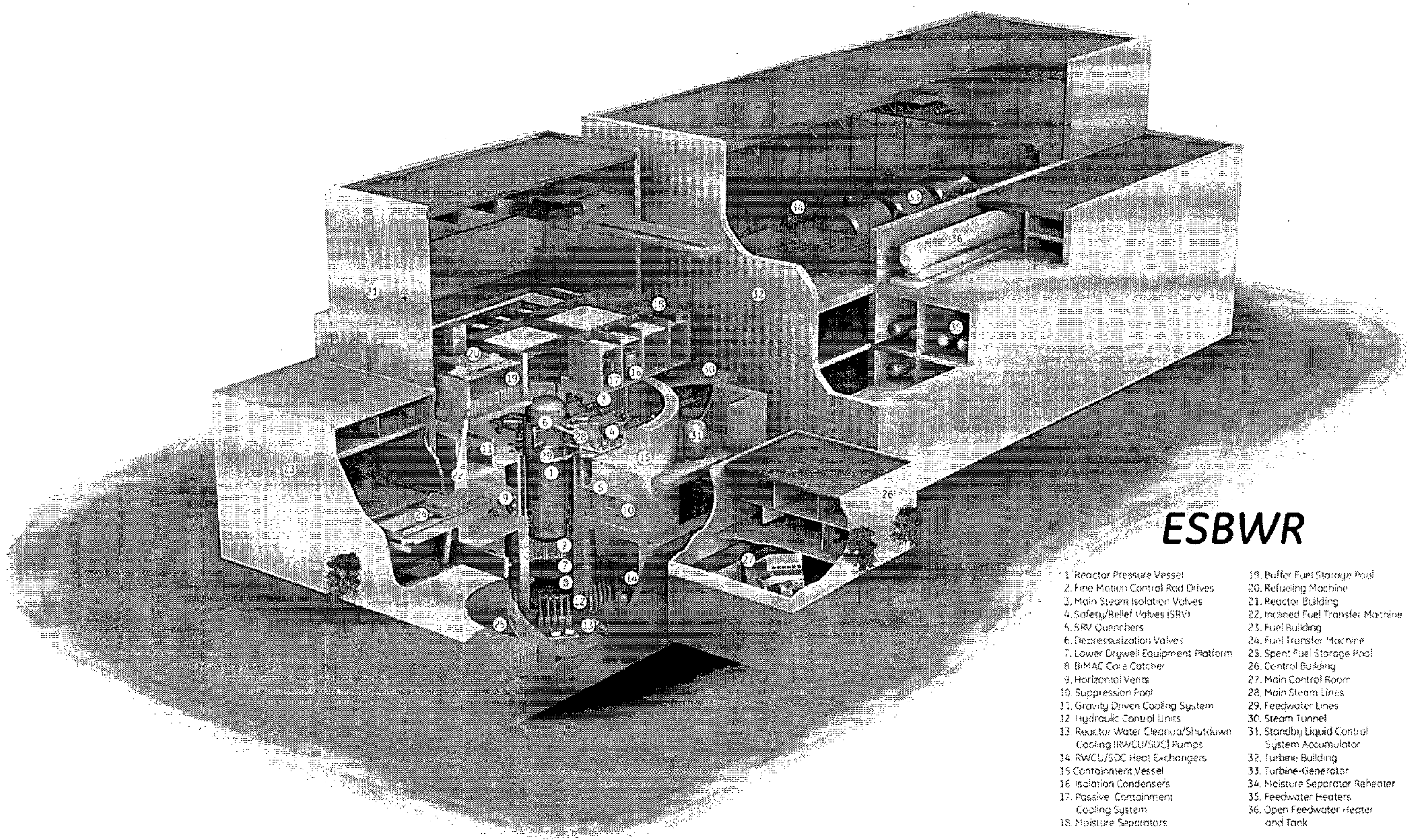
Presentation Content

- BWR Design Evolution
- Design Improvements
- ESBWR Primary Characteristics
- ESBWR Passive Systems
- PRA Summary

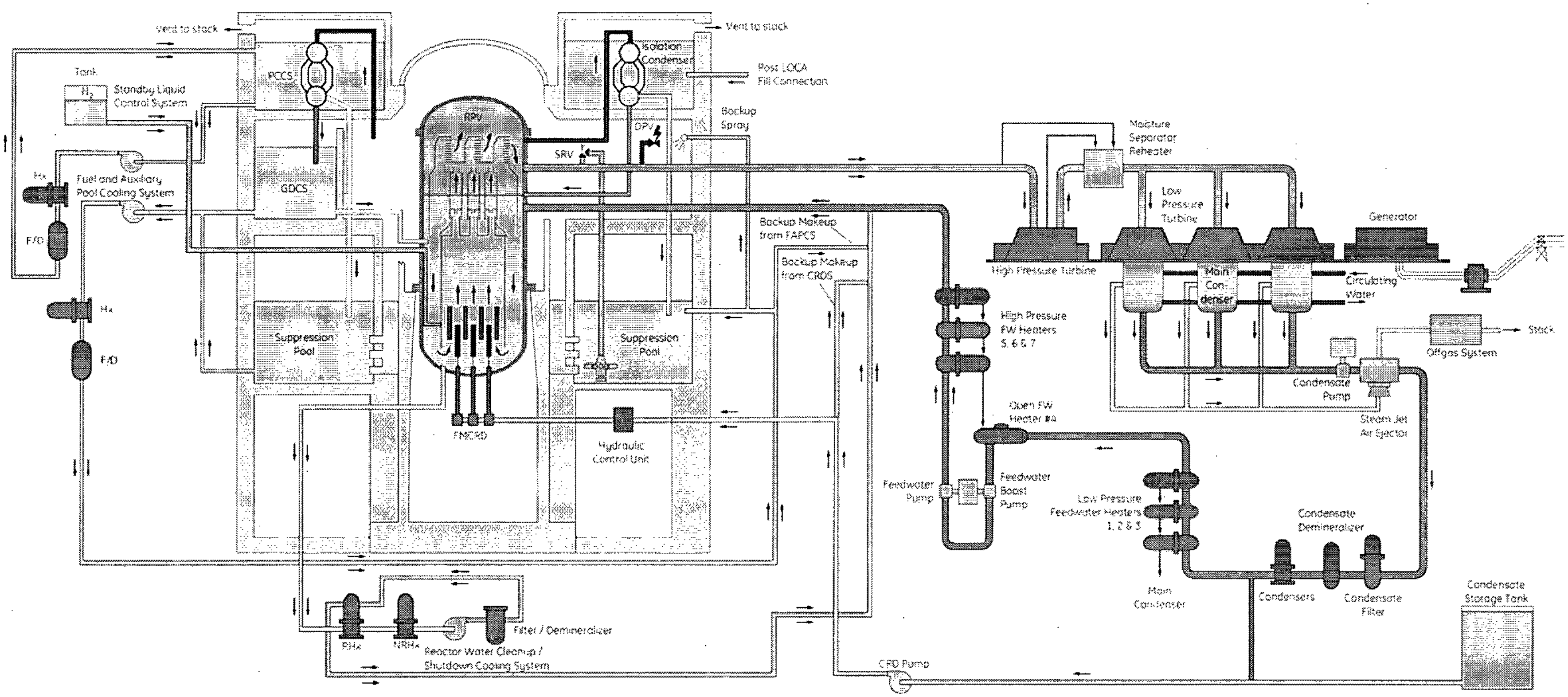
BWR Evolution



ESBWR 3D Cutaway View



ESBWR Overall Flowchart



ESBWR Basic Parameters

- 4,500 Megawatt core thermal power
  > ~1, 575 to 1,600 Megawatt electric gross
    - Nominal summer rating
- Natural circulation
  > No recirculation pumps
- Passive safety systems
  > 72 hours passive capability

What's different about ESBWR

ABWR	ESBWR
Recirculation System + support systems	Eliminated – natural circulation used
HPCF System (2 each) LPFL (3 each)	Eliminated need for ECCS pumps Utilize passive and stored energy (gravity)
Residual Heat Removal - containment (3 each)	Replaced with PCCS heat exchangers
Safety Grade Diesel Generators (3 each)	Eliminated – only 2 non-safety grade diesels
RCIC	Replaced with IC heat exchangers
SLC – 2 pumps	Replaced pumps with accumulators
Residual Heat Removal – shutdown cooling (3 each)	Non-safety, combined with cleanup system
Reactor Building Service Water (Safety Grade) And Plant Service Water (Safety Grade)	Made non-safety grade

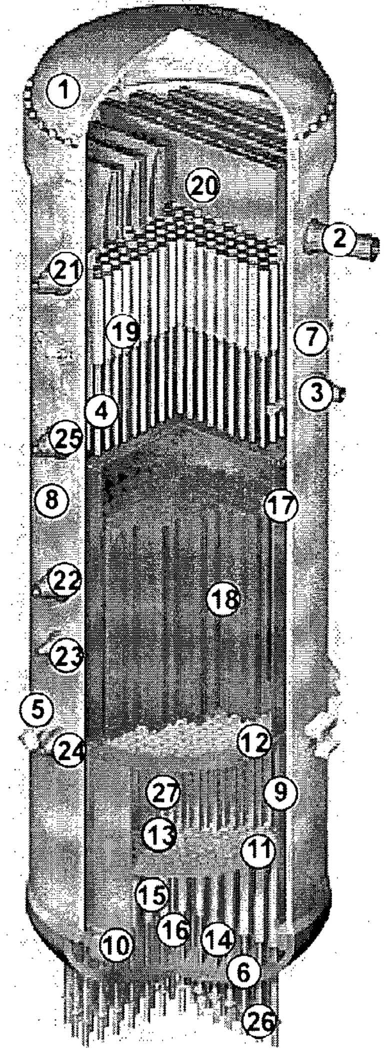
Design Improvements

- 100% steam bypass
  - > Island mode of operation
- Fine Motion Control Rod Drives (FMCRD)
  - > CRD hydraulic system provides backup non-safety high pressure makeup
- Some systems combined, e.g., RWCU/SDC, FAPCS
- Improved In-core Instrumentation
  - > Fixed Start-up Range Neutron Monitors (SRNM)
  - > Fixed Gamma Thermometers
    - No Traversing In-core Probe (TIP) System

Other Design Improvements (cont)

- Reactor Water Cleanup/ Shutdown Cooling System
  - > Combined system shares pumps, heat exchangers, piping
  - > Full pressure shutdown cooling capability
- Fuel and Auxiliary Pool Cooling System (FAPCS)
  - > Combines cleanup and cooling of auxiliary pools
  - > Has a non-safety LPCI mode
- Shoot-out Steel Eliminated
- Integrated Head Vent Pipe
- Stainless Steel Lined Suppression Pool

ESBWR Reactor Pressure Vessel



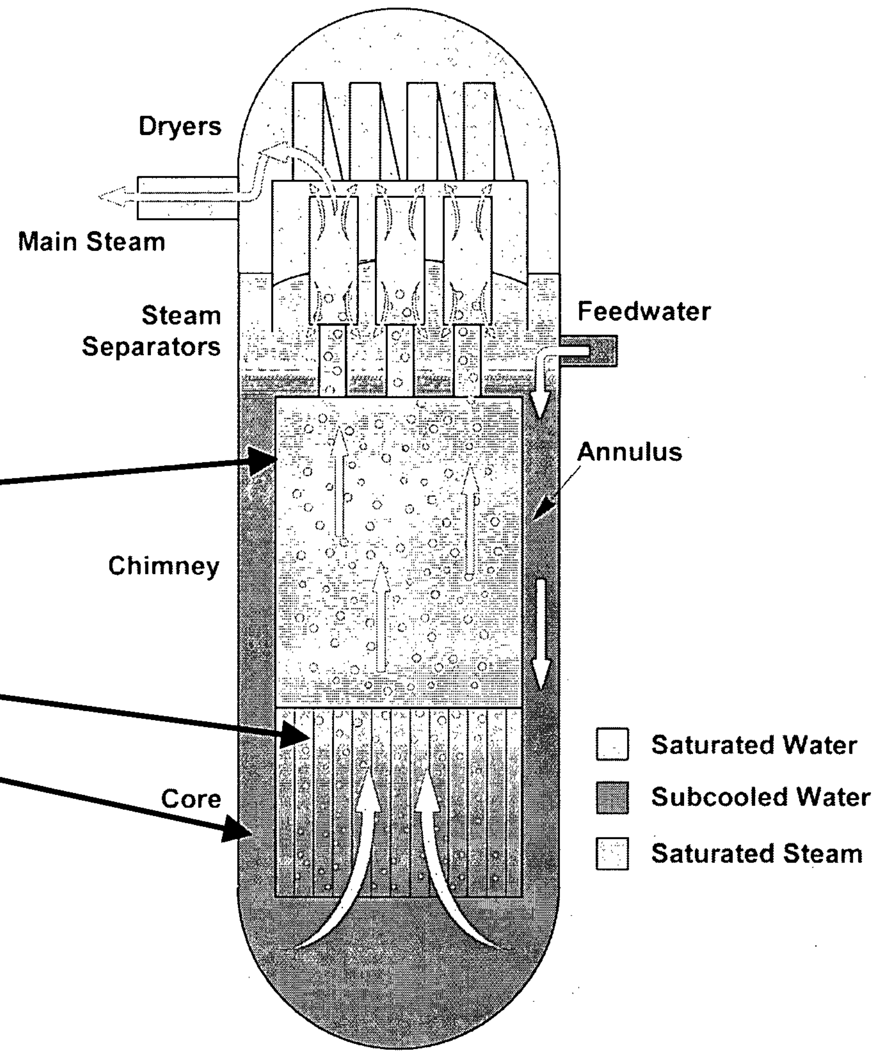
ESBWR

1. Vessel Flange and closure head
2. Steam outlet flow restrictor
3. Feedwater nozzle
4. Feedwater sparger
5. Vessel support
6. Vessel bottom head
7. Stabilizer
8. Forged shell rings
9. Core shroud
10. Shroud support brackets
11. Core plate
12. Top guide
13. Fuel supports
14. Control rod drive housings
15 Control rod guide tubes
16. In-core housing
17. Chimney
18. Chimney partitions
19. Steam separator assembly
20. Steam dryer assembly
21. DPV/IC outlet
22. IC return
23. GDCS inlet
24. GDCS equalizing line inlet
25. RWCU/SDC outlet
26. Control rod drives
27. Fuel and control rods

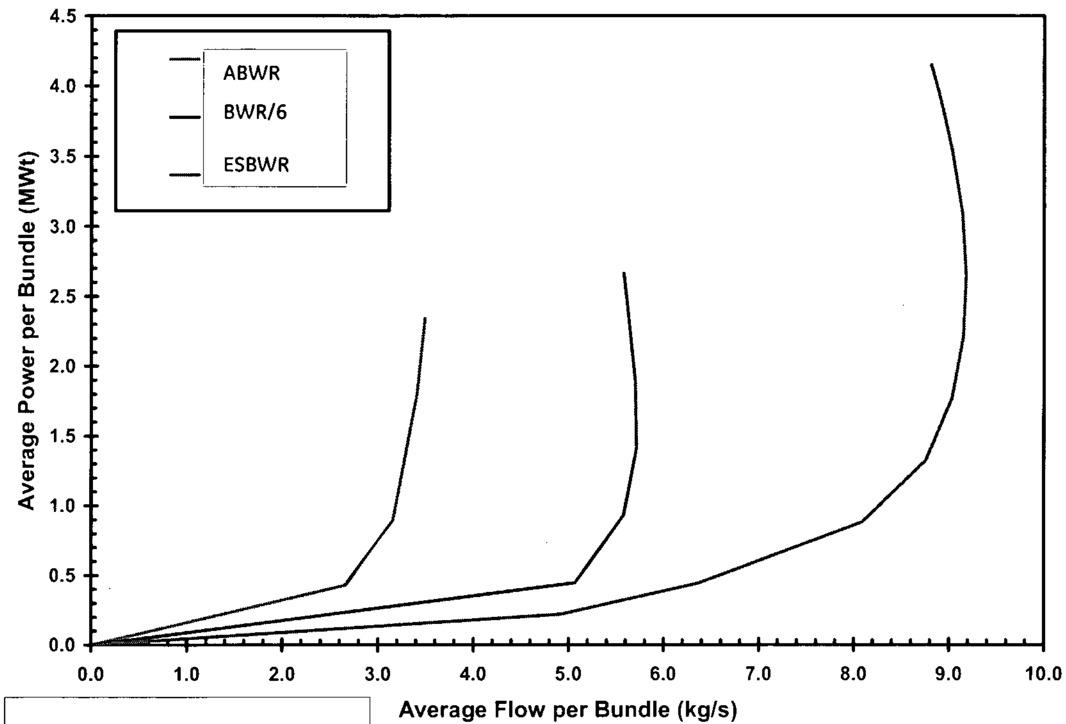
Natural Circulation

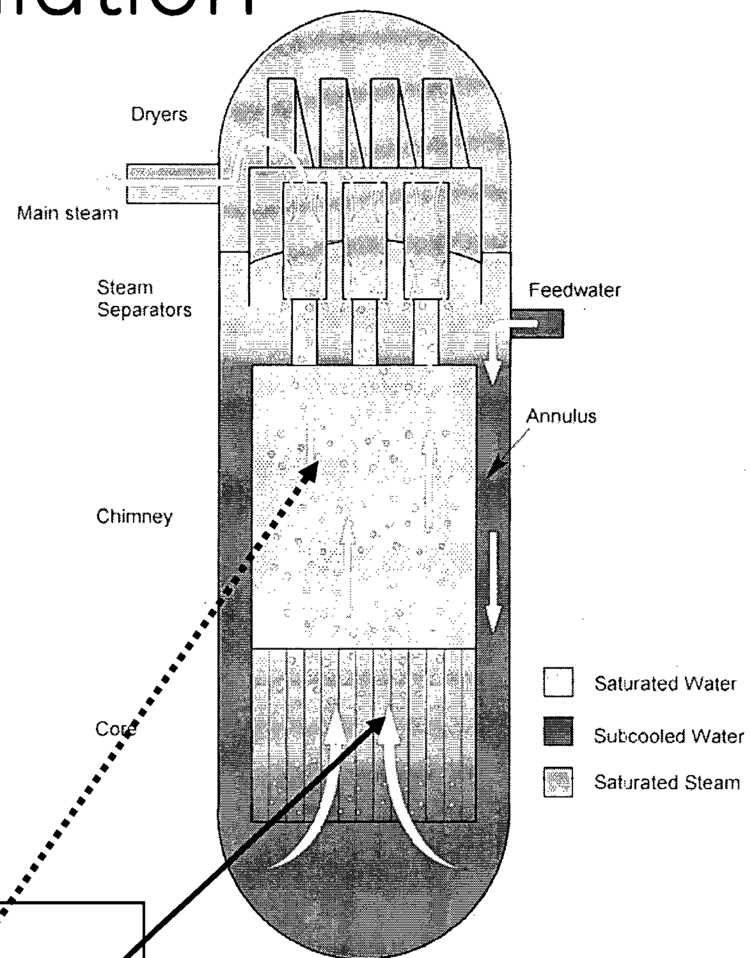
Simplification without performance loss ..

- **Passive safety/natural circulation**
  - Increase the volume of water in the vessel
  - Increase driving head
    - –Chimney, taller vessel
  - Reduce flow restrictions
    - –Shorter core
    - –Open downcomer
- **Significant reduction in components**
  - Pumps, motors, controls, HXs
- **Power Changes with Control Rod Drives**
  - Minimal impact on maintenance



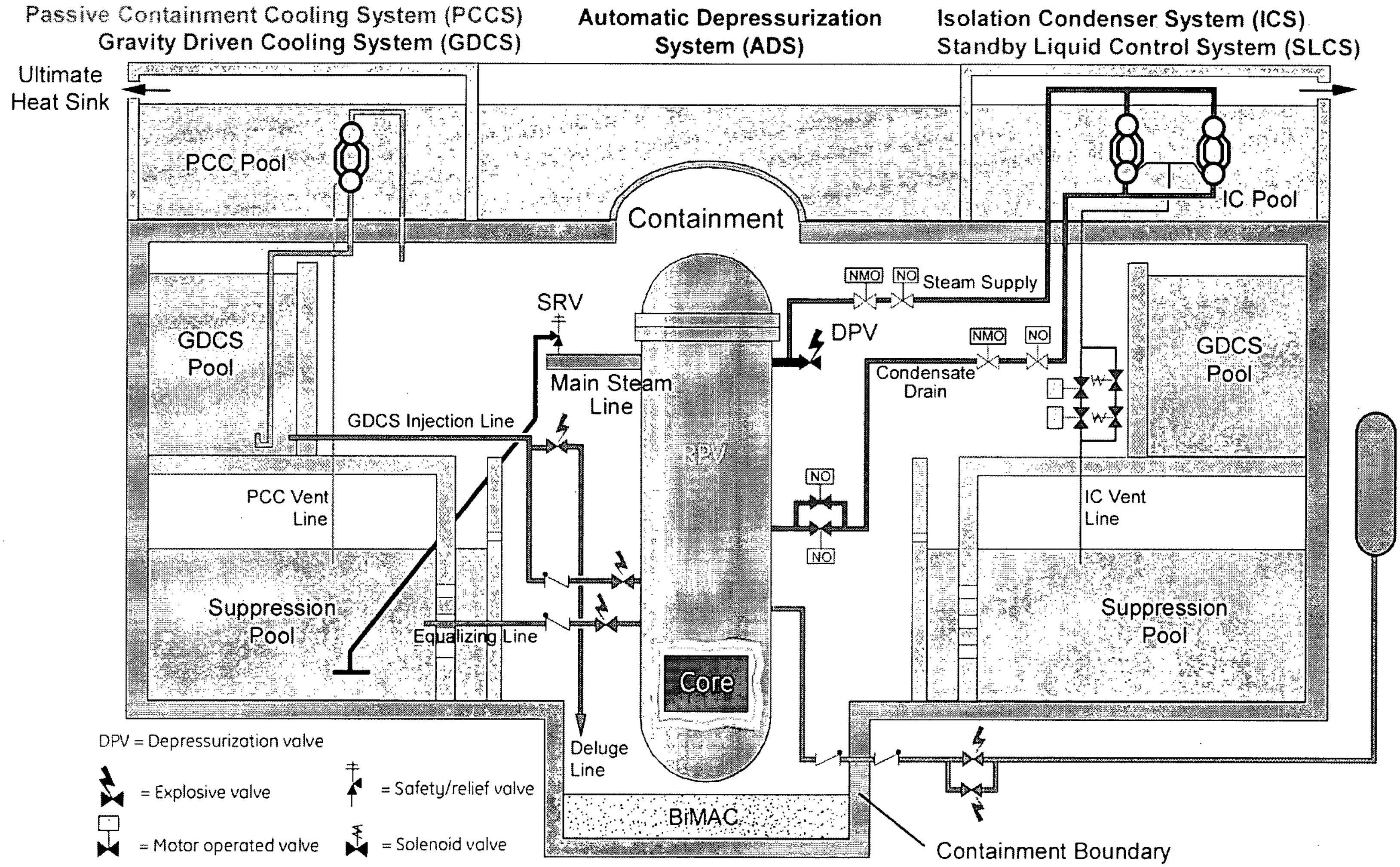
Enhanced Natural Circulation



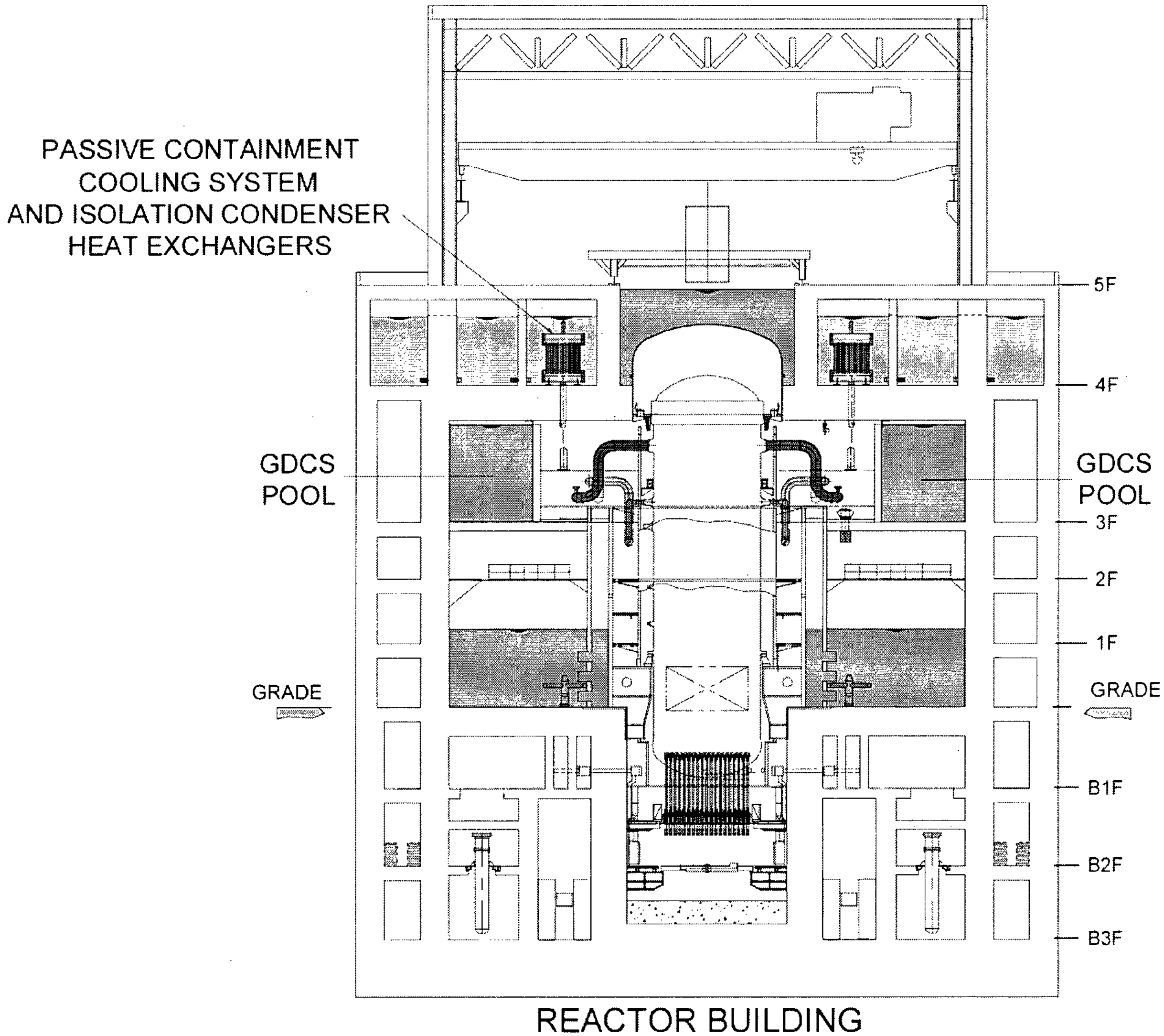


- Higher driving head
  - Chimney/taller vessel
- Reduced flow restrictions
  - Shorter core
  - Increase downcomer area

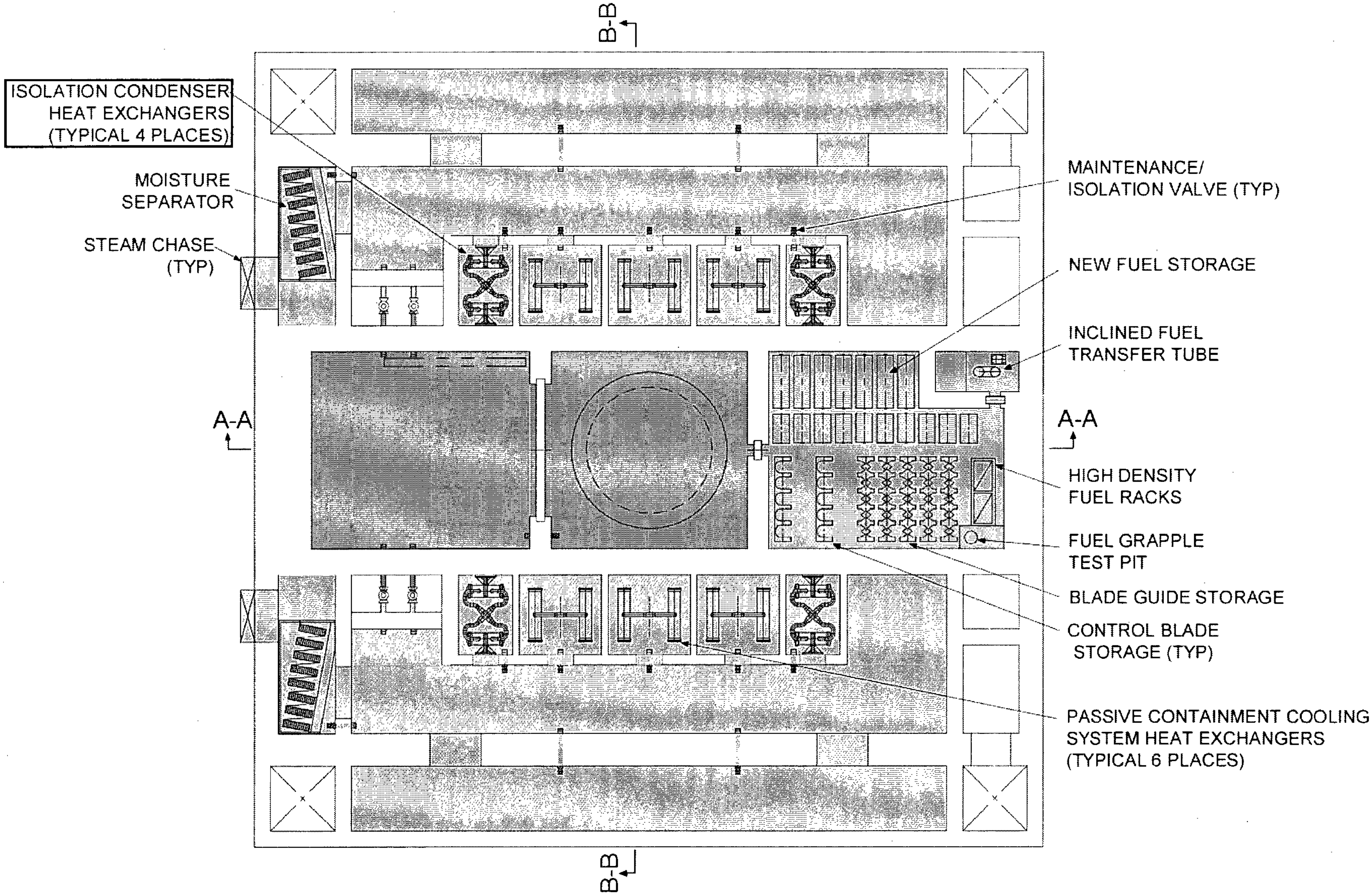
Passive Safety



ESBWR Reactor Building Section B-B



ESBWR Reactor Building IC-PCCS Elevation



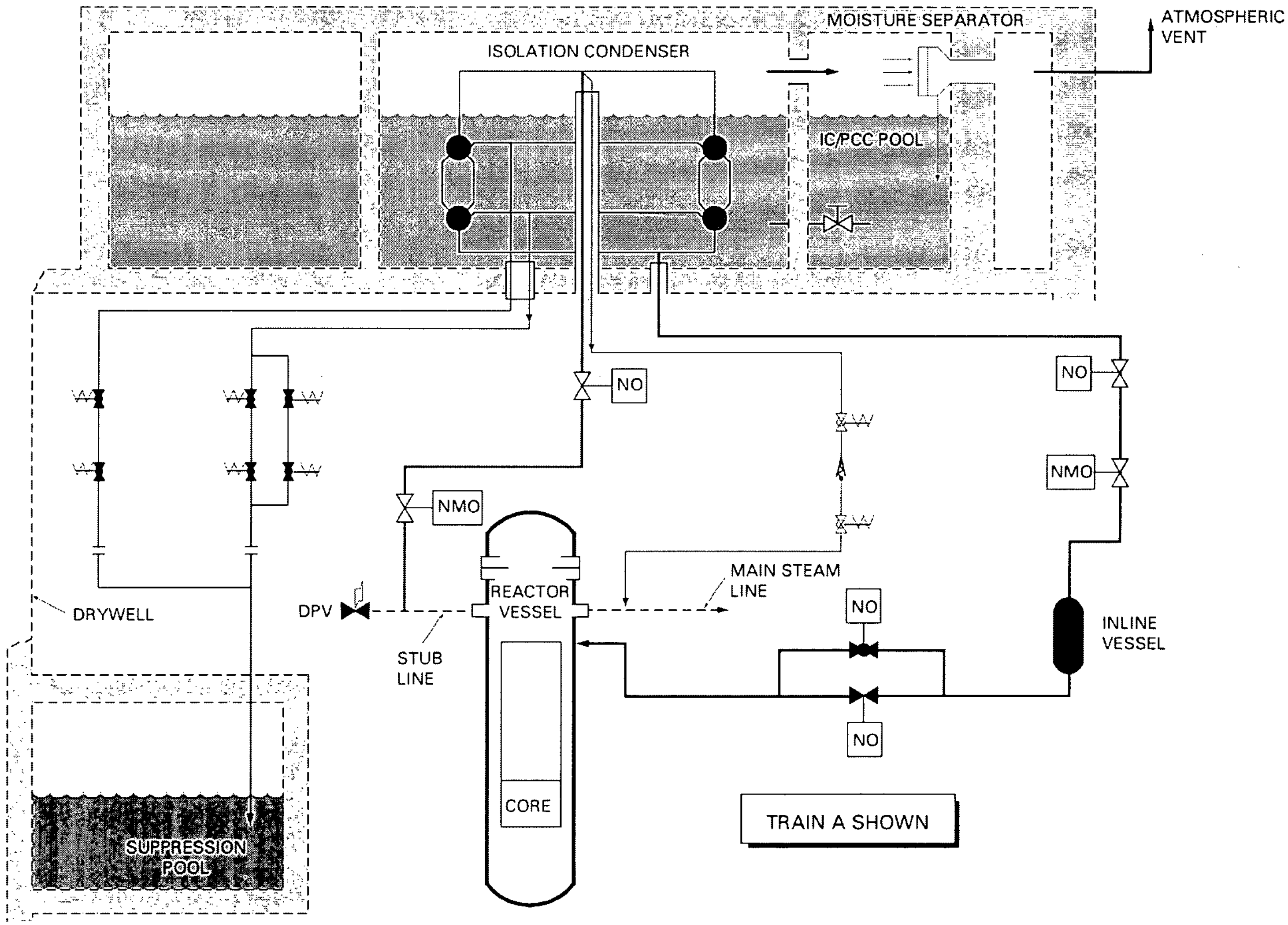
Isolation Condenser System

- Limits Reactor (Rx) pressure & prevents SRV operation following MSL isolation
- ICS provides passive decay heat removal
  - > Single failure criteria apply
  - > No lift of the Safety Relief Valves (SRVs)
  - > Operates in all design basis conditions
  - > 4 IC HXs transport decay heat direct from NSSS to the Ultimate Heat Sink
    - – No steaming in the primary containment
  - > Rapidly reduces RPV pressure
  - > Redundant and diverse "active" components

Isolation Condenser System Characteristics

- Safety-related
- Independent of AC power
  - > Super Station Blackout
- 4 high pressure heat exchanger units
  - > Each unit is two identical modules
- Capacity with 3 of 4 units operating is 101MWt (2.25%NBR)
- Sufficient pool water for 72 hours

Isolation Condenser - Standby



ICS Operation

- ICs are in standby mode with water filling condensate lines and heat exchangers to IC pool elevation during normal operation
- IC operation is initiated by opening one or both condensate return valves.
- Initiators include:
  - > High reactor pressure (for 10 seconds)
  - > MSIV closure (2 or more with Rx Mode Switch in RUN)
  - > Reactor water **Level 2 plus time delay**
  - > Reactor water **Level 1**
  - > Loss of power generation buses (Loss of Feedwater)
  - > Manual

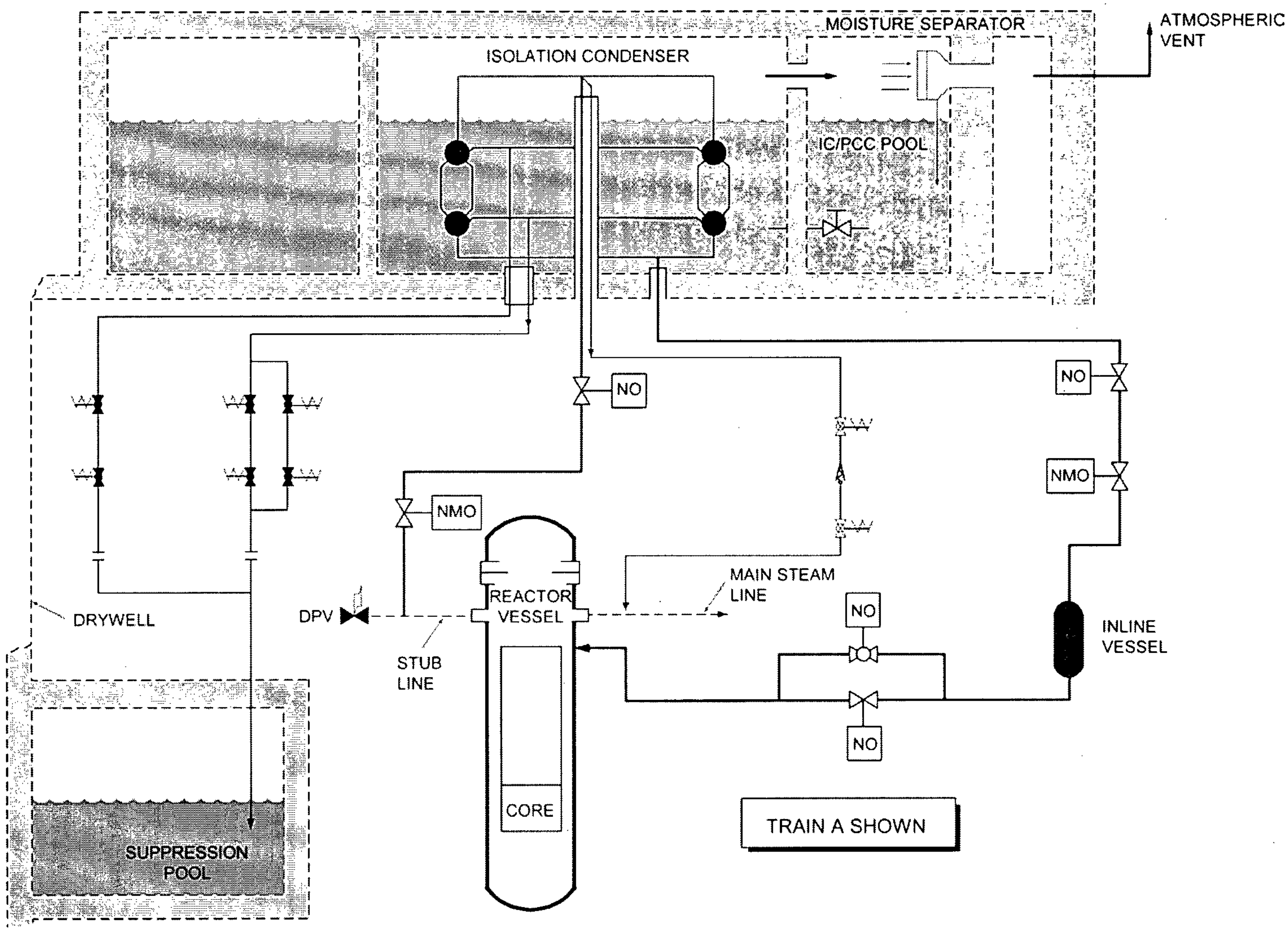
Isolation Condenser Operation (cont'd)

- Steam is generated on pool side of the ICs, passes through moisture separators and is vented from Reactor Building

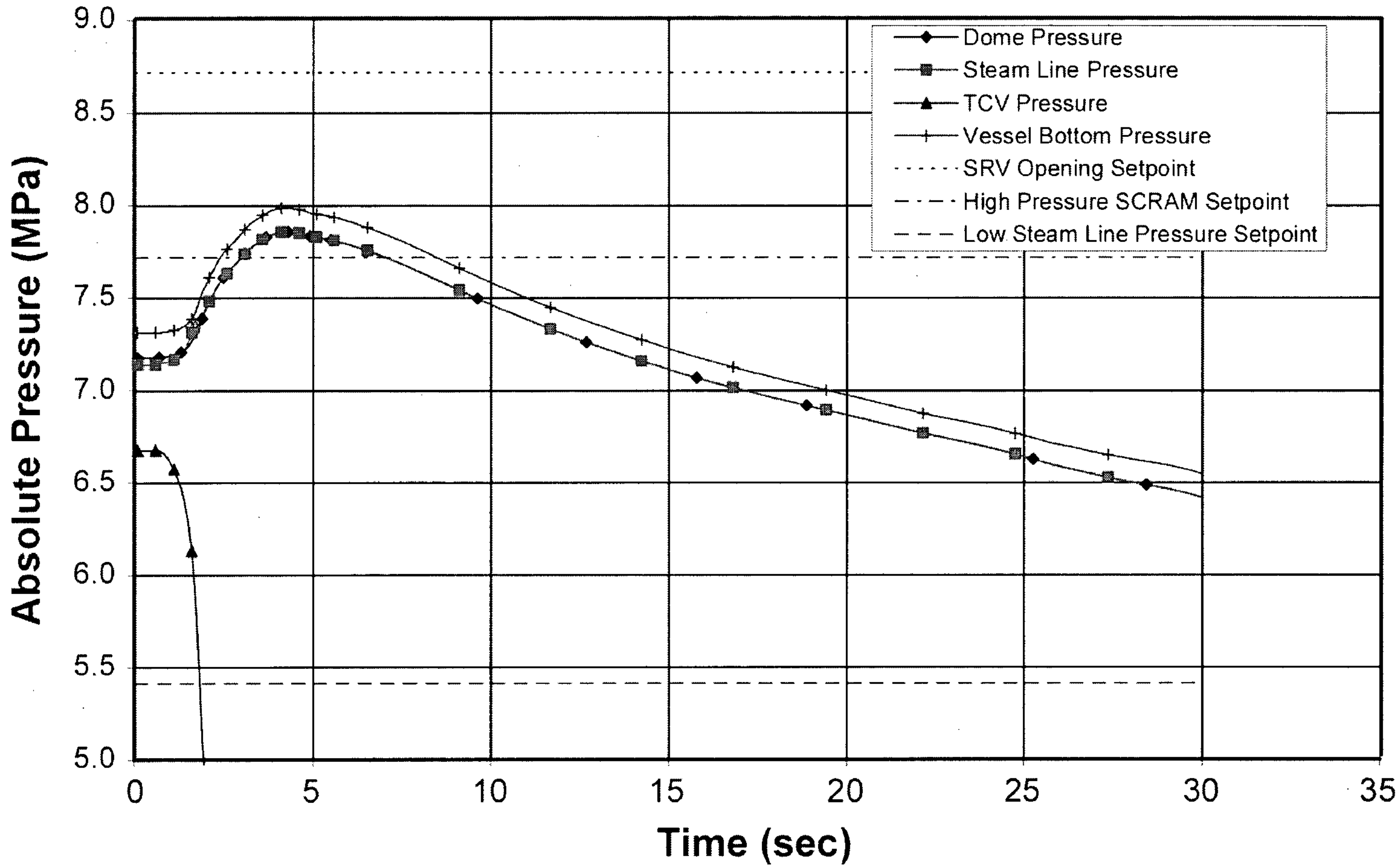
- Makeup water for the pool side can be supplied through FAPCS piping

- Vent lines open automatically on high pressure, or by operator action
  > Indication that non-condensables have accumulated in ICs, reducing heat removal capacity

Isolation Condenser - Operating



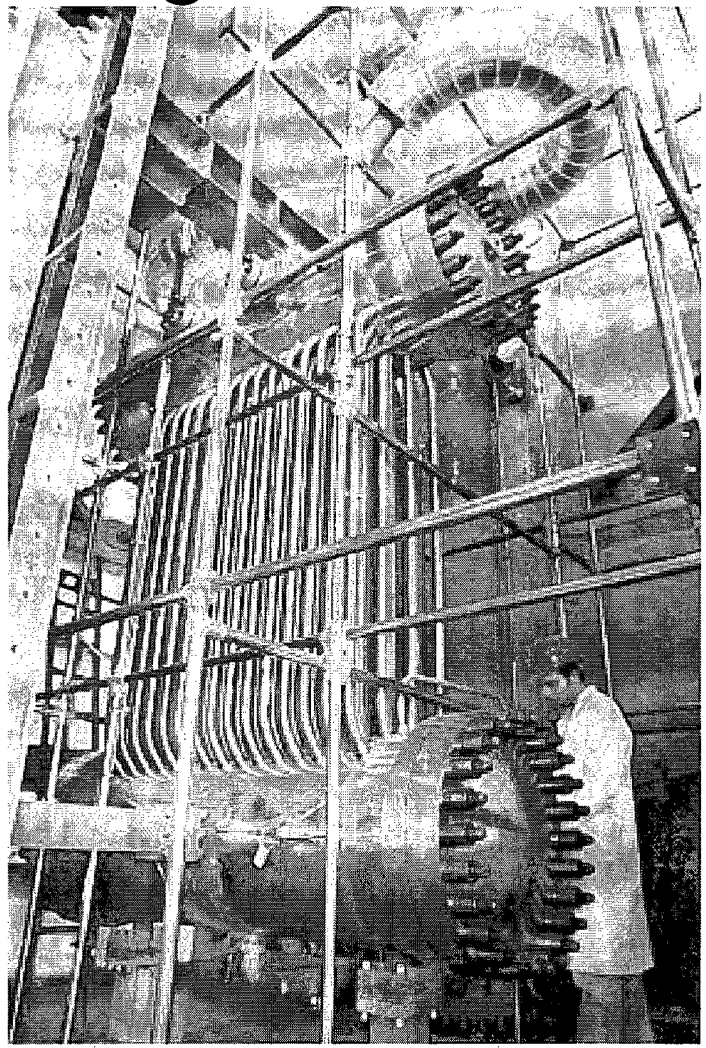
MSIV Closure Transient



Limiting pressure transient – no SRVs open

Isolation Condenser Testing

- ICs have been used in BWR/3s
  - > Dresden 2/3
  - > Tube and shell configuration
- ESBWR is same in principle, but different geometry
  - > One full-scale half unit tested over wide range of operating conditions

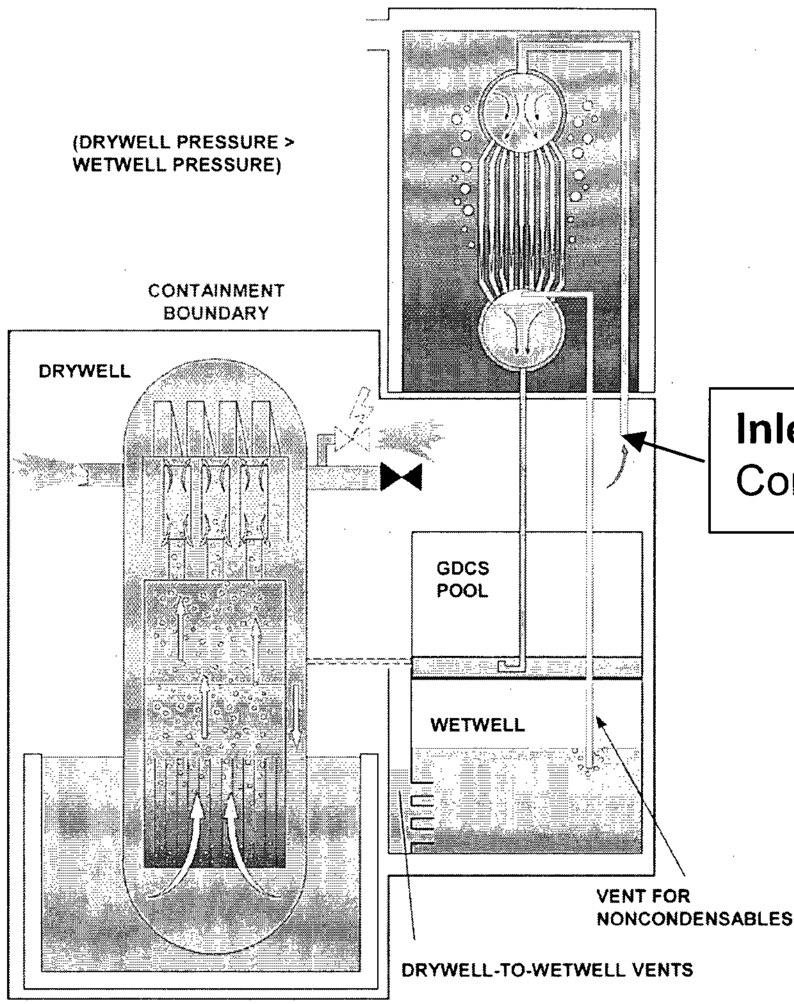


Passive Containment Cooling System

- PCCS provides passive decay heat removal from Containment for DBAs
  - > Operates in medium and large break LOCAs
  - > Provides backup of ICS if needed
    - – RPV is depressurized using DPVs
  - > Entirely Passive
    - – 72 hours water supply

PCCS Thermal Hydraulics

PCCS loops are part of the Containment

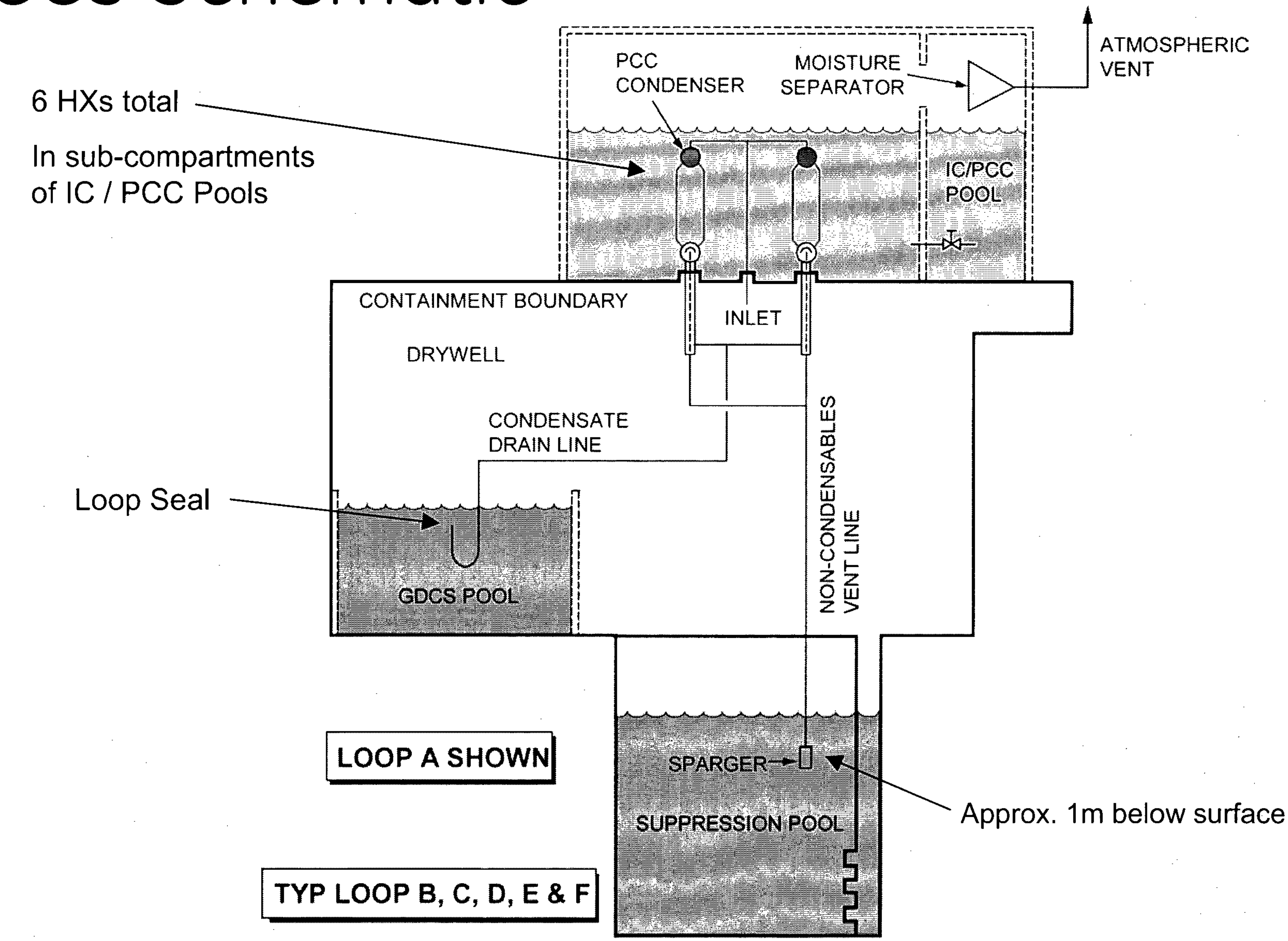


Inlet - open to Containment

PCCS Characteristics

- Safety related
- Keeps Containment pressure within limits after DBAs
- Six low pressure heat exchanger units (HXs), similar in design to the ICS HXs
- Total capacity 66 MWt (1.5% NBR)
- Sufficient pool water for 72 hours
- No valves; HX tubing is part of Containment boundary

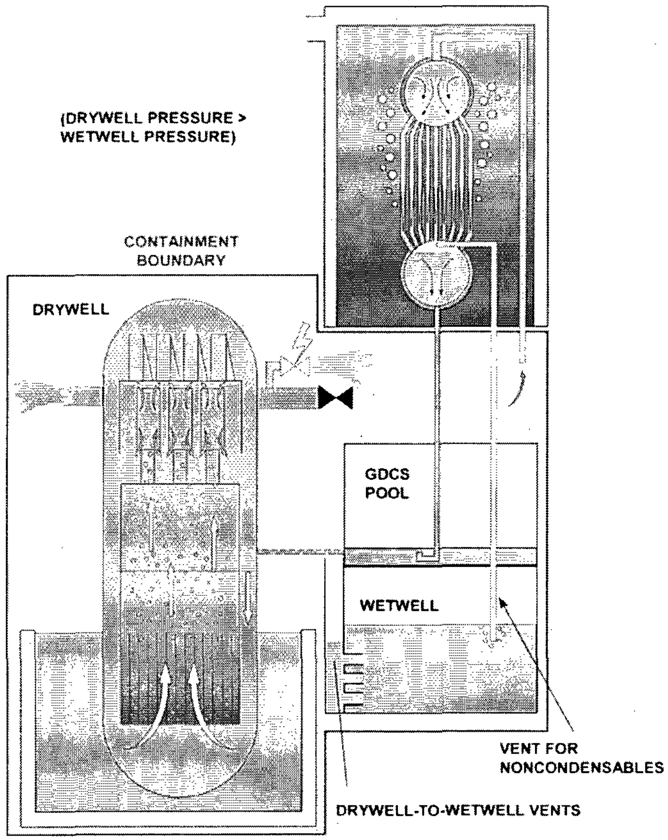
PCCS Schematic



PCCS Operation

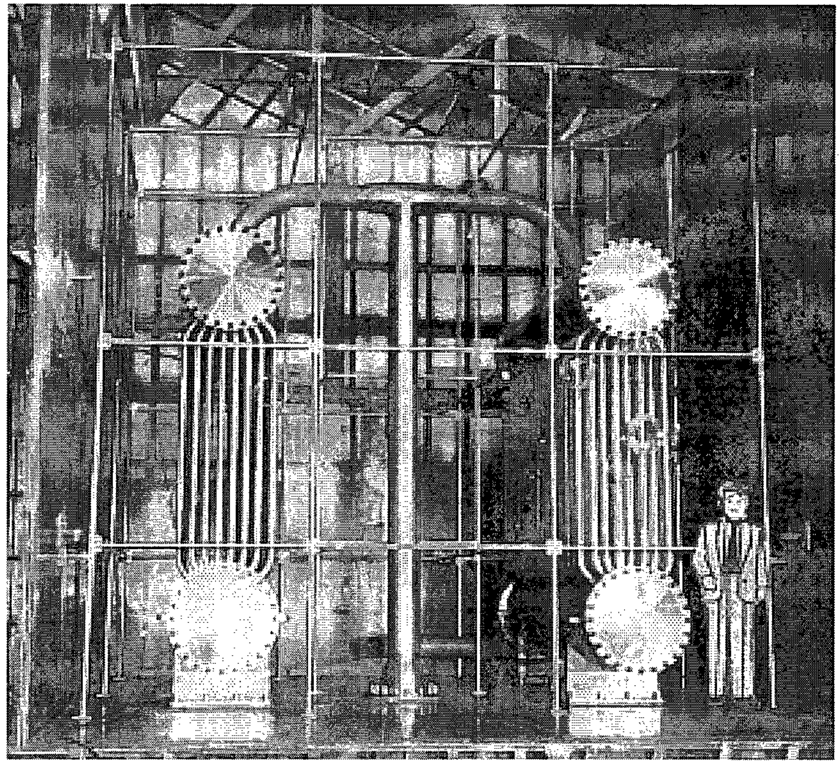
Entirely Passive

- PCCS only works as hard as it needs to in removing decay heat
- Inside heat exchangers there is a moving boundary established between fluid rich in steam and fluid rich in non-condensables



PCCS Heat Exchanger Test

- PCCS is new feature; extensive testing
- PCCS heat exchanger testing was done in Italy in same facility used for ICS HX testing
- Because of lower power, both halves of full-size unit could be tested



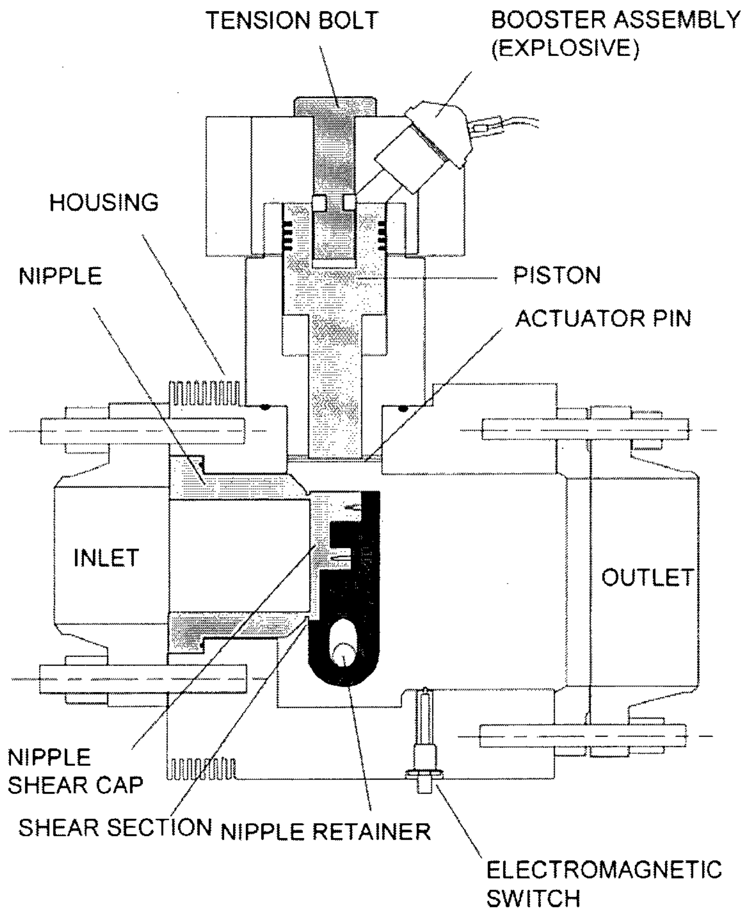
Emergency Core Cooling System (ECCS)

- Automatic Depressurization System (ADS)
- Gravity Driven Cooling System (GDCS)
- Secondary supporting systems
  - > Isolation Condenser System
  - > Standby Liquid Control System
- Core remains covered for entire range of Design Basis Accidents
- Stored water is sufficient to flood containment and RPV to > 1 m (3.3 feet) above top of fuel

Automatic Depressurization System

- ESBWR has 18 SRVs mounted on 4 steam lines
  - > 10 SRVs have pneumatic actuators to permit opening for ADS function when needed
- To rapidly reach and maintain low pressures needed for gravity flow of water, ESBWR has installed 8 Depressurization Valves (DPVs)
  - > 4 DPVs on MSLs
  - > 4 DPVs on stub lines
  - > DPVs are squib actuated; once open stay open
  - > Each valve is ~twice the capacity of an SRV
- Ensure that RPV pressure is equal to Drywell Pressure

Depressurization Valve (DPV)



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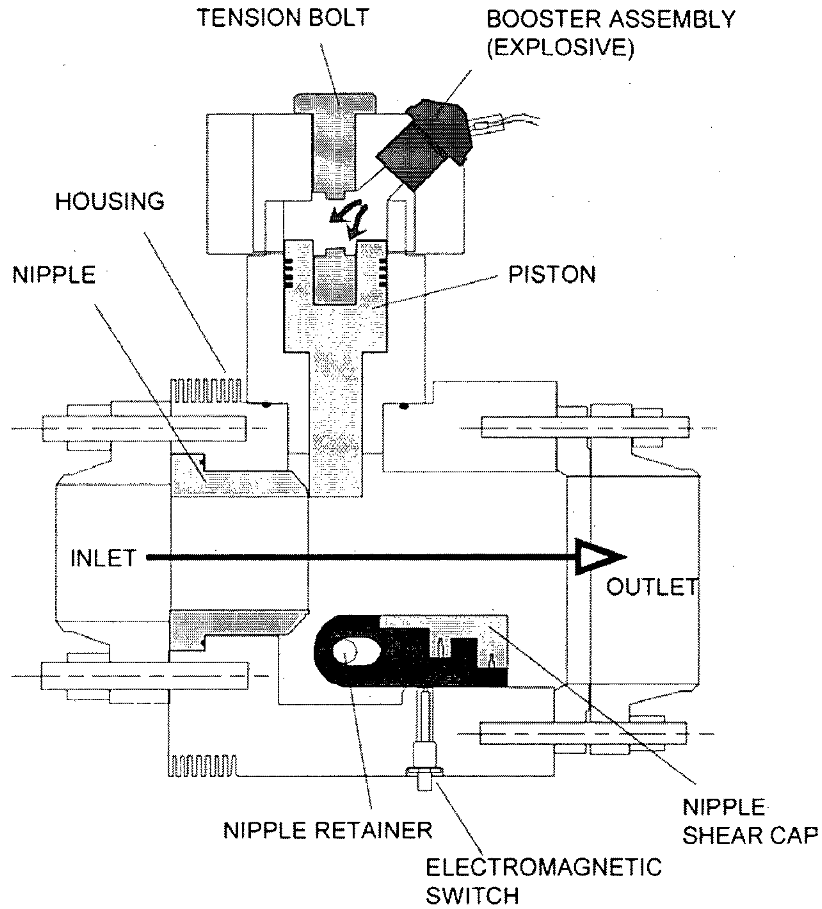
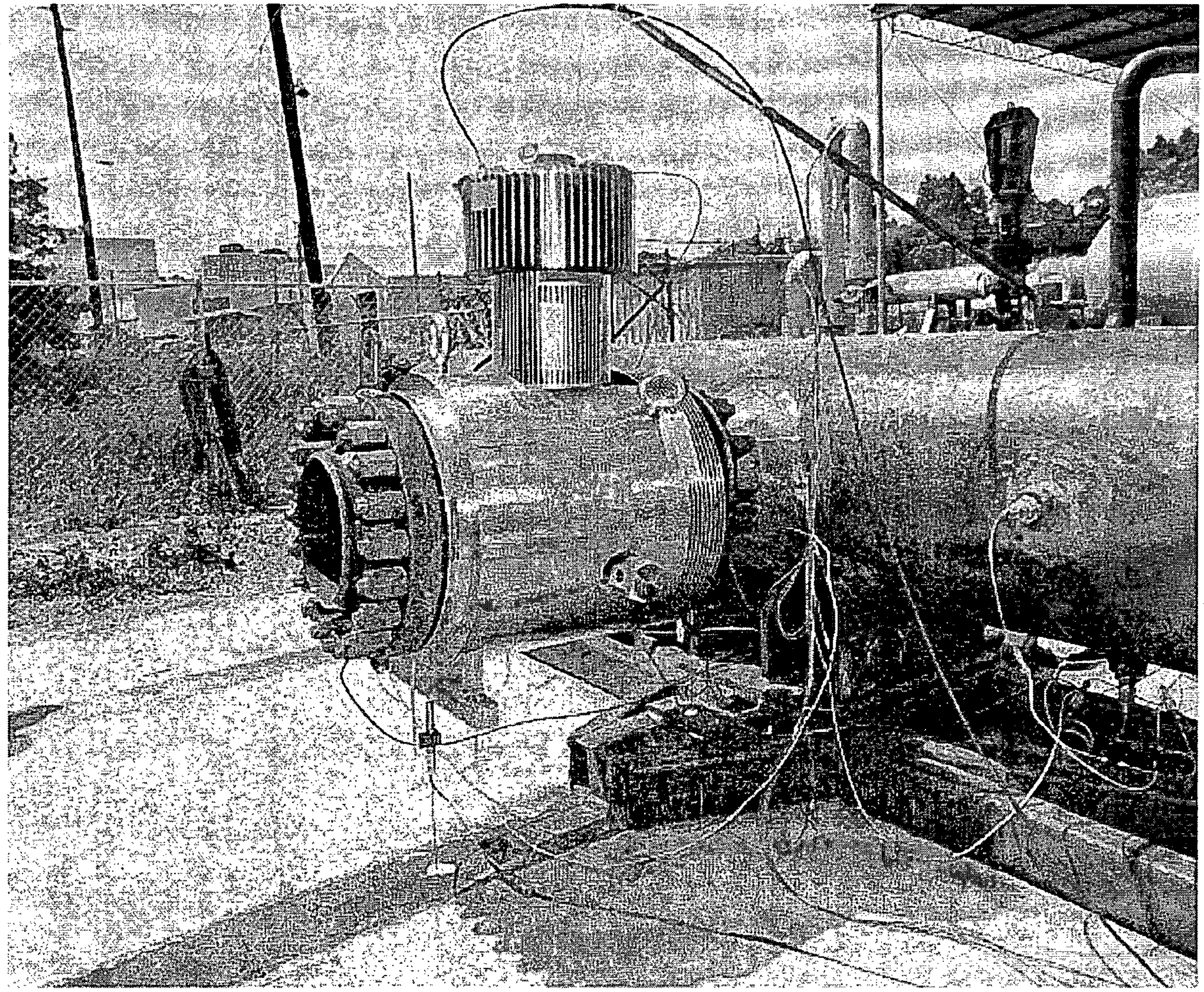


OPEN

DPV Under Test at Wyle Laboratories



Gravity Driven Core Cooling System

- 3 Pools of water located in the Upper Drywell
- 4 divisions of plumbing
  - > Short term cooling
    - – Vessel injection
  - > Long term cooling
    - – Equalization lines from Suppression Pool
  - > Severe Accident
    - – Deluge

ECCS Operation

- ECCS operation is initiated by the following:
  - > Water level 1 persisting for 10 seconds

- ADS valve openings are staggered to limit two-phase water level swell in RPV
  - > 5 ADS SRV – no delay
  - > 5 ADS SRV –10 sec delay
  - > 3 DPV – 50 sec delay (also initiates SLCS injection)
  - > 2 DPV – 100 sec delay
  - > 2 DPV – 150 sec delay
  - > 1 DPV – 200 sec delay

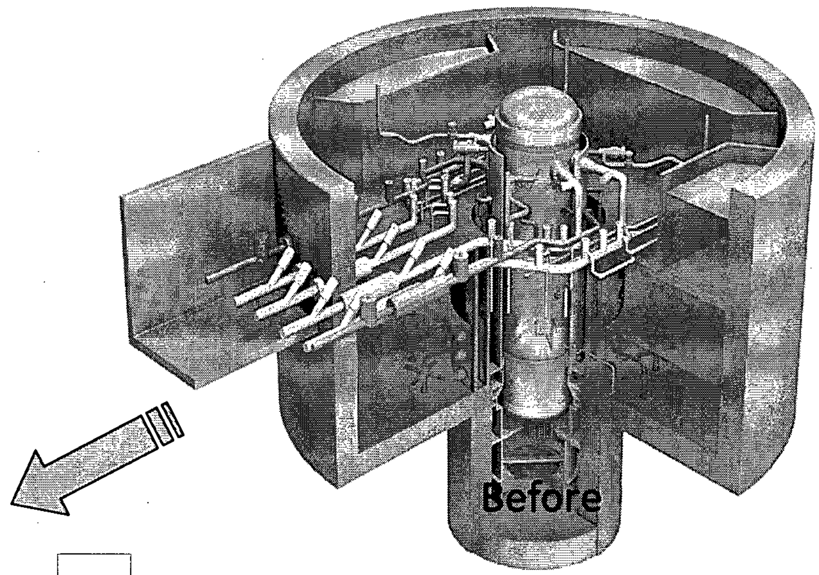
ECCS Operation (cont'd)

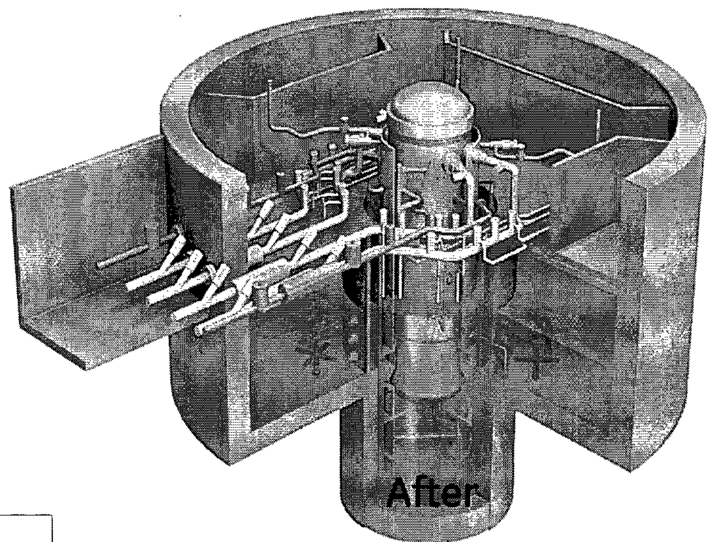
- SLCS operation is initiated coincident with DPV opening
- Need for equalization lines depends on amount of liquid transferred to SP long-term, via PCCS, or condensation in Drywell
  - > Equalization value opening occurs if RPV water level reaches **Level 0.5**: 1 m (~3.3 ft) above TAF
  - > Current evaluations show Level 0.5 will <u>not</u> be reached
- Containment heat removal and inventory conservation is via PCCS

Gravity Driven Cooling System ...

Simple design
Simple analyses

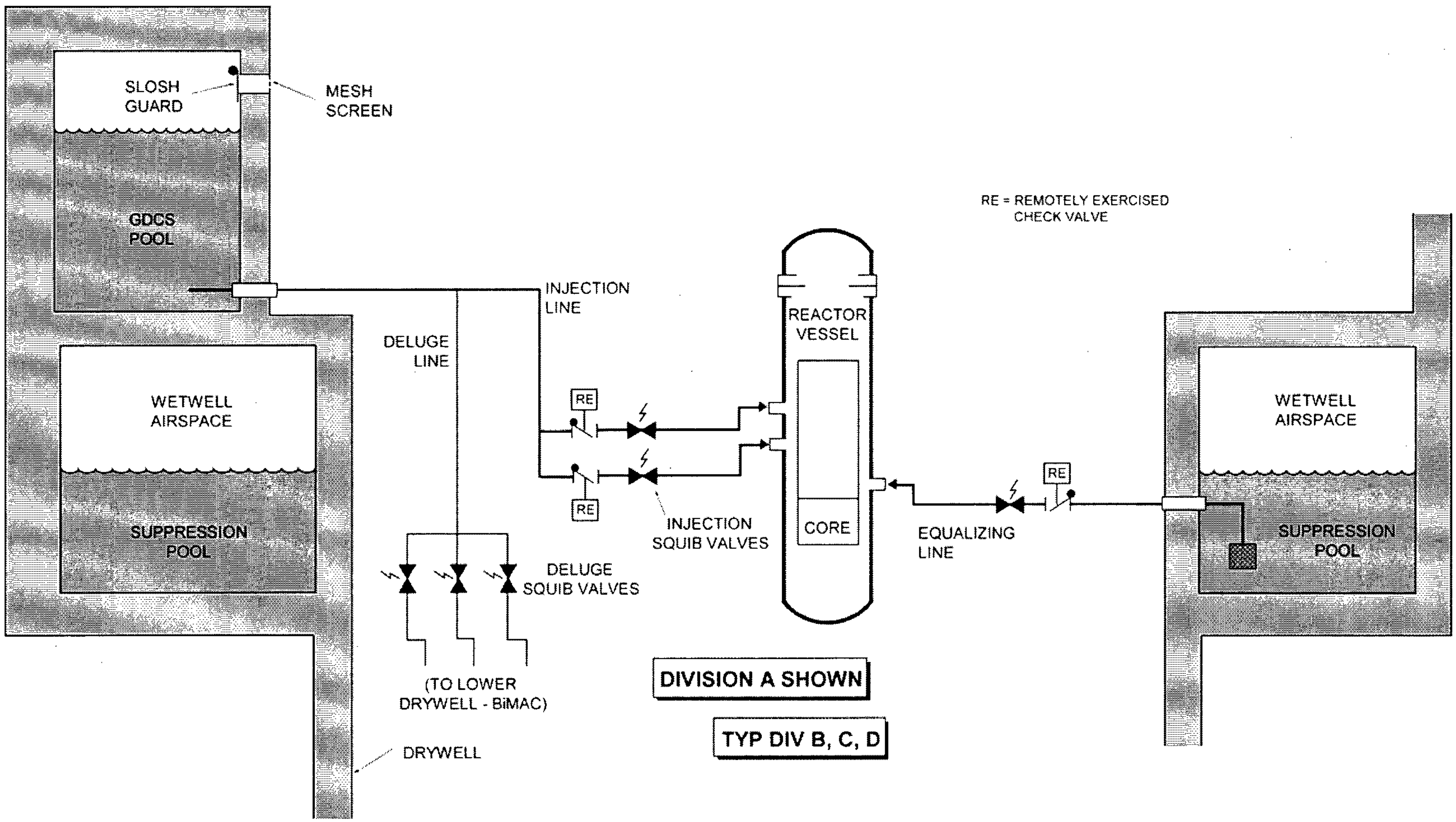
Extensive testing
Large safety margins



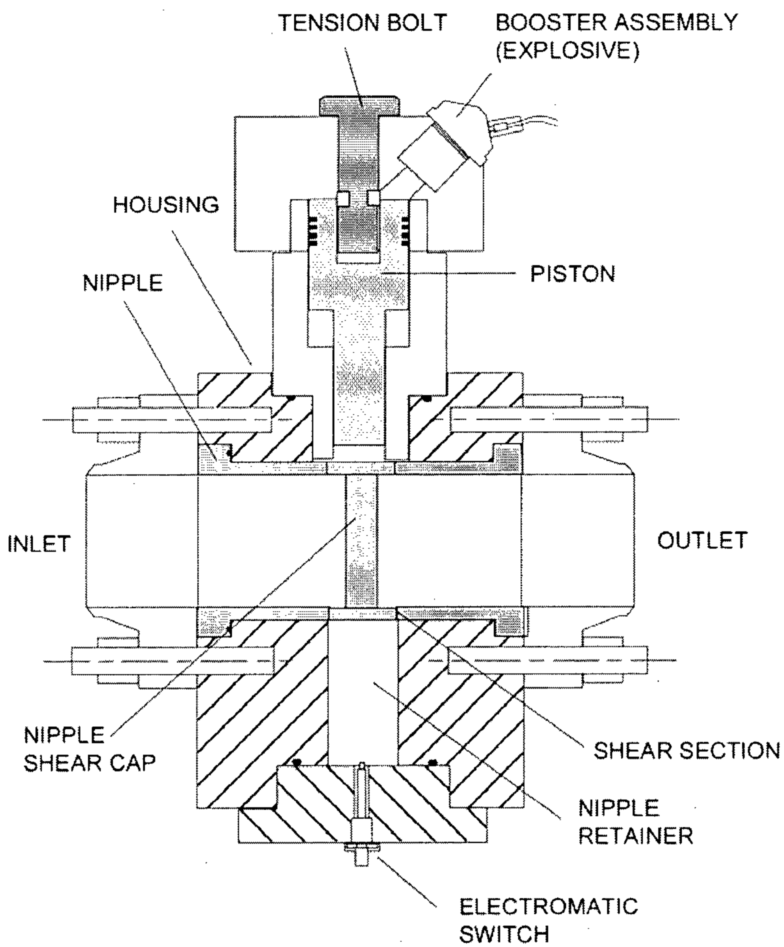


Gravity driven flow keeps core covered

GDCS Schematic



GDCS Squib Valves



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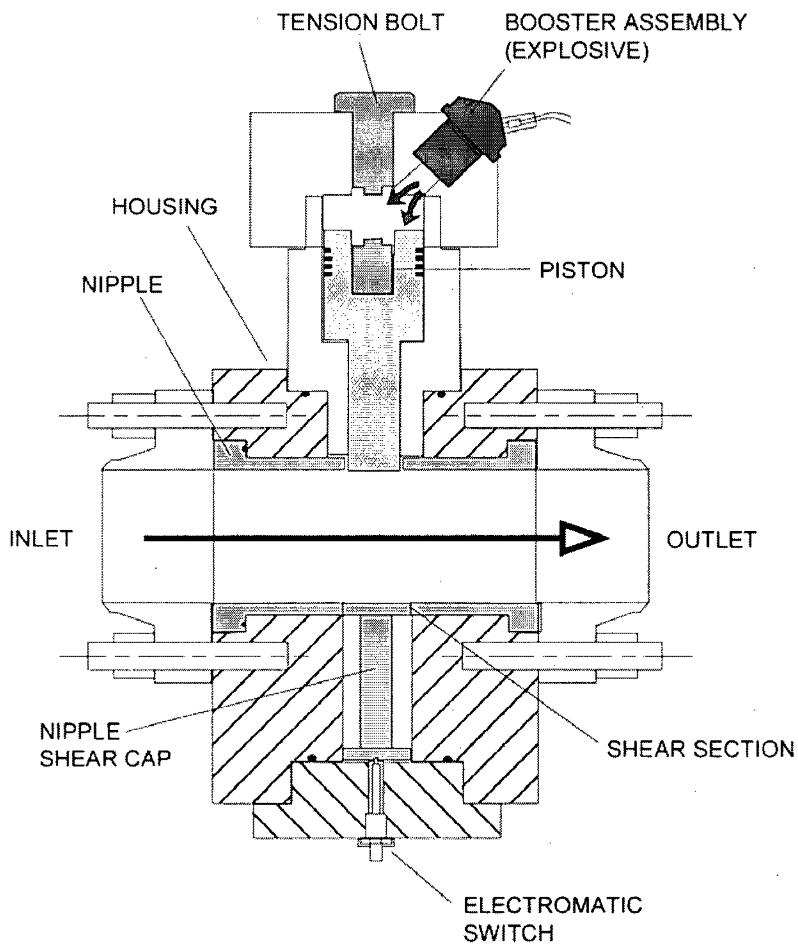
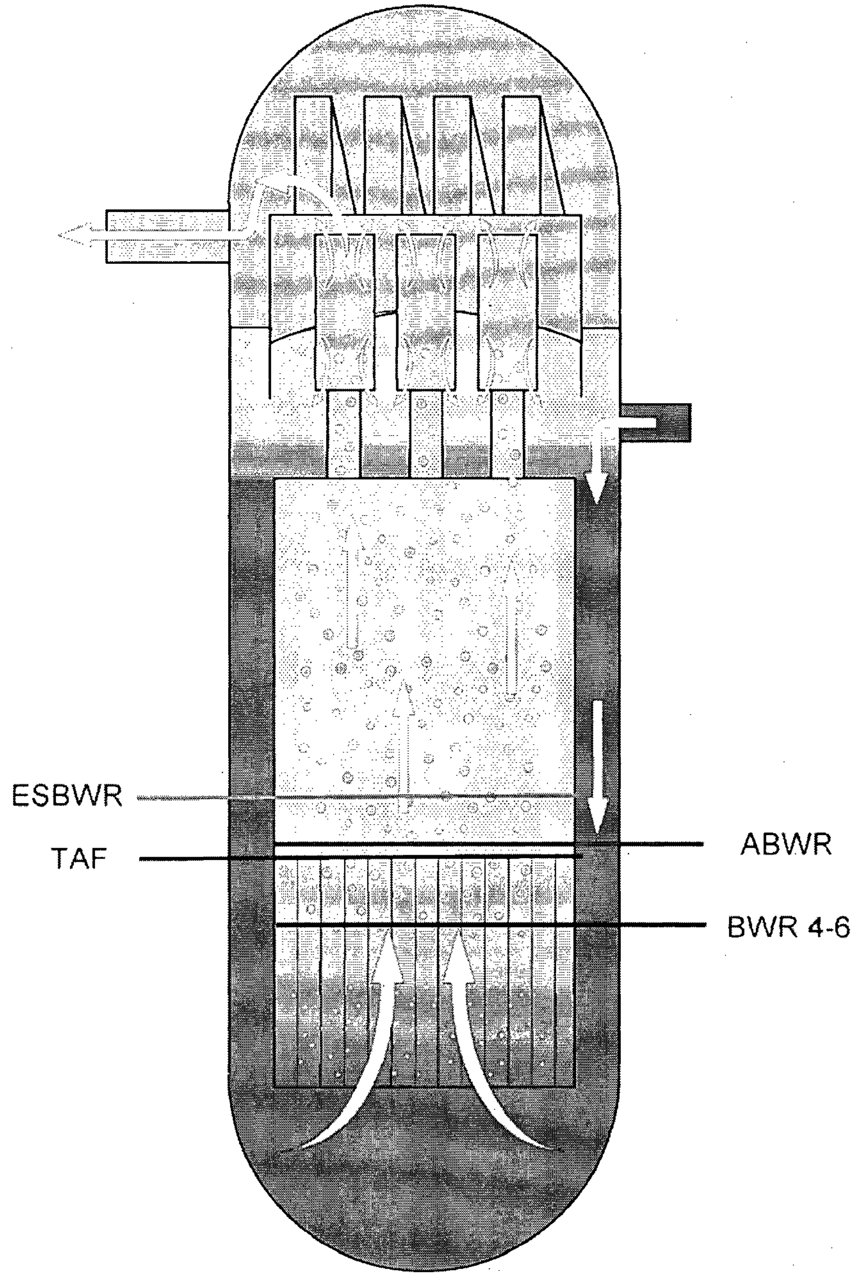


OPEN

LOCA Water Level Response

ESBWR never uncovers the core

> ESBWR has almost 3m (~10 ft) margin

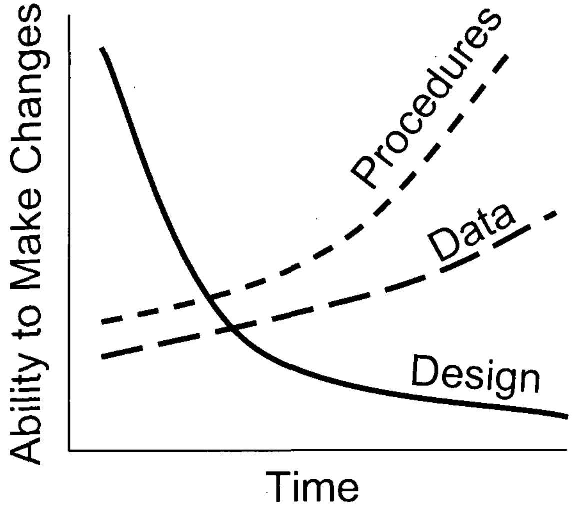


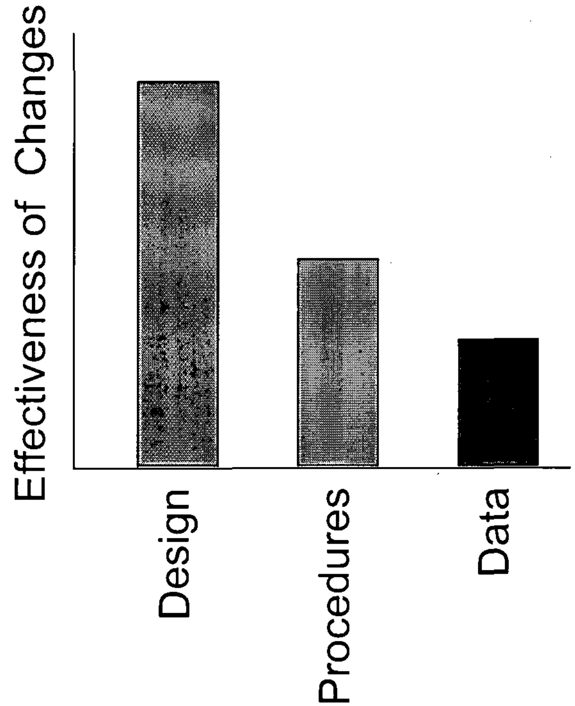
LOCA Animation Video Clip

PRA For A New Reactor Design

- Determine risk management strategy
- Consider all aspects in the design
  - > Core damage
  - > Severe accidents
  - > Internal and external events
- Design PRA provides a bounding assessment
  - > Provides the safety case for the plant license
- Make risk assessment an integral part of the overall design process
- Updated PRA prior to fuel load is required

Three Chief Methods to Affect Risk





Using a PRA early provides maximum benefit

PRA as a Design Tool

- Overall Objective: Eliminate Severe Accident Vulnerabilities
  - > PRA provides a systematic means for finding and eliminating these vulnerabilities
  - > GE utilizes the PRA as an integral element of the design change process
  - > Easier to make corrections earlier in design phase
  - > Any PRA tools are helpful in reducing risk during the early design phases

Key Features of ESBWR Design Risk Management

Passive safety systems

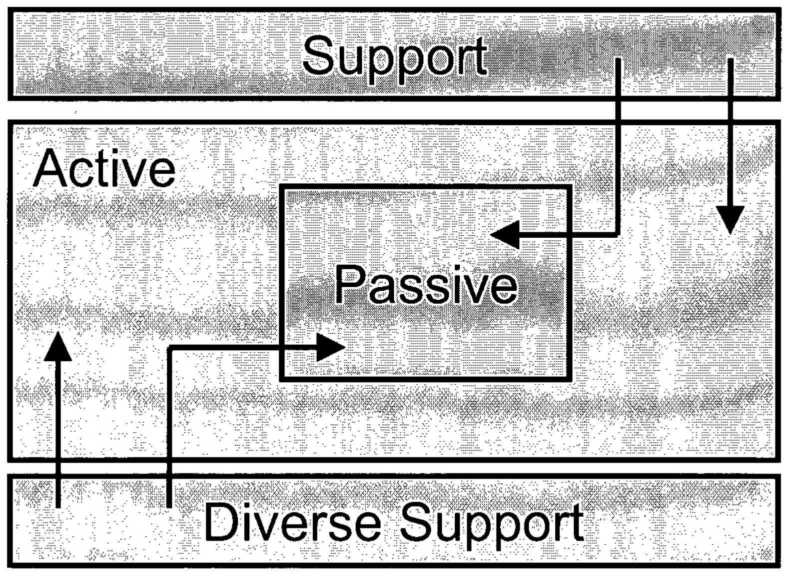
Active asset protection systems

Support system diversity

Minimize reliance on human actions

Use historical data

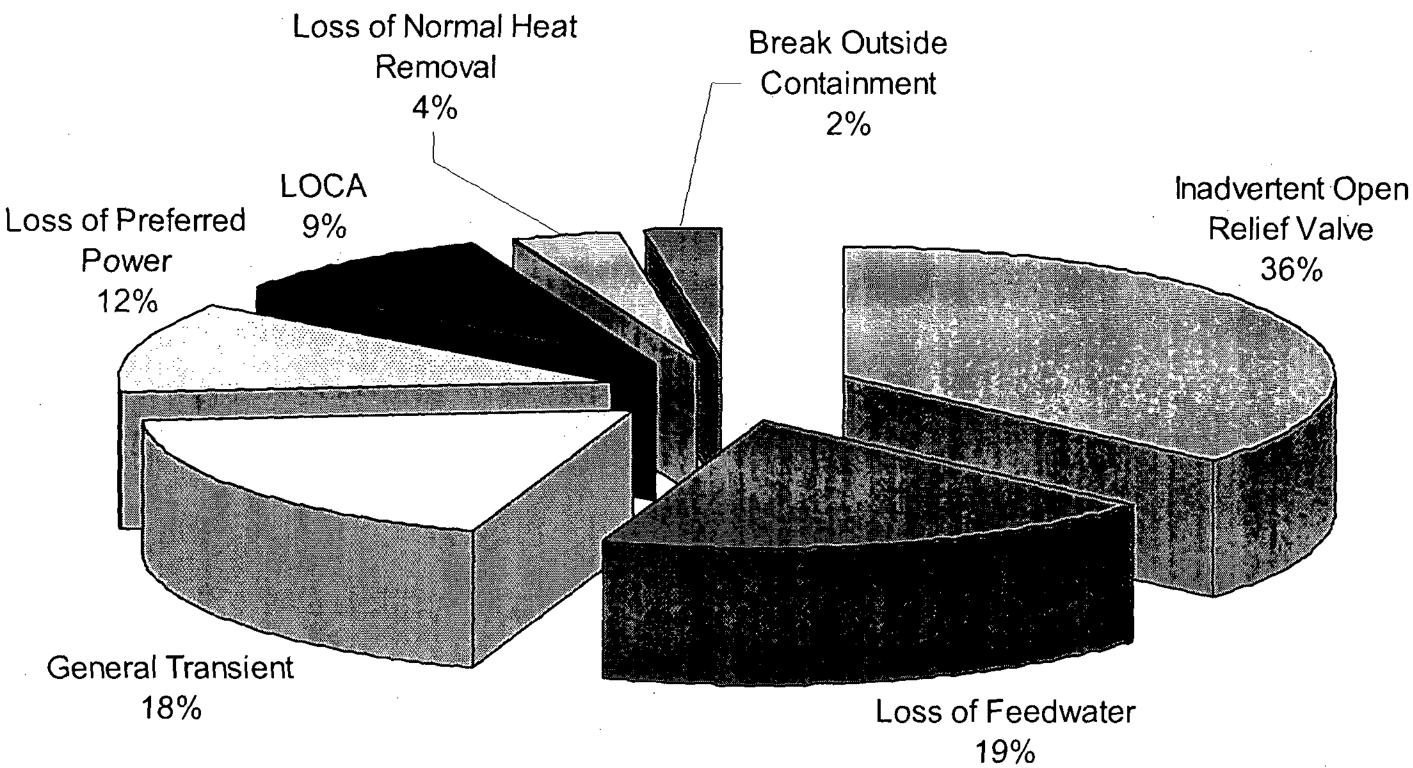
Target configuration for core damage prevention functions



Features of ESBWR PRA

- Detailed Fault Tree / Event Tree Models
- Level 1, 2, and 3
- Internal & External Events
- All Modes
- Seismic Margins
- Generic Data
- Historical Initiating Event Frequencies
- Parametric Uncertainty
- Systematic Search for Key Modeling Uncertainties

ESBWR Core Damage Risk Profile



$CDF = 1.2 \times 10^{-8}\ yr^{-1}$

At power internal events

Design Improvements Resulting from PRA

- Redundant flow paths for low pressure injection
- Definition of the Diverse Protection System
- Improved Digital I&C
  > Decrease probability of inadvertent actuation of specified systems
- Redundant supply valves IC/PCC pool makeup
- Redundant drain valves for ICS
- Re-routing of some fire protection lines
- Location of I&C cabinets
- Basemat Internal Melt Coolability Device (BiMAC)

Summary

- ESBWR is GE's latest evolution in BWR design
  - > 4500 MWt / ~1520 Mwe Net
  - > Natural circulation
  - > Passive safety features
  - > Significant simplification
- ESBWR was chosen by NuStart and Dominion as the reference design for the DoE 2010 program