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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

June 6, 2007

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

543rd MEETING

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WEDNESDAY,

JUNE 6, 2007

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The meeting was convened in Room T-2B3 of Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Dr. William J. Shack, Chairman, presiding.

MEMBERS PRESENT:

WILLIAM J. SHACK	Chairman
SAID ABDEL-KHALIK	ACRS Member
GEORGE E. APOSTOLAKIS	ACRS Member
J. SAM ARMIJO	ACRS Member
MARIO V. BONACA	ACRS Member
MICHAEL CORRADINI	ACRS Member
THOMAS S. KRESS	ACRS Member
OTTO L. MAYNARD	ACRS Member
DANA A. POWERS	ACRS Member

NRC STAFF PRESENT:

JOSE IBARRA
SUNIL WEERAKKODY
ERASMIA LOIS
RAY GALLUCCI
PHIL QUALLS
ZENA ABDULLAHI
GREG CRANSTON
MICHELLE HONCHARUK
TONY ULSES
RICHARD LEE
RANDY GANT
MICHELLE HART

ALSO PRESENT:

ALEX MARION
CHRIS PRAGMAN
RICK KINGSTON
SCOTT BOWMAN
JOSE CASILLAS
JENS ANDERSEN
JOSE MARCHE-LUEBA
JESS GEHIN
BERNARD CLEMENT

I-N-D-E-X

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

8:30 a.m.

CHAIRMAN SHACK: The meeting will now come to order. This is the first day of the 543rd meeting of the Advisory Committee on Reactor Safeguards. During today's meeting the Committee will consider the following: draft NUREG-1852 demonstrating the feasibility and reliability of operator manual actions in response to fire; maximum extended load and line limit analysis plus (MELLLA+) and supporting topical reports; an overview of the PHEBUS-FP experimental program and results of recent tests; a subcommittee report on the Vermont Yankee renewal application; a status report on the quality assessment of selected NRC research projects; and preparation of ACRS reports.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mr. Sam Duraiswamy is the Designated Federal Official for the initial portion of the meeting. We have received no written comments or requests for time to make oral statements from members of the public regarding today's session. A transcript of portions of the meeting is being kept and it is requested that the speakers use one of the microphones, identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

And we're going to start this morning with the draft 1852 on operator manual actions in response to fire and George will be leading us through that.

DR. APOSTOLAKIS: Thank you Bill. Sometime ago, the staff was developing a rule to credit operator actions during a fire and as part of that, there was a draft regulatory guide which the Committee had the opportunity to see some time ago. The rule was withdrawn about two years ago, but now the draft regulatory guide has come to us as a NUREG report and the intent is to support the staff's review of possible exemption requests of the utilities, of the licensees, that they may submit to the NRC. All this is within the deterministic space of Appendix R.

The Committee had decided some time ago not to review the draft guide, but wait until after the public comments were received and resolved and this is where we are today. You will hear about the report itself but also the public comments and how the staff disposed of them. So we start with Jose, I think.

MR. IBERRA: Good morning. My name is

Jose Iberra and I am the Branch Chief of the Human Factors and Reliability Branch in the Office of Nuclear Regulatory Research. We're here today to brief you on the NUREG and request your endorsement so we can public NUREG-1852 and the title of that is "Demonstrating the Feasability and Reliability of Operator Manual Actions in Response to Fire."

We have three presenters today. Dr. Sunil Weerakkody, the Branch Chief from Fire Protection Branch in the Office of Nuclear Reactor Regulation, and Sunil will discuss the use of this regulatory NUREG. Dr. Erasmia Lois from the Office of Research will summarize the contents of the NUREG and tell us the revisions that were made due to the public comment. And then Ray Gallucci from the Office of NRR will discuss the public comments and the staff's response to that. Sunil.

DR. WEERAKKODY: Why don't I go ahead and start what I have to say. My objective is to share with you as Jose said the role that this NUREG will play in ensuring the safety of our plants. Go to the second slide.

For the benefit of the members here, especially after hearing the number of issues you go through in one day, let me quickly go through the context of this NUREG. In the fire protection regulations, we have labeled the typical use called III.G.2. It's pretty much when we say an area is a III.G.2 area, we refer to an area where redundant safety equipment or cables are located.

In maintaining fire safety, the regulation has provided three provisions for III.G.2 areas. You are required to have a three hour fire barrier or a one hour barrier with detection and suppression or an 24 foot separation with detection and suppression. There is no provision for III.G.2 areas for operator manual actions.

When this issue came to life that some licensing are used unapproved manual actions, there were a number of deliberations with the Office of General Counsel, CRGR, the Commission and as Dr. Apostolakis summarized here, you know, the industry said to us if based on the staff position the implementation could result in the Agency receiving about 1,000 exemption requests. At that point, we went to the Commission and said let's amend the rule and the provision to enable the user of operator manual actions given that the licensees had detection and suppression and needs criteria which we typically call as feasibility and reliability criteria.

The Commission received the proposed rule. They approved the proposed rule with a 5-0 vote and basically those in the staff, we do and at the time when they issued the SRM, they did agree with the staff on the detection and suppression and also specifically mentioned in the SRM some of the controversial issues, things like time margin and agree that the time margin should be addressed. And this is the time as Dr. Apostolakis said, we were due to do a NUREG.

The rule when it was proposed, we got a lot of public comments. Other industry stakeholders said if the rule stays as is, we are still going to get thousands of exemptions. Our stakeholders like the public, they basically said we are watering down fire safety. So we weren't making anybody happy. We withdrew the rule.

When we withdrew the rule, by process, we go and tell the Commission here is why we are going to withdraw the rule. It's not meeting the intended purpose. The Commission endorsed again with the 5-0 vote that the rule should be withdrawn, but more importantly, in the SRM, they basically said we need to deal up some guidance to deal with the 1,000 exemptions that we would get and that meant an extension to SRP-951. That's the standard review plan for the fire protection. If you go to that, there is a post reference coming from there to the reg. guide to this NUREG.

So the place of this NUREG, the reason we want this NUREG, is if we then receive the 1,000 exemptions we want the staff here in the NRR to perform consistent reviews. That is the intent and that is the only intent. But we recognize that a structure or streamline, the knowledge, was out there in fragmented fashion. So we like this NUREG.

As I said, the intended role of this draft NUREG is if a licensee chooses to rely on an OMA as opposed to the passive features required by the regulation and seeks NRR approval of the exemptions from the rule or an amendment for the post-79s for the license, the NRR staff will use this NUREG to enter consistent reviews of those requests, i.e., the NUREG is an extension to our SRP. Let's go to the next slide.

Before you hear from Erasmia and Ray which will be a number of details that some of it would be tough to understand, I want to put forth the context of the public comment. When we sought comments on the NUREG, we were asking comments on the content of the

NUREG, not the regulatory context of the NUREG. Nevertheless we got a large number of comments on the regulatory context of the NUREG. In our way -- we had addressed those ways not one but a couple of times with CRGR, with the Commission and the Commission endorsed our positions with 5-0 vote each and every time. However, just so we put all the information in front you, the memo from our Director captured all comments whether they were pertaining to the NUREG or they were pertaining to the regulatory context.

Finally and last, we are here, NRR is here, to seek your support, your endorsement, to this NUREG in a final form because we truly believe that this NUREG together with all the other elements out there is going to make a real difference to the safety of our operating plants which may be operating for 40, 50 or 60 more years. The reason I emphasize that point is we have some plants out there who want to rely on OMAs or operator manual actions as opposed to the engineered factor features and this Agency is dead against that. So for some plants where they have a few operator manual actions, they would work. But if you have 100 operator manual actions and you don't know whether they are feasible or reliable, the pressure is on and we want to get to that end. Thank you very much.

DR. APOSTOLAKIS: Now you mentioned the three requirements that are in III.G.2. Three hour barrier, one hour barrier with detection and suppression capability and 20 foot separation again with detection and suppression. The licensees can use the operator manual actions in lieu of any one of these? In other words, in the absence of the three hour barrier somewhere, they can say we were doing something else plus we rely on manual action.

MR. WEERAKKODY: Yes.

DR. APOSTOLAKIS: Any of the three?

MR. WEERAKKODY: Any of the three, that's correct.

DR. APOSTOLAKIS: Because my impression was that it was primarily in the second one, one hour fire barrier, but it's --

MR. WEERAKKODY: It could be just another option. The other things we're emphasizing is if you are replacing your passive feature which is in III.G.2 you need staff to even approve it and we are telling when you send that in, I'm telling my staff, here are the elements that the amendment or the exemption should address. So, for example, if a plant area doesn't have detection and suppression, then in addition to meeting the criteria that are listed here, they still can ask for approval but we would look for some additional information to justify why it is still good even without --

DR. APOSTOLAKIS: Now, the other impression I have is that you don't -- I mean, you don't intend to approve manual actions alone. I mean, they have to be accompanied by something else, too, like detection and suppression capability or something else. Can someone come in there and say, look, "We don't have a one-hour fire barrier, we don't have detection and suppression, but boy, we have trained our people and they can do this in 30 seconds". Is that something that you would look into or is it dead on arrival?

MR. WEERAKKODY: It's not dead on arrival. What we would look for is, if you don't have detection and suppression, we would look for a higher level of safety in terms of you mentioned we have crane operators. We would look for the combustible loadings. We would look for, you know, what are the emission frequencies, the other features they have before we -- it's not dead on arrival.

DR. APOSTOLAKIS: Can you look at ignition frequencies in a Appendix R?

MR. WEERAKKODY: Qualitatively, you could.

DR. APOSTOLAKIS: Qualitative, that's an interesting idea. The qualitative frequency is what, yellow per year?

MR. WEERAKKODY: If you look at before PRA, how we approved some of these exemptions, okay, we would -- you know, really we would be looking at the singular elements but the decisions were made in a qualitative manner. Like a licensee would say, "I have no combustibles in this area", or they might say, "I have only one cabinet and some features," and say, "it's 50 feet away from the two trains", that type now.

But now, there is the PRA, obviously, it's most likely going to be into the PRA area here. If you have PRA.

DR. APOSTOLAKIS: You said frequency, you made a mistake.

DR. MAYNARD: What is the situation right now because most of these exemptions are not going to be because people want to remove something they have, it's because they can't meet one of these requirements and they haven't met it for some time? So without issuance of this, we're in the situation right now, so what is the current situation of plants that aren't in compliance with these three?

MR. WEERAKKODY: There's 42 plants who have -- who are addressing this issue through the 805 transition using five PRAs.

DR. APOSTOLAKIS: I'm sorry, say that again, 40?

MR. WEERAKKODY: There are 42 reactor units who are addressing all of operator manual actions, everything out there, the barrier issues through the risk informed process, 42, 805.

DR. APOSTOLAKIS: 805?

MR. WEERAKKODY: Yes. Out of the remaining 62 plants, this is the non-805, there's a number of plants who don't have -- now, I don't have the exact numbers, who don't have that many operating manual actions and they're okay. You know, if you go to the later vintage boiling water reactor where the -- you know, even the old vintage boilers where you have a lot of space and they can easily do this, but then there's a set of plans, you know --

DR. APOSTOLAKIS: How many are out there? I mean, what are we talking?

MR. WEERAKKODY: I don't want to give you numbers that I can't defend, but there's a number of plants and, you know --

DR. APOSTOLAKIS: But it's a small number? Is it half or is it -- I mean, you don't have to be specific. I mean, is it a big deal for the industry or is it a few licensees that worry about this?

MR. WEERAKKODY: Okay, this is personal speculation but I'll answer your question.

DR. APOSTOLAKIS: All right.

MR. WEERAKKODY: When I, based on my personal experience and what I have observed, all the PWRs which are compacted design don't have a lot of separation and if they are using a number of operator manual actions, then right now, you asked for right now the situation, the Commission said they have three years to fix the problem which ends in March 2009.

I have gotten so far as opposed to the 1,000 at this point, like two exemptions in house. We have -- like there was one case where you know, I vaguely recall, there was a 3(D)(2) area that was a top of a roof, okay. So we look at what can happen and we approve that. So the thing is though, not every 3(D)(2) area is the top of a roof, okay.

DR. MAYNARD: Well, I'm trying to understand for those who are like using the PRA and some other -- is everybody -- no matter how they're showing compliance right now or how they're doing it, is everybody going to have to come back in with exemptions then?

MR. WEERAKKODY: Some will have to come in with exemptions, yes. It's a choice of the licensee.

DR. APOSTOLAKIS: Not under NFPP 805.

MR. WEERAKKODY: Not under 805. Under 805 they send out this one big submittal.

DR. APOSTOLAKIS: Yeah, it's very difficult.

MR. WEERAKKODY: The other plants, we expect some plants to see some situations. Let's say, you know, Plant X has only three operator manual actions and they want to address that and they might send, you know, single exemptions or three and ask us the --

DR. MAYNARD: And just one last question. You said that the Commission gave the industry three years to fix it. What form did that come out in?

MR. WEERAKKODY: It came out in a Federal Register notice. When we -- when the Commission approved the finding that we draw the rule, in that FRN, they told plants that they are required to put comp actions right away and then fix the problem by March 2009. If you want me to provide you that FRN.

DR. MAYNARD: No, thank you.

DR. APOSTOLAKIS: So shall we go on? Erasmia?

MS. LOIS: Sure. So, I would like to note here that the NUREG 1852 has been developed with strong collaboration, actually, it's a project of both offices, Research and NRR. NRR has been given all of the qualitative criteria, the determination criteria, research with the development of the build base analysis and I would like to note that Sandia National Laboratories has also supported this activity.

What I will try to do very quickly is summarize the content of the NUREG and then actually Dr. Gallucci will address the public comments and also note how changes were made. And again, we would like to have the ACRS endorsement to publish the NUREG.

In terms of background, Dr. Busalike (phonetic) discovered it. It did start as a Reg Guide drafted guide 1136 and after the Commission approved the withdrawal of the rule, we recognized that we need the technical basis that was developed for the draft reg guide to support the staff reviews of exemption requests. And therefore, the NUREG was developed to retain the technical work and support the NRC staff reviews.

It has been referenced in the Regulatory

Guide 1.189 and the ACRS has been briefed frequently on this topic. What are the objectives of the NUREG is to provide the technical basis and deterministic guidance for justifying manual actions that manual actions about feasible and reliable and to be used as a reference guide. In terms of scope, it addresses feasibility and reliability criteria but it does not address control room evacuation type actions and also this -- the third bullet here does not establish defense-in-depth criteria. We note that during the public comment it was pointed out that as you substituted the Appendix R criteria with this NUREG, and it does not.

In terms of status, we are briefing the ACRS today and we are planning to submit to the NUREG's publication in September of '07. So what is the approach? The approach is to develop deterministic criteria on the basis of, and I'm noting here all four different bullets. First of all, we build on the inspection guidance and insights and experience that were developed through the inspections that have been done through the years on manual actions. So that was a primary resource for developing the criteria.

Also, a big aspect is the input from human factors guidance and the related documents and I'm referencing here some. The review and insights and experience that we have developed from reviewing PRAs, the IPEEE reports, the NUREG-6850 for quantification, fire quantification study and also the HRA development activities and applications.

And the final note here is that in many respects the NUREG criteria were implicitly used by the NRC staff and inspectors and therefore, it is not a new position, a staff position that has been noted sometimes in the comments. The last comment here is that we are working with EPRI to develop a risk-informed approach for those plants that are going to use an NFPA 805 and this work is started this month.

I think the committee's interest today is more on what are the comments and how the NUREG was revised, so I don't plan to go into any kind of depth in citing what are the criteria, what is the content of the NUREG but I do note that it contains both feasibility and reliability criteria and first, it has two divisions, the criteria documented and the technical basis for those criterias is also recommended and then we provide guidance for the implementation. And the guidance, actually -- the content is actually the same with Reg Guide 1136 and where the differences are in the Reg Guide we had recommended a factor of two to be used as a time margin, kind of a universal factor and that was -- has been changed because we recognize that there are many different ways that you can demonstrate that you have extra time for example, or you may come in with a conservative analysis, et cetera. However, demonstrating that extra time needs is needed to be available to cover the variability and uncertainty of the fire conditions and the manual actions that are going to be taking place is still emphasized in the report.

And the other change is that licensees can justify their approach for addressing the availability and the uncertainties. They don't have to use a specific time margin factor. These changes were done as a result of public comments and also Commission recommendation in the SRM Of January '05.

What are the criteria? I mentioned here, time is -- so in order to implement a human action, you have to come to estimate time for -- needed to implement the action and it has -- the time estimations have to address both feasibility and reliability and when you do time estimation with respect to the feasibility, you have to take into account all of the unrelated uncertainties with those uncertainties that are foreseeable for example, the type of the fire, it's slow, fast, et cetera with the possibility that you may have to take a human action in a toxic environment, the indications, et cetera.

So when you estimate the time for the feasibility you have to address availability and uncertainties that are, epistemic type of uncertainties when, however for the availability, you have to take into consideration the unknown, the fact that you may not have your best crew. Your crew may be doing something else and they have to -- and therefore, it may take a little bit more time to prepare for doing the action, et cetera. The environmental factors, if you would like to have human actions, you would like to make sure that the environment under which the human action is going to be performed has to be according to the guidance we have for human actions, the lighting, the toxic environment, humidity, et cetera has to be addressed. The functionality and accessibility of the equipment has to be insured. The available indications must be available so that for both the diagnostic the need to make -- to diagnose the need for the action and also communicate with appropriate staff and also to respond back to the staff.

Communications, another issue, I don't think I really have to go down this unless there are specific questions from the committee but these are the criteria.

DR. APOSTOLAKIS: Well, one thing that strikes me when I see all this is that we are asking the reviewer, and of course the licensee who is preparing the request, to make an awful lot of judgments regarding all these factors which are, of course, legitimate factors. And at the same time, we have in another context, developed ATHEANA which, in fact, does a very good job identifying scenarios and deviations from the expected scenario and so on. It's really very surprising that this kind of guidance here does not take advantage of work that the agency has done in a different context and doesn't even say that, you know, you may want to use event trees to identify the various possibilities, the various contexts that ATHEANA has defined. And I'm wondering why that is.

I mean, it would be -- why this context which is real life regulation rely on judgments of people but when we do a PRA, we develop all sorts of tools to help people structure their judgments and make a better job, do a better job, and also we make the life of the reviewer much easier when the reviewer has in front of him or her trees with an identification of the various conditions. So I'm wondering why that is.

MS. LOIS: I'll try to answer and then probably Ray and Sunil may have a better answer for you. ATHEANA starts with a PRA and yes, identifies context but identifies context but identifies context with respect to specific scenario and the specific human action that has to be performed for addressing that specific scenario. Here this is a deterministic evaluation and it's been structured so that all -- it would have to address all human actions that may be implemented. So it's not an NFPA 805 kind of analysis where you go into the specific area, "This is my scenario, this is my area and therefore, what is the context under this scenario?" So that's going to be done by this collaborative effort for 805.

However, and this is what I tried to say before, all of the insights to the ATHEANA development and the reviews of IEEEs and the expertise that has helped us out and you're familiar with expertise, Sandia, et cetera, we believe that we have brought in those aspects when we built the availability concept and the time margin and the feasibility and also in the criteria here about demonstrations and how licensees can -- what are the criteria for demonstrating the feasibility and availability of the action. So it is a deterministic approach that has been building tremendously on the risk-informed approach but it's the deterministic approach.

DR. APOSTOLAKIS: I think what you're saying is that that the application is different and that's true. In the intended use of ATHEANA, you would have a PRA, so you will have your sequences and so on and you look at human actions. But the concept, though, still applies, because you can say, "I have a fire in this location". Essentially, you're asking is what can happen next. What are the events that would follow that fire and where so the operator manual actions come into the picture to save the day? And it seems to me that this kind of analysis would be helped a lot by having those diagrams, you know, some sort of event tree.

Another thing is that if we say that some regulation is not risk-informed, that does not mean that we are excluding automatically all the methods that have been developed under the PRA factor. And event tree is just a systematic way of structuring sequences, scenarios. And it seems to me it can equally well be applied to a deterministic analysis ad in a probabilistic analysis because now you are asking both -- as I said earlier, both the analyst and the reviewer to make a lot of judgments regarding -- and these may be dependent, too, and I'm sure that it's mentioned someplace that, you know, if you have this communication, we can go this way and so on, but I think it would have been helpful to borrow -- to have borrowed from those things. Sunil, you have something to say.

MR. WEERAKKODY: No, I agree with pretty much everything you said, Dr. Apostolakis. What I wanted to say was, you know, just the use of the word ignition frequency got me into a lot of trouble right there, okay?

DR. APOSTOLAKIS: If you think that's a lot of trouble, Sunil --

DR. MAYNARD: You haven't seen anything.

MR. WEERAKKODY: And here's the vision the Agency has in terms of curing fire protection. We envision that there will be a set of 805 plants and then there will be a set of plants who would maintain their deterministic basis. And this document is for those people who want to maintain deterministic. So unless -- even though technically, I agree with everything you say, unless you have the capability to basically say everybody should adopt 805, which Dr. Gallucci likes to do but we can't do it, we have to have that deterministic part available. And that's why -- but I would say, Dr. Apostokalis, that one of the key things you said in terms of modeling, I wasn't closely molding the development of each guidance but if you put the factors you consider in developing an HRA, and you look at these factors, I think you're going to find a lot of correlation and consistency.

One final thing, with respect to the judgment, I remember after the last meeting that in the trade press there was a lot of concern as to the judgment, the need for judgment on clarity. I again, agree there's going to be a lot of judgments. That's what happens when you try to replace a passive feature with the operator manual actions. So in my view, there are going to be cases where it's all very clear that an operator manual action is safe or safe enough. That's fine. Then there are going to be a number of cases where we could show that it's not acceptable and then there's going to be some middle degree but I can't see -- I mean, we have tried very hard to make it as easy as possible but there's still going to be some judgment. I agree, again, I have --

DR. APOSTOLAKIS: Again, it seems to me that implicit in your answer is that if we are in Appendix R space or deterministic space, then we don't even look at the methods PRA that's developed and I think that's not the way to look at it. I mean, you're not going to do a probabilistic analysis but to structure the scenarios using some event trees is not being risk-informed. It's just making your life easier. So that is my main point.

DR. MAYNARD: I think that that's a tool that should be available but not required for this situation. I really would rather see simple as opposed to more complex -- I believe that this NUREG and the criteria set out, I think, overall was very good. I think these are the things that need to be considered. My concern is in the level of detail that it's going to take to justify a lot of these things. And I appreciate your comments about some are going to be obvious and some are going not be obvious. And my concern is that if, even for the obvious ones, if we go to requiring far too much, we're going to get bogged down not only with the licensee but also the regulator on trying to process these things. And the NUREG has a lot of detail on some things that I'm not sure how they'd be addressed anyway.

I mean, you talk about having to take team dynamics into account and a number of things like that that, you know, depending on who is reviewing it and what guidance is out there, you know, I can see getting bogged down in a lot of things, where I would like to have some assurance that this is going to be kept to a reasonable of effort for the given situation that's having to be reviewed there.

DR. APOSTOLAKIS: But my point, Otto, is that by using those diagrams, you do make it simple.

DR. MAYNARD: But I don't think you should be required to do that for --

DR. APOSTOLAKIS: But it's not even mentioned, they are not even mentioned that these may be tools that will help you structure all these judgments.

DR. MAYNARD: I wouldn't mind if there are tools that are available. I just --

DR. APOSTOLAKIS: There should be.

DR. MAYNARD: -- not requiring them for everything. It is a way to approach it and deal with it because some of these things are going to be fairly simple. Some of these things you should go through the check list and say, yeah, yeah, yeah, yeah, and "Yes, we can easily do it. We've got five hours to do it. We can do it in 30 seconds, no big deal". But others are going to be far mor complicated and you may need some of those tools to demonstrate it.

DR. APOSTOLAKIS: Yeah, but it's not that you always have to do this. I mean, screening and looking at the cases, it's obvious what you should do. It's part of the game. I mean, there's no question about it. Okay, you have one more slide?

MS. LOIS: Yes, in terms of comments, I guess there were --

DR. APOSTOLAKIS: Is Ray going to cover this?

MS. LOIS: Yes, Ray will cover that and what I would like to note is that we haven't done substantial changes in the NUREG. We've done some clarification changes to clarify things and also with regard to technical comments that came in, we've change the content as well.

DR. APOSTOLAKIS: Well, I have a few comments on the report itself, the NUREG itself and I guess this is the time to ask them.

MS. LOIS: I probably --

DR. APOSTOLAKIS: Not on the comments, on the report itself.

MS. LOIS: Sure.

DR. APOSTOLAKIS: There's something I don't understand on page 17. Well, you don't have to go there. "Operator manual actions can be used to satisfy paragraph III.G.1 requirements since these areas do not contain redundant safety shutdown plans". What do you mean by that?

MR. WEERAKKODY: There are -- let me take an actual situation. Let's say you have a plant which has a high pressure injection Train A and a high pressure injection Train B. Okay, they're in two separate crews. However, you postulate a fire where you may have to take an action to trip one of the pumps. Okay, so in other words, you have done your separation. You meet the regulation but you still need to do some operator action, maybe walk into some cabinet and then take an action and in terms of making sure that that action can be done, you could use this as a guidance but the bigger question is operator manual actions, they're not allowing II.G.2 but they are allowing II.G.1 and III.G.3 like control room, okay. So did I answer your question, kind of?

DR. APOSTOLAKIS: Kind of, yeah. But that's not a very important question. I have a couple of other questions that I think are a little more substantive. So we talked about the scenario and all that. Now, when it comes to judgments, there is a very detailed evaluation in the appendices especially and basically the examples point to the factor of two as an appropriate or sufficient margin. Although the Commission don't specify and you don't. We just say this is what came out of this.

What's troublesome about this is that we all know that these judgments are biased, not because people are bad people. Most likely it seems to me when a licensee does this, they will rely a lot on their operators. And by the very nature of the operators, we tend to be optimistic, again, not because they are bad people. That's how they think. "Oh, sure, I can do that", which of course in a real situation may not be so easy to do.

And there was a study sponsored by the NRC a long time ago, at Oakridge National Laboratory, that came up with a conclusion that -- I can in fact -- that study found that the median response time for inadvertent safety injection and particular human action, based on operating experience is about three times larger than the value estimated by the operators. So the operators under-estimated by three times again because of this intrinsic bias that things will be okay. Then we have the study that the staff did on estimating the frequency of pipe failures when we were looking at the risk informing 5046. And they, in fact, "corrected" in quotation marks, the expert judgments and that was part of their final proposed curves. They corrected them for biases. And yet, here, we just go with those judgments and then we say, you know, roughly a factor of two will be satisfactory because in the exercises that the staff did which involved PRA analysts, that's what they found. So again, this is a problem with judgments and especially in this case. I mean, the other case we're talking about, there was specific actions in specific scenarios, under specific conditions.

Now, we are talking about, you know, having a whole list of bullets that they have to take into account and pass judgment. And that worries me, that, you know, they may think they are conservative, when, in fact, they may not be. And I wonder how we can handle that. I mean, and the other thing, of course is, which is related also to my comment about event trees, as an agency, it seems to me it would be nice to have consistent approaches to various problems when they involved the same underlying issues. So we can't use event trees here and then not here because this is deterministic. We cannot correct expert judgments here because it just so happened that a statistician was part of the team and he was sensitive to it and not do it here, when, in fact, what we're talking about here is the real regulatory activity of the agencies, not just a study. I mean, this is what people will do.

So this inconsistency bothers me a little bit. It bothers me a lot, not a little bit.

MR. WEERAKKODY: What I'm going to address, Dr. Apostokalis, is your question about -- and you were mentioning this and in fact said, "Can you give some assurance". If you look at your comments in the following context, you would understand where the staff is on this. We had operator manual actions 20 years ago or 15 years ago, you know, some plants in III.G.1, III.G.3.

We didn't have a NUREG. Inspectors used their judgment to make sure that the licensees complied with the rule. The rule simply said you should be able to, I can't remember the exact words, shut down the plant and reach your or stand by your shutdown, whatever the tech spec said. That's what we operated on. And there is always going to inconsistency at the inspector level.

The next level comes in when we went to

the proposed rule. Both the Agency and the stakeholders got sensitive to this issue more and more and then we created the list that in my view, this is again a personal option. That should have been sufficient for inspectors. Okay.

But then again, we get hit with more guidance. So now we write a book and there are still going to be judgments within the book and if I write another book, there's going to be more guidance.

And here's how this would play out in the regulatory exemption space. First off, if you have a licensee who has a large number of factions because you have compact spaces, lack of separation. What the Agency and regions, they don't go the exemption rule. They just fix the plant with the barriers where they should be and forget it. Don't come to us for exemptions because if they come for any exemptions for that kind of scenarios, that judgment is going to play a significant role and depending on the staff, I mean we try very hard to be consistent, but let's say three years down the line, okay, I can't give any assurance. I don't know if I'll be in a different job. The staff may be doing different jobs. This book would be there. There will be judgment.

But if you look at whether it relates to the PRA experience or deterministic space, the judgment is there. You cannot get away with it. However, there are clear cases where a -- test III manual actions, no combustibles, have plenty of time. So you don't run into these margin issues and the staff doesn't ask a lot of questions. The staff has the latitude to use their brains and ask the questions to get reasonable assurance. There will be judgment there. There are no assurances. The staff experience level will prompt them to ask the right question. If the margin is too low, it is like containment pressure. If you say you have to meet 48 and you come in 47.9, there are going to be a lot of questions. If you come in at 20, less questions. The same thing applies here. I don't --

DR. APOSTOLAKIS: Sunil, you are making the case that this necessarily will involve judgment.

MR. WEERAKKODY: Yes.

DR. APOSTOLAKIS: This is not contested. It's true. What is contested is that precisely because there are a lot of judgments, we have developed tools to try to structure those judgments and reduce the biases and these tools are not used to the extent they should be used, in my view anyway, in this report. That's really the issue.

MR. WEERAKKODY: Okay. That's --

DR. APOSTOLAKIS: But maybe we can go on with Ray's presentation.

MR. WEERAKKODY: No, I agree with that.

DR. APOSTOLAKIS: Because we have to finish -- I understand NEI would like to address us.

CHAIRMAN SHACK: Just to be fair, George, if you look at page B-8, they do in fact discuss your factor of three in that Oak Ridge report and one of their arguments here is that they are doing this demonstration which gives them a little bit more and they're still adding the factor of two on that because they feel that there's an optimism there.

DR. APOSTOLAKIS: Where is that discussion?

CHAIRMAN SHACK: At the bottom of page B-8, section B.2.2.4.

MS. LOIS: So all of these actions have to be demonstrated --

CHAIRMAN SHACK: Right.

MS. LOIS: -- for their reliability and you add time to that.

CHAIRMAN SHACK: And we haven't gotten away from the judgments, but at least these people have considered this problem and that's their judgment that the two was still sort of right.

DR. APOSTOLAKIS: I just don't see that factor of three anywhere.

CHAIRMAN SHACK: Go down to the last paragraph on B-8.

DR. APOSTOLAKIS: On B-8.

CHAIRMAN SHACK: They said it took 30 minutes and it took almost 90. That's a factor of three, although they don't say a factor of three.

DR. APOSTOLAKIS: The last paragraph says, "For the same reasons as cited above..."

CHAIRMAN SHACK: No. "However, in extreme cases as a high as a threefold increase has been observed."

DR. APOSTOLAKIS: On B-8?

CHAIRMAN SHACK: Page B-8, bottom line at least on mine.

DR. APOSTOLAKIS: Not on mine.

CHAIRMAN SHACK: Okay. Well --

DR. GALLUCCI: It's the third paragraph in section B.2.2.4.

CHAIRMAN SHACK: Right. Whatever page number that's on.

DR. GALLUCCI: In mine, it's the middle of B-8.

DR. APOSTOLAKIS: The second paragraph of B-2.2.4.

DR. GALLUCCI: Third paragraph. "However, in extreme cases..." B-2.2.4.

DR. APOSTOLAKIS: Yeah, okay. And that doesn't surprise me because of the people who participated.

CHAIRMAN SHACK: Right.

DR. APOSTOLAKIS: But just saying that, yeah, it has been observed, what does that do? How does that help me?

CHAIRMAN SHACK: Well, then they go onto argue what's different about their case and again you can accept or not accept that. But they present at least a discussion of the issue is all I'm saying.

DR. APOSTOLAKIS: I think there is overkill here, but I'm pretty sure as Erasmia mentioned knew about it at least. The question is not it's determined by and the fundamental problem that I have is this utilization, this inconsistency between this approach and what we're doing now. That's really -- Ray, why don't you go ahead?

DR. GALLUCCI: Okay. My part -- Ray Gallucci from Office of Nuclear Reactor Regulation. I'm going to go over the highlights of the public comments and the responses to these public comments. I'm not going to go into all of them obviously for time purposes. Next slide please.

There were 110 total comments. The breakdown is shown there. The one shown in red are the ones that I'm going to discuss today as in our opinion these were the key comments, but obviously we received comments on all these different areas. Go ahead to the next slide.

The first comment, "Area was operator manual actions versus the passive features for fire protection." The theme of the comments, "By allowing industry a compliance strategy through submission of a massive number of exemptions or a complicated array of dubious operator manual actions in lieu of qualified passive fire protection features as intended by law, NUREG-1852 diminishes the defense-in-depth for fire protection of safe shutdown systems and increases the risk to the public's health, safety and security."

The NRC response, "NRC has granted plant-specific operator manual action exemptions in the past where criteria such as those in NUREG-1852 were met. Plant-specific exemptions cannot be applied universally. The appropriate regulatory vehicle remains the issuance of an exemption under 10 CFR Part

50.12." Next slide.

Comments related to regulatory footprint and this again ties -- Some of these were already covered by Sunil.

DR. BANERJEE: Excuse me. In the previous slide.

DR. GALLUCCI: Go back one.

DR. BANERJEE: Do you actually substantively address the issue there or are you just skating around it? I mean, the issue is that there are and many chemical plants and all one uses passive fire protection systems.

DR. GALLUCCI: And it's the same type for plants. The preference is to use passive protection features. However, there are situations where you can see where if you have a lot of time and a very simple manual action where all would have to do is step outside the control room, press a button and step back in. The fire is far away, somewhere else in the plant. It's conceivable that the manual action could provide just as much safety as the passive feature. There are situations -- And those are the ones for which exemptions would be granted.

DR. BANERJEE: So is it not -- Maybe that's what you responded, but the responses that you are having qualified passive fire protection features required in plants where a fast response is required.

DR. GALLUCCI: That would be applied. A manual action, if --

DR. BANERJEE: But isn't that something that --

DR. GALLUCCI: If you have a limited time frame to do this, these manual actions are unlikely to be feasible, let alone reliable, and an exemption would not be granted and our understanding is that licensees are not even attempting to do operator manual actions in those situations. If they are, they're going to have to go back and replace them with passive fire protection features if they aren't already doing so.

DR. BANERJEE: Okay. So it's sort of included in the statement that --

DR. GALLUCCI: This is a summary. The statement is longer. This is a summary.

DR. BANERJEE: And you go through all this stuff in some detail.

DR. GALLUCCI: Yeah. I mean if you --

DR. BANERJEE: Fine. I think that's fine.

DR. GALLUCCI: Okay.

DR. BANERJEE: Carry on.

DR. GALLUCCI: Next one, regulatory footprint and as I was saying, Sunil covered some of this because a lot of these related more towards what went on with the rulemaking and how the NUREG will be used in regulatory space. But we address these anyway. "Theme of comments. Will suppression and detection be required when applying for an exemption? Also the NUREG should reflect that NRC exemptions of certain types of operator manual actions."

The NRC response. "RIS 2006-10 regulatory expectations with Appendix R, III.G.2 operator manual actions describes the corrective actions for failures to have a required fire barrier and use of operator manual actions as an interim compensatory measure." That really is the regulatory footprint as coming from the RIS and not from the NUREG. "RIS 2006-10 not NUREG-1852 addresses regulatory requirements including the need for fire detection and automatic suppression." So we didn't really get into re-explaining this issue in our comment response. We refer to the RIS. Next slide please.

Demonstration and time margin. These are the two key criteria for feasibility and reliability, demonstration mainly for feasibility, time margin for reliability and this had the majority of comments, a mixed bag between technical comments and regulatory related comments and the theme, "The NRC has previously accepted use of nominal values and best estimate codes for plant response to fire events. Sufficient margin exists in these analyses which assume that all fire damage occurs and consequently evaluate all manual actions in the timing."

Staff response. "The NUREG guidance is flexible on treating uncertainties. However, remember that a tradeoff exists between the realism of the demonstration and the uncertainties to address in the time margin and these two criteria are inherently interrelated. Shown in red, red indicates that there was a change to the NUREG as a result of the comment and the NUREG has been enhanced to address consideration of uncertainties in the demonstration to justify adequate operator manual action time."

DR. BANERJEE: How many of these comments came from the public at large and how much from industry?

DR. GALLUCCI: Five came from the -- Five came specifically from NIRS. No other came from the public. The other 105 came from industry.

DR. APOSTOLAKIS: What did you say again?

DR. GALLUCCI: Five came NIRS, Nuclear

Information and Resource Service, Paul Gunther's organization.

DR. APOSTOLAKIS: They were supposed to be --

DR. GALLUCCI: Yes and 105 came from various industry sources.

DR. APOSTOLAKIS: But there were some comments that what they're doing were use of safety.

DR. GALLUCCI: That was from the public. That was from Paul Gunther and these are comments -- His comments, all except one of his comments, were comments that had come in before with regard to the rulemaking.

DR. BANERJEE: And were the industrial comments mainly that you are putting too stringent regulation or what was it?

DR. GALLUCCI: It was a mixed bag of some things were too stringent. Others that this is not appropriate for the regulatory process. So you're probably not surprised. The public thinks operator manual action shouldn't be allowed at all. Industry thinks they should be allowed and we're right in the middle of trying to strike a balance.

DR. BANERJEE: So those previous comments, which were sort of saying that should have more automatic actions, detection, suppression, stuff like that, that came from the public?

DR. GALLUCCI: Yes. Regarding your comment on passive features came from the public.

DR. BANERJEE: Interesting.

DR. GALLUCCI: They would be prefer to see passive features and no --

DR. BANERJEE: And industry wants us to have more operator manual.

DR. GALLUCCI: Industry would like to be able to use operator manual.

DR. BANERJEE: Thank you.

DR. MAYNARD: I'd like to address that issue just a little bit. Well, if there was going to be used by industry to go and rip out all their fire protection and replace it with operator manual actions, then I would be very concerned with that. This is not going out and ripping out everything and reducing the level of safety. It's dealing with the constraints that people have to deal with right now based on designs, old designs, and stuff and they've been relying on operator actions and various aspects for some time. This isn't going to reduce the level of current safety that's out there right now. It's not taking something that's in place and reducing it.

It's taking a better approach at dealing with issues to where the design can't support what the current requirements and stuff are.

DR. BANERJEE: But about new designs then? Is it going to -- Are you going to urge them to move away from these OMAs?

DR. GALLUCCI: For new reactors, the preference is for passive features and the new reactors are being designed to be pretty much redundant trains or three hour barriers completely separated. This will have the advantage of designing the new plant, not going back to plants that were existed. Browns Ferry happened after most of the plants had been built.

DR. MAYNARD: And recognize that the regulator has control of this because this is an exemption to the regulations. This isn't an automatic right that the licensee has to take advantage of.

DR. BANERJEE: The only reason I bring this up is we are going to face Browns Ferry, right, and there are some issues as to the separation of trains and things. Can you address that?

MR. WEERAKKODY: Yes, I can address that. Browns Ferry is operating now. They had a number of questions with respect to their fire protection program. What they did was we raised the issue to them before the restart. They identified all their critical operator manual actions. They put all them in the corrective action program. I'm not saying they have fixed them, but they have done and they are working to fix them by March 2009. In the meantime, they have -- measures.

DR. ARMIJO: Could you provide kind of a number of how many operator manual actions are included for, let's say, Browns Ferry. Because my concern is if there were few difficult areas that you couldn't have passive systems and you had a few exemptions for manual actions in those cases, that should be no problem. But if somebody has hundreds in a plant, there is something wrong.

MR. WEERAKKODY: Yes, there is something wrong.

DR. ARMIJO: And so the question is a real case, Browns Ferry, where do they sit?

MR. WEERAKKODY: I don't know the number. Phil, can you give some specifics on how many? Phil Qualls reviewed the fire protection program at Browns Ferry.

MR. QUALLS: Hi, this is Phil Qualls. I can't give you the exact number. It's, let's say, numerous, probably on the order of 100 or more for Browns Ferry Unit 1. However, because of the issue of feasibility and reliability, these were closely inspected, random sampling, I suspect, but closely inspected by the region prior to start up of Unit 1.

MR. WEERAKKODY: Exactly. We put a lot of effort on Browns Ferry before the restart, a number of inspections.

DR. MAYNARD: Are these necessarily 100 different operator actions or -- My gut tells me that there's probably fewer actual operator actions, but it is dealing with maybe two or three. The same action may take care of three or four different items in an area.

MR. WEERAKKODY: Phil, can you give some context based on the issue at Browns Ferry?

MR. QUALLS: Well, I hate to just address Browns Ferry because in some cases it will be the action will be very similar, rearranging power supplies and such. But it's fire area dependent. In many cases, there will be different areas, different actions, depending on what may be affected in that fire area.

And one of the reasons that we had some of these issues is there were numerous manual actions coming up in the early 2000s that were just clearly not possible and there was no guidance and no standard for people to review with. You know, if I made the judgment that someone could not do a local manual start of a diesel generator with no control power, something, they had no procedure and no -- that was an actual finding. What's our basis for saying they can't do it? They've never practiced it. What's our real basis for saying that that's not feasible or reliable?

DR. APOSTOLAKIS: You say they never practiced it?

MR. QUALLS: No sir. On what basis?

DR. APOSTOLAKIS: So what is my basis for saying that it's not feasible. I think you have your basis.

MR. QUALLS: You have it. I'm an inspector. What's the guidance? That's what they need. We didn't have any written guidance.

DR. APOSTOLAKIS: So you're saying with this NUREG now you will have the guidance.

MR. QUALLS: We would have some kind of standard to evaluate things by. That's why -- I've been in this since Day 1 on this issue and that's why I've contributed a lot to developing it. We needed a standard.

DR. GALLUCCI: Next slide please.

DR. APOSTOLAKIS: Can you finish in eight minutes?

DR. GALLUCCI: Yes. Continue with demonstration and time margin. The theme of the comments, "Due to a lack of clear quantitative guidance, both utility analysts and regulators will default to the factor of two inferred in Appendix B which is the summary of the expert solicitation to determine time margins that was conducted during the rulemaking. The panel consisted entirely of NRC and their contractor staff, mostly PRA practitioners, thereby not providing the necessary diversity for practical assessment and implementation of nuclear plant operator manual actions."

The response. "NUREG Appendix B provides an example of how (1) expert panel developed a time margin. It's an example. A six person panel consisted of a former senior reactor operator, two NRC regional fire inspectors, one human factor specialist and two PRA practitioners with sufficient expertise considered to provide one reasonable method to address time margin. Only two of the six were actually PRA practitioners. NRC reviewers will not default to the factor of two time margin. The appendix is not binding. Nonetheless, the licensee still needs to consider time margin."

DR. APOSTOLAKIS: Why don't you give any guidance to the licensee as to what kind of a panel they should have to come up with these evaluations?

DR. GALLUCCI: We don't even know if a licensee would want to use a panel to do this. We happened to do this because we were trying to develop a surrogate for the reliability in an HRA, so there's nothing -- there's no specifics as to how the licensee should develop a panel. It's their choice.

DR. APOSTOLAKIS: No, there isn't, but if you tell them, there will be, that's what I was saying.

DR. GALLUCCI: We could offer suggestions but we leave it to them.

DR. APOSTOLAKIS: The reason why I'm saying this is because it's most likely that they will use their own engineers and their own operators. But if you tell them to also use maybe a PRA or an HRA expert, then maybe some of these biases will not be there. We've done that. We've done that it the past in other context. You know, they're telling us who the panelists will be, which one was that --

CHAIRMAN SHACK: 5069.

DR. APOSTOLAKIS: Yeah, 5069, so it's not unheard of to say, you know, that --

DR. GALLUCCI: We could list the functional backgrounds for the panelists. The key is if they submit a time margin that they use, they will have to tell us what their panelists were and what their capabilities were, so if they do it strictly with operators and not consider any human factors people, we would be --

DR. BANERJEE: I guess you don't want to be too inbred. Really, the concern here is that the --

DR. APOSTOLAKIS: It will be the utility personnel. I mean, they're not going to create a panel from outside but at least within the organization to make sure that there are people like HRA to have some idea of what is going on.

MS. LOIS: Here I believe that we can use the ATHEANA tools and we have developed an expert -- the code for conduct and an expert on it and some --

DR. APOSTOLAKIS: I understand.

MS. LOIS: -- a lot of that can be borrowed and integrated here.

DR. APOSTOLAKIS: Some guidance here to

alert people to the fact that there may be some biases but if you do this, maybe, you know, it will not be that bad.

MR. WEERAKKODY: I think, you said, if we could do it without overstepping, obviously, our boundary now, if I use the right words, but that's a good idea, like you said earlier, we could incorporate those as suggestions.

DR. APOSTOLAKIS: What does "could" mean, Sunil?

MR. WEERAKKODY: The reason I didn't want to say we will do it is --

DR. APOSTOLAKIS: I know that I have never heard anybody here say, "We will do something". We always think about it. But my question is, my question is, what does it mean? I mean, you're asking us to write a letter blessing this.

MR. WEERAKKODY: Oh, I see.

DR. APOSTOLAKIS: If we gave you some time to do it, would you be too unhappy?

MR. WEERAKKODY: No.

DR. APOSTOLAKIS: No, okay.

MR. WEERAKKODY: And we will -- what we will be looking for is, you know, quickly, do this quickly so we could get you something. We will do it.

DR. APOSTOLAKIS: I understand what you are looking for.

MR. WEERAKKODY: We will do it, how is that?

DR. APOSTOLAKIS: Great, great.

DR. GALLUCCI: Okay, next slide? Okay, this is a public comment. "Operator manual actions in terrorism", this comment was raised several times during the rulemaking itself. The theme, "The NUREG fails to account adequately for mitigating responses to aircraft impacts and other forms of terrorism. Broad industry non-compliance with physical fire protection does not lend public confidence to the Commission's assertions that plant operators can and will control and contain the consequences of terrorism causing significant fires.

In NUREG CR-2859, Argon experts state that the claim that these fire explosion effects do not represent a threat to nuclear power plant facilities has not been clearly demonstrated." And the response on the next slide, "A February 2002 NRC order required licensees to examine the effects from extensive losses due to fires, explosions and identify mitigated strategies using resources already existing or reliably available. NRC inspections conducted" --

DR. APOSTOLAKIS: Don't read it.

DR. GALLUCCI: Don't read it.

DR. APOSTOLAKIS: Read in the results. I mean, summarize what it says, otherwise we'll never finish it. We can read it as well as you can. Can you just tell us the essence of it? I mean, what is the essence of the --

DR. GALLUCCI: Terrorism has been considered and the probability of a fire coincident with that is considered low based on studies and the NRC continues to monitor plants for the effects of security concerns.

DR. APOSTOLAKIS: And I don't think Appendix R -- this really refers to Appendix R, doesn't it? And that was developed apparently --

MR. WEERAKKODY: This is beyond Appendix R but it was a public comment so we thought we ought to scope --

DR. APOSTOLAKIS: No, you should respond but all I'm saying you can summarize it. Okay, shall we move on?

DR. GALLUCCI: Continue. Okay, NUREG 1852 versus fire safe shutdown. Comments, "Feasibility criteria requires safe shutdown analysis when they should only support such analysis. Verifying that equipment be available requires safe shutdown analysis specifically for operator manual actions." The response, "To the extent that the safe shutdown analysis already addresses equipment needed to conduct the operator manual actions that analysis suffices, and a change to the NUREG, the NUREG now emphasizes the functionality of equipment and cables needed to implement operator manual actions".

Next slide. Comments on fire design basis, the theme. NUREG 1853 reclassifies post-fire safe shutdown as an abnormal operating occurrence, thereby imposing the radiation does requirements from 10 CFR Part 20, Section 1201. Fire with post safe shutdown and manual operation occurs at a frequency much less than one per year. Two ANSI standards classify post-fire safe shutdown as a quote 'special event'." The NRC response, "ANSI 51.1, 52.1 classifies fire as an abnormal operating occurrence within normal radiation exposure limits. And initiating event is just the single abnormal occurrence or condition that can trigger an accident scenario and exclude subsequent failures that comprise the scenario frequency".

So the claim that the initiating event is much less than one is incorrect. The scenario may be for much less than one but the initiating event is typically on the order of .1 to .21 per year per a plant. So we consider the classification correct.

Next slide. Continuing with fire design basis, "NUREG requirements exceed those for other design basis events and EOPs, Emergency Operating Procedures." The response, "Unlike the EOPs which; one, generally assume no plant damage; two, involve mostly control room actions and; three, are integral aspects of regulations and design basis analysis. Operator manual actions in III.G.2 areas constitute a deviation from regulatory requirements.

They are postulated in lieu of redundant train separation or alternative safe shutdown. Nonetheless, NUREG has been revised to recognize that specific operator manual actions may need to meet the guidance to varying degrees. That is some of the factors within the criteria may not always be relevant", and that would be based on looking at the specific manual action and its circumstances.

Next slide, please.

DR. APOSTOLAKIS: Ray, do you -- would you mind moving down to defense in depth?

DR. GALLUCCI: Skip, keep going? Okay, defense in depth. The theme of the comments, "Defense in depth considerations exceed the minimum requirements from the boundary conditions in a post-fire safe shutdown analysis. Many are theoretical in nature and very difficult to apply." The response; "RIS 2006-10 not this NUREG addresses defense in depth for post-fire response including passive fire protection through highly reliable operable fire barriers. Reliance on typically less reliable operator manual actions still requires that adequate fire safety be maintained." So defense in depth is really the subject of RIS 2006-10 and that's your fire detection, automatic suppression considerations, not the feasibility and reliability criteria.

DR. APOSTOLAKIS: What did the comment mean by "many are theoretical in nature"?

DR. GALLUCCI: I assume they were talking about the -- what -- the variability in fire, just what will be your boundary conditions during a fire, how bad will it be, where might the smoke go, et cetera. That would be what I would think.

Next slide. Continuing with defense in depth, this is the last slide, "Reference to reg guide 133, Appendix A requiring post-fire safe shutdown procedures is a new Staff Position, inconsistent with generic letter 8610, Staff Position 532. The NUREG reinterprets the administrative and detection suppression echelons of defense in depth." Our response, "The generic letter position addresses the use of procedures for areas requiring alternate shutdown capability, that's III.G.3, does not address fire brigade activities. NRC expected licensees to comply with III.G.2. The NUREG criteria are consistent with NRC guidance and requirements.

NRC still requires post-fire safe shutdown procedures. The QA program requirements of the referenced reg guide and an ANSI Standard 3.2, 1982's reiteration of the need for safe shutdown procedures gives guidance on operator manual action feasability and reliability and supportive of the statements in the NUREG." That's the highlights of the comments.

DR. APOSTOLAKIS: Thank you. Any comments or questions to the staff? Thank you very much, and now we have Mr. Marion.

MR. MARION: Good morning. My name is Alex Marion. I'm the Executive Director of Midland Engineering (phonetic) and I thank you for the opportunity to offer two comments on this issue. We have been actively engaged with the NRC staff in trying to establish a coherent consistent approach to evaluating the feasability of operator manual action since June 2002. We originally agreed upon straightforward acceptance criteria and also agreed on the appropriate regulatory vehicle to capture or document the acceptance criteria so that going forward, the NRC and the utilities had a clear understanding of what criteria had to be satisfied to demonstrate feasability of operator manual actions.

And the regulatory vehicle was rulemaking with the draft regulatory guide. And there were some discussions this morning about what happened with that rulemaking and now from our perspective, we see that draft regulatory guide which was the subject of significant critical comments from all stakeholders, has taken the form of a NUREG document and the concept of reasonable, coherent, practical acceptance criteria has evolved into an exercise that regrettably has gone beyond the original concept. It's become an academic exercise.

I always worry when I have this vision of an expert panel thinking about what a fire brigade has to do at a nuclear power plant to execute their responsibility of putting out a fire. Moreover a key aspect of this involves the regulatory process and quite frankly, it's confusing. The NRC indicates in their presentation this morning that the NUREG is an extension of the standard review plan.

And that says to me that that's guidance for NRC staff reviewers. But unfortunately, as we all know, that guidance also becomes a reference document for NRC inspectors and we talked this morning about the judgment factors that come into play on a lot of these acceptance criteria that we have before us. So I don't believe that this document will address the issue or the concern that the NRC has relative to the extent to which utilities are crediting operator manual actions in their fire protection programs.

One of the things I would like to do is we've developed a document at NEI on the regulatory process and what I would like to do if it's acceptable to the chairman, make copies of that available to you folks and I'll send it up this afternoon when I get back to the office.

DR. APOSTOLAKIS: Is this an alternative to the NUREG?

MR. MARION: No, this is a document that captures the regulatory -- that discusses the regulatory process from the legislation that established the NRC to all of the NRC guidance documents and regulations, et cetera, and it's a good tutorial on the regulatory process, at least we think it is.

We're also disappointed that some of the significant comments that had been submitted by NEI on behalf of the industry as well as other industry representatives, have not been adequately dispositioned and I understand the staff is trying to differentiate between technical comments and process comments. But unfortunately, there isn't an activity that the NRC is involved in which does not have technical aspects as well as process aspects.

So I encourage this committee to consider both elements, if you will. The issue that Sunil Weerakkody expressed about the staff concern relative to the licensee's reliance on operator manual actions as an alternative to the specific requirements in the regulations the passive fire protection features, is not going to be addressed by this particular NUREG document. The concern in our mind is a separate issue that needs to be addressed by NRC assuring compliance by individual plants to NRC regulations.

And we recognize that the fire science and technology and understanding has evolved over the years, so what may have been acceptable 15, 20 years ago, may not be acceptable today. That has to be dealt with in some mechanism other than a NUREG document.

There is a current inspection procedure that's been on the books for a couple of years that contains a practical set of acceptance criteria for demonstrating the feasibility of operator manual actions. And we have always felt that the inspection procedure is where you document the acceptance criteria. Now you have this book. And I can tell you from a utility perspective if you look at the inspection guidance to evaluate what the NRC is going to look for. Now you've got to look at this book that has additional judgment in play and it's not going to address any issues. It's not going to address this issue.

There's going to be as much confusion, I speculate and this is a personal thing, probably more confusion going forward if this NUREG document is published in its current form with its intended use. Operator manual actions are credited in a number of programs as you're all familiar with operating procedures in a nuclear power plant. Normal operating procedures, abnormal operating procedures and emergency operating procedures credit operator manual actions when the situation in the plant calls for it.

Why we're treating fire protection so

special has never been clear to the industry and I think we need to be very careful because you're setting situations where you have double standards and double expectations that may result in a condition where there may be some confusion in responding to a fire or a projected fire or a planned fire as opposed to responding to a plant condition that's happening right now. So we need to keep that in mind as we go forward.

There is a theme here that comes across that suggests that for plants that have not transitioned to 805, are going to have a different threshold of acceptability to overcome in terms of NRC acceptance going forward. But the intent appears to be driving utilities into 805. And I would like to make this very, very clear.

805 in itself is not a solution. It is not a solution to fire protection issues. All 805 does is provide a framework for licensees to apply risk-informed and performance-based approaches to deal with these issues. Dealing with the issues and finding the resolution has not been established yet in lot of cases. So let me make it clear, I'll say it once again; 805 is not the solution.

At this point, I -- what we proposed to do is once we see this next version of the NUREG document, we'll take a review of it and send a letter to the NRC on areas that we had commented on that were not specifically addressed to our satisfaction, and I don't have any specifics. I can't develop any specifics at this point because we haven't seen the next version of the document.

But fundamentally, I would like to make a request that this committee consider our comments and not endorse the publication of this NUREG at this particular time for the reasons and the points that I made in my brief comments and at this point, this completes what I have to say. I'd be more than happy to take any questions.

DR. APOSTOLAKIS: Well, I'm a little curious why you think this is, I don't know, too theoretical and so on. I mean, aren't the elements that -- at least that are in the report important to operator actions? I mean, shouldn't they consider environmental effects, all sorts of --

MR. MARION: As I recall from that one slide and I didn't bring the slide with me, that had the elements of the acceptance criteria, the only one that we were really concerned about was the time margin factor which in the draft was treated as a penalty. I don't know how it's being treated in the final document, but we agree in concept with the others because they're consistent with what is already delineated in the inspection procedure.

DR. APOSTOLAKIS: Basically, what they are saying is that the time available should be significantly greater than the time required to diagnose and perform the action. And in their example it's a factor of two but they say that --

MR. MARION: They say that's not going to change. Well --

DR. APOSTOLAKIS: So that's where the main disagreement is?

MR. MARION: One of the areas. The other area was the -- significant disagreement was the expectation that you would have detection suppression in the areas where you --

DR. APOSTOLAKIS: Yeah, I remember that.

MR. MARION: I don't know if that's in here or not.

CHAIRMAN SHACK: That's a different issue.

DR. APOSTOLAKIS: Yeah, that's a different issue whether they should be but you do agree -- you do agree that there should be some margin. I mean, if I do a calculation and I find exactly 10 minutes, I mean, that would be a source of --

MR. MARION: Absolutely, but establishing a factor of two margin is just ludicrous. Okay, because here's the scenario; the utilities will determine the extent to which the amount of time they need to execute an operator manual action and personnel will be trained on executing that action. And whatever that time is, is the time that they can demonstrate as adequate. Now for someone to come in now and say, "Well, it says 20 minutes, so we'll throw in an additional 50 percent and have to consider 30 minutes", I mean, what's the basis. We've already demonstrated that you can execute the action in 20 minutes and I agree that if the NRC does a review of the utilities program, the operator manual actions, and they don't have a clear demonstration of the time to execute the action, then that needs to be addressed, but it is being addressed. Now, you can identify antidotal cases that have been found over the years and we can always argue about those.

DR. APOSTOLAKIS: But at the same time, though, surely you agree that there are uncertainties in these things, so by putting this margin there, the staff is trying to account for these uncertainties.

MR. MARION: Theoretically, I agree with

uncertainty as a concept but where I'm coming from is you've got personnel assigned at a nuclear power plant. An individual walks into an area and discovers a fire. The first action is call the control room. The fire brigade is dispatched and people are going to put the fire out. Theoretical situations and uncertainty don't come into play because the personnel involved in that decision from the time it's identified, until it's mitigated and the plant is recovered, are fully trained on taking those actions to deal with that fire.

So academically, you come in here and you say, "Okay, you've got people, you've got humans involved, so the individual may not be feeling well, he might -- he or she might have had an argument with their spouse, and you know, where do you stop? And where do you capture all that in a practical effective manner to give you confidence that people can execute these actions? And that's my point.

I think we've gone beyond, well, beyond what was originally intended.

DR. APOSTOLAKIS: Well, at the same time, I mean, one can say that when you say they call the control room, the fire brigade comes, puts out the fire, that's as theoretically as anything I've heard of.

MR. MARION: I would --

DR. APOSTOLAKIS: That's academic as anybody's. They come in and put out the fire and we all go home and be happy. Thank you.

MR. MARION: I would fall back -- I would fall back on the operating experience. The NRC has collected a database of fire events at nuclear power plants and I'm not familiar with the current statistics but a few years ago all the fires were extinguished within 20 minutes or so.

DR. APOSTOLAKIS: That should be a factor.

MR. MARION: Yeah, and there wasn't an issue of people not being able to get there and do what has to be done and execute the mission, that's my whole point. Okay, so we need to maintain a balance of some sort but this --

DR. APOSTOLAKIS: No, I agree. If you have evidence of this type, certainly then it should be part of the evaluation, but to say they would come and put it out and everything will be cozy, I mean, come on, we don't know that. Anyway -- okay, thank you very much. Any other comments?

DR. MAYNARD: So how do you see this playing out? If we were to say don't issue it and it wasn't issued or whatever, what -- time line-wise, what do you think would --

MR. MARION: I would like to have -- to go back to where we were five years ago. Happy anniversary, incidentally, it has been five years June, I forget the specific date. But five years ago, we met with the staff and we said, "These are the criteria". We all generally agree the adequate and sufficient, currently captured in an inspection procedure, okay. I forget, Chris, do you remember the number seven?

MR. PRAGMAN: 71111.05 Tango.

MR. MARION: 71111.05 Tango.

DR. APOSTOLAKIS: Mike, can we get that procedure today?

MR. MARION: And that is in place. Operator manual actions have been reviewed and accepted by the NRC over the years. That inspection procedure is being used by inspectors to evaluate the feasability of operator manual actions that are being credited by plants today. Going forward is the question. If a utility decides to develop a new manual action to respond to some situation at the plant, then clearly if it's a pre-1979 licensed plant, it has to submit an exemption. If it's a post-1979, they can do an evaluation to determine the adequacy of that. And the evaluation that they will use and the criteria they will use will be in that inspection procedure.

That process is in place. I look at this NUREG and I don't see it adding a whole lot to that. That's the whole point. It just makes it a little more complicated.

DR. APOSTOLAKIS: That's interesting. I would like to see that procedure today. Any other comments or questions for Mr. Marion?

MR. IBERRA: Mr. Chairman, do you want any more question of the staff?

CHAIRMAN SHACK: No, I do think we need to see the inspection procedure.

MR. WEERAKKODY: We will send it to you.

CHAIRMAN SHACK: Do you have any comments on the adequacy of that inspection procedure compared to the --

MR. WEERAKKODY: Are you asking the staff?

CHAIRMAN SHACK: Yes.

MR. WEERAKKODY: Yes, sir. The inspection procedures for the inspectors to rely on to make sure what we call the feasability, it's a feasability of in our view a temporary measure that's not complying to regulation. In our view, if you are relying on an operator manual action in a fire area where a fire, if propagates, can take out both your plants, if you look at the operator manual action as the permanent solution, we hold the licensee to a high standard and the word "reliability" comes in. So the big distinction you would find between what's in the inspection guidance and what's in this NUREG is we are looking for higher level of assurance so that this plant, when this becomes a permanent fix, you know, this action is good for the next 60 years, okay, or 70 years or 40 years or 50 years daily operation. So in our view, if the guidance is adequate as a temporary measure, so then we tell inspectors, we tell them, "Use the inspection guidance to make sure that the operator manual action is good enough as a temporary measure". If the licensee wants to rely on it forever, then they need to come in for an exemption.

CHAIRMAN SHACK: Any other questions?

DR. MAYNARD: I have one other quick question for -- I understand -- how does it, or does it apply at all to where a plant finds they're non-compliant. Let's say we find a fire barrier that doesn't -- for some reason, doesn't meet the requirements on it, put compensatory measures in. I take it the compensatory measures for that time period would not have to fall under this NUREG. I mean, if you wanted an exemption to handle that later, you might, but there's no way you're going to be able to do that type of analysis and demonstration and everything to put the compensatory measures for a deficiency.

MR. WEERAKKODY: I agree, yes.

CHAIRMAN SHACK: If there are no other questions, we're almost on schedule. It's time for a break until 10:15.

(Whereupon, a short recess was taken.)

CHAIRMAN SHACK: We are now back into session. Our next topic will be the maximum extended load and line limit analysis plus (MELLLA+) and the supporting topical reports and Professor Banerjee will take us through this.

DR. BANERJEE: Okay. Can you hear me through the mike there? All right. So let me introduce this by saying that the Thermal Hydraulics Phenomena Subcommittee met on May 24^{th} and 25^{th} and there were several presentations made and you see this pile here. This is only the tip of the iceberg. It doesn't contain the GE things.

In any case, we had to consider a number of GE topical reports, staff SERs, all this related to the MELLLA+ and the methods proposed for the analyses. This is a pretty complex subject and we could have taken at least two or three more days on this. So we are going to capsulate all this in one or two hours now. In any case, what -- I'm sure that you all know about, but what you will see is that it's being proposed that operating region be enlarged so that a reactor can be operated at about, for a BWR, 120 percent of the originally licensed power down to about 80 percent of the flow.

There are, I think, several advantages to this which should be made clear right at the beginning because it gives the operator a lot of flexibility and actually in that sense, I think, enhances safety quite a bit. Now there are also, of course, down-sides associated with it and we need to consider these and the staff have really done a pretty good job at reviewing these topicals and coming up with the safety evaluation report.

At the subcommittee meeting, and I'm going to just briefly talk about this so the main committee with so little time has some understanding of what concerned us, early on in the presentations the subcommittee was concerned about the enlarged operating domain coming closer to various limits and they asked the staff and General Electric to take, say, one specific plant and show us where the different limits were and how much margin we were cutting into.

So I hope that the staff and General Electric will show us this because it's a complex issue. At some points, it's the critical power issue. Some points, it's instability. Some points in this operating domain, it is maybe LOCA due to lower more sump cooling. So to get a pretty idea of what these margins are, that was the first issue and how much we are cutting into them.

The second issue that the subcommittee dealt with was that this enlarged region led to higher void fractions beyond the normal operating range and several associated issues arose. One was how good is the reactor physics associated with it, how good are the correlations for void fraction, how good are the critical power ratio correlations being used. In particular, the path shapes are very different and we were interested to know whether there was testing with these different path shapes and all these sorts of things and this is for the committee to discuss. The staff dealt with this by asking for some additional margins. What we would like to know is whether these margins were sufficient really. If they were more than sufficient, that's also important. So this is for the committee to discuss.

The third major issue which I don't think is a real issue anymore was because of the operation at this, let's say, the rod line which comes from 80 percent to about 55 percent brings you closer to the region of instability and whether the measures taken to deal with this instability are sufficient or not. The proposal is to add to what is called Solution 3 a certain additional measure which is called a confirmation density which they will talk about. This committee has never reviewed any of this and I don't know why, either the TRACG calculations or this confirmation density methodology. We should have. We have not and I'd like to go on the record as saying this is very surprising to me.

Anyway to deal with this, the staff also required and I think with reason an automatic backup system which then makes assurance doubly sure. So I don't know if there is an issue here, but it was certainly something we discussed.

The fourth major issue I would say is that the enlarged region leads to more severe conditions during ATWS and instability is related to ATWS. It brings you closer to the regions where you can get instabilities and brings you into a power flow region, let's say, if you had an ATWS with certain things which could lead to an instability, power flow region where potentially your oscillations could grow more rapidly so, let's say, that root mean square of these oscillations if we looked at them and to a large amplitude.

There were some calculations done with TRACG which showed that actions such as reducing water level and therefore, increasing the inlet temperature due to the condensation of steam into the feedwater would mitigate this. But the timing in some cases was pretty short. It was about two minutes. There is an issue here as to whether these calculations are right or wrong. There is no validation of this because there are no experiments in this region. There's been no confirmatory analysis of any significance done. The reasons for this, the staff will say due to not having a code which would do it which is a really big hole right now, the staff not having a code to be able to use this which is why we've been pushing TRACE.

And finally, even with ATWS itself, there are some issues as you'll see with higher containment, over-pressures and all sorts of other things, possible re-criticality which the staff had dealt with. In all these, there are measures being taken to deal with. So if all these measures are okay, then at least on a plant-specific basis, I think we can have some assurance of safety.

The one point which I have and I think the subcommittee had some concern about was that GE and the staff were thinking of dealing with ATWS instability on a generic basis. Whether this is justified or not, you have to decide and see what you feel. This was on the basis I thought of very scanty evidence, but that was my personal opinion. But you'll see the data and see what you think about it.

So I think without further ado, I'm going to turn this over to NRR to introduce it and then GE to take over at that point.

MR. CRANSTON: Good morning. I'm Greg Cranston, the Branch Chief for the Reactor Systems Branch. This morning we're going to start the presentation on MELLLA+ and supporting topical reports with GE. So I'll turn the meeting over to GE.

MR. KINGSTON: Thank you, Greg. My name is Rick Kingston. I'm the GE Project Manager for the Licensing in the Regulatory Affairs group and we have a support team here. They have all been involved in this. I would like to introduce them now. Patricia Campbell is our Director of Washington Regulatory Affairs. P.T. Tran is the Project Manager for New Project Introductions and MELLLA+. Scott Bowman is the Manager for Methods and Software Development. Jose Casillas is a Consulting Engineer for BWR Plant Performance. Randy Jacobs is the Manager of Transient Analysis. Brian Moore is the Manager of Methods and Software. And Jens Andersen is a Consulting Engineer for Thermal Hydraulic Methods.

As Dr. Banerjee mentioned, two weeks ago we were here with the staff presenting a two-day review of MELLLA+ and the associated topical reports. Let me start this for you. What we are doing today is seeking the ACRS acceptance for use of the methodology in the MELLLA+ report and the supporting topical reports in conjunction with plant-specific applications for EPU and MELLLA+.

Just a brief review of where we are and how MELLLA+ came about. This was the original reactor operating domain and we recognized for that domain we needed an additional flow window to help the operators maneuver in that range.

(Off the record comments.)

MR. KINGSTON: If you're at 100 percent power or 100 percent flow it's very difficult to maneuver other than with pulling control rods. Thank you. And moving rods at high power release is a discrete very rapid change in power that's not good for the fuel. Moving control rods is also not a simple maneuver. It requires a lot of people in the control room. So it's much better to have a flow window where you are able to adjust the reactivity changes by adjusting flow. And we'll see that a little bit more in a later slide.

We then added the increased core flow window. Increased flow again, improves your ability to maneuver the plant. The added MELLLA, which MELLLA is the Maximum Extended Load Line Limit Analysis, that provided an additional flow window for maneuvering which is a big help to the utilities and let them run the plant much more efficiently.

DR. CORRADINI: If I may just interject for just background, the light green, the yellow and the blue have all been accepted and procedures accepted and current plants using.

MR. KINGSTON: That's correct. I believe almost all of our plants today use MELLLA+ at the MELLLA state. When we went to the -- We started on the power uprates. What we did is to we went ahead and just extended this MELLLA line five percent more power, 105 percent power, which was the stretch power uprate.

Then EPU is what we're looking at today, extended power uprate, to 120 percent. The increased core flow just goes along that way. This is actually achievable flow that you're able to get at that high power. It's a larger pressure drop into bundles and the recirculation pumps couldn't keep it at the increased core flow power.

So where we are again is at this 120 percent original license power and 100 percent flow. We're back at the situation we were initially in terms of there's no maneuvering room in that window and so we're -- the topical reports should implement MELLLA+ to give us that maneuvering room. As Dr. Banerjee said, the MELLLA+ window extends from about 80 percent core flow down to 55 percent core flow and then flat along to the 100 percent flow.

DR. BANERJEE: I think you should point out that the reasons for that precipitated drop thereof and going to the natural circulation line.

MR. KINGSTON: Yes. We have that on the next slide.

DR. MAYNARD: So far, this is all being done through this analysis to gain these margins or are we also changing any type of set guides? I'm trying to get an understanding. Basically, it seems to me like we're reducing margin. We're doing better analysis, fine-tuning the analysis, but we're really not doing anything physically in the plant to maintain margin.

MR. KINGSTON: Well, the margins, the SAFDLs on the fuel are really not changing. We're keeping essentially the same margin that we had originally.

DR. GALLUCCI: I think we'll come directly to your question in a couple of slides and the short answer is that fuel performance has improved and that's an enabler for this as well.

DR. BANERJEE: More subdivision of the fuel.

DR. MAYNARD: Okay.

DR. CORRADINI: So, before we leave this slide since this is a nice graphic to talk from, so let's go back to the light green, the blue and the yellow.

MR. KINGSTON: Yes.

DR. CORRADINI: You don't have to go back again.

MR. KINGSTON: Okay.

DR. CORRADINI: So those are design goals that you now say current plants are operating. Do all current plants have approval to operate in that full window?

MR. KINGSTON: In the MELLLA+ window?

DR. CORRADINI: No, in the ELLLA, MELLLA and ICF.

MR. KINGSTON: Yes.

DR. CORRADINI: Okay.

MR. KINGSTON: I think almost everyone --

MR. CASILLAS: Let me say --

DR. CORRADINI: Because let me tell you why I'm asking that question that way because my next question is going to be the purple is a design goal but every plant has to get blessed within that design goal. So my first question is, let's go back to the first three things, have all plants been blessed.

MR. CASILLAS: Well, let me say that the light green, the ELLLA, every plant has that approved and has been using. Everybody but two or three plants do not have the blue and also everybody except a couple of plants do not have the increased core flow.

DR. CORRADINI: Okay, and the reasons

there will probably then spill over to the purple, but the reasons are potentially equipment that would have to be changed that the utility, the licensee, decided not to do and therefore they take those limits in terms of what they can operate in. Is that correct? Do I have that approximately right?

MR. CASILLAS: Yes, and in the case of the increased core flow, that is true. That is the use of added equipment margins and so if you do not have it, you will not have the increased flow and the MELLLA, if you do not, if you just have ELLLA and are able to accommodate your operation, that's all that a few plants, that all the plants have ELLLA. But a couple of them do not need the MELLLA and so they do not have it.

DR. CORRADINI: So can we just -- I know I'm backing up a bit, but just for the sake of broad because I think it does apply to the purple, is it a matter of nobody wants to spend the money to get blessed for the MELLLA and they don't need the flexibility or is it it requires equipment changes? What are some of the reasoning that I wouldn't want to have the flexibility in the blue region?

MR. CASILLAS: It would require equipment changes.

DR. CORRADINI: Okay. Such as?

MR. CASILLAS: The instrumentation for the -- the added instrumentation for detecting local power changes.

DR. CORRADINI: Okay. Fine. All right.

DR. BANERJEE: I think you should point out and I'm sure they will that to get to the focal region there are things that have be done, of course.

DR. CORRADINI: Right. The reason I asked the question was to lead to this one which is the purple is a design goal and a methodology which we are looking at to consider as good, bad, indifferent. But still, every plant has to come in and submit a safety evaluation report to be allowed to operate in any part of the purple. They may not be able to operate in the purple.

DR. BANERJEE: They are asking us to approve certain dispositions on a generic basis.

DR. CORRADINI: Right.

DR. BANERJEE: So that they are not plant specific and they'll clarify that.

MR. KINGSTON: What we're asking is our MELLLA+ licensing topical report is a process for qualifying a plant to operate in the MELLLA domain. So we are asking for approval of that process and every plant that goes into MELLLA+ would have to go through the processes in that topical report.

DR. BONACA: Well, it seems to me that the first big step that you do, have to make, is the one to the red region, I mean, the EPU.

DR. ARMIJO: The response provided by the Mr. Casillas had double negative and I just want to make sure that the record is correct. You said that everybody but two or three plants do not have approval to operate in that MELLLA and ELLLA regions. Is that a correct statement, everybody except two or three plants do not?

DR. CORRADINI: Do, I thought he meant.

MR. KINGSTON: Yes. All but two or three plants.

DR. ARMIJO: Okay. So it's important that the record reflects that. Thank you.

] DR. MAYNARD: I understood it the way you heard it, Mario.

DR. BONACA: I understood it that the majority.

MR. ANDERSEN: The majority of the plants are approved to operate with MELLLA?

MR. KINGSTON: Yes, that's correct. That's good.

DR. CORRADINI: That double negative.

DR. BANERJEE: And perhaps you will come to DSSCD and then you can tell us how many plants have DSSCD right now and how many don't.

MR. KINGSTON: I can't tell you that.

DR. BANERJEE: When you go through that, you'll tell us.

DR. CORRADINI: And just to get to Mario's point -- I want to get back to Mario's point. It's key. So in the red region now, we're just starting to go into it, so to speak, by a case-by-case basis.

DR. BANERJEE: Yes. Right.

DR. BONACA: But what I was trying to say before was that the big step as far as plant modifications is to go the red region.

MR. KINGSTON: Yes.

DR. BONACA: From there to the MELLLA+, it's more of an analytical, I mean, it's fuel improvements and not necessarily plant modifications anymore. My understanding is that you will not have further modifications to the plant except to the --

MR. KINGSTON: It's just principally the fuel performance that allowed us to go to the higher power.

DR. BONACA: Okay.

MR. ANDERSEN: Just one. Yesterday we had a presentation from Vermont Yankee which is operating at 120 percent.

MR. KINGSTON: That's correct.

MR. ANDERSEN: And they claim they had sufficient margin without MELLLA+. In fact, they're operating and have been operating for --

MR. KINGSTON: Plants can operate without MELLLA+. It's just more efficient and easier for them and better human factors to use the flow window.

MR. ANDERSEN: What's the penalty they're paying right now for not having MELLLA+ and operating at 120 percent? What are they doing now that they wouldn't have to do?

MR. KINGSTON: Their reactivity, and, Jose, help me, their reactivity adjustments are much more complicated to do to make sure you stay in the allowed domain.

DR. BANERJEE: They have to use rod adjustments rather than flow adjustments.

MR. ANDERSEN: Maybe four percent low or something like that.

MR. KINGSTON: Which means now you would have to go significantly down in power before you make your rod adjustments.

DR. ARMIJO: In their case, this dotted line for the achievable flow does not go down to 100 percent. It's about 104 percent or thereabouts. So they have a little bit of flow margin.

DR. CORRADINI: You're talking in the yellow.

DR. ARMIJO: Right.

DR. BANERJEE: Yes, the Yankee.

DR. CORRADINI: Got it.

DR. BANERJEE: Vermont Yankee. But in general, I think you can make a case which the subcommittee understood that this operation in this extended region makes it perhaps more safe to operate the plant.

MR. KINGSTON: Yes, that's correct.

DR. BANERJEE: In that sense, it adds positively to safety.

MR. KINGSTON: And if you were to poll our utility operator colleagues and ask them if adjusting fore reactivity they would rather use control rods or the flow window, I think they would all want to go with the flow. No pun intended and we have some scenarios we can go through and you see how these adjustments were made.

DR. CORRADINI: And just one last thing

which I know you're going to cover because I remember a lot of questioning in the subcommittee, the kink at 55 percent --

MR. KINGSTON: Yes.

DR. CORRADINI: -- and the kink at 80 percent involves some physical phenomena that I think the rest of the committee wants to at least appreciate.

MR. KINGSTON: The 80 percent kink, that was the minimum practical flow at which 120 percent power could be utilized and you're not going to be able to get, with lower flow than that, you're not going to be able to get, you're not going to be to stay at 120 percent power.

DR. BANERJEE: Well, but what is the limitation there. Is it CPR? Low flow CPR, right?

MR. KINGSTON: That's what I --

DR. BANERJEE: But I think the problem that we ran into in the subcommittee meeting was to show where it's a CPR limit. That point I presume is a CPR limit.

MR. KINGSTON: Possibly.

DR. BANERJEE: And what is a limit, say, at the 55 percent point which I presume is getting close to an instability.

MR. KINGSTON: That's the stability point.

DR. BANERJEE: This is what we wanted to clarify.

MR. KINGSTON: Right.

DR. BANERJEE: For specific plants because it's very plant-specific. So take any one plant and show us.

MR. KINGSTON: The 55 percent was stability margin in sump cooling concerns.

DR. BANERJEE: Right, but what wasn't clear is, perhaps it will become clear in your presentation because we specifically asked for this, was whether it's a LOCA limit in some cases, whether it's a stability limit in some cases. We want to understand how we are cutting into the margins.

MR. KINGSTON: We'll talk -- In two slides we have that.

DR. BANERJEE: Okay.

MR. KINGSTON: Three slides, excuse me. The flow window benefits are here. You can read them as well as I can. The plant really like MELLLA now and they want MELLLA+.

Now we can go through some applications with the flow.

DR. BANERJEE: The vibration thing is

interesting. Can you go back to that? You didn't speak of that to the subcommittee. Can you -- The previous slide had this vibration rate.

MR. KINGSTON: That's right.

DR. BANERJEE: Now can you tell us whether this is something which is verified that you know that this will give you less problems with things like steam dryers and things?

MR. KINGSTON: Jose, do you want to take that?

MR. CASILLAS: This has to do with not the dryers but more of the internal components where the higher recirculation systems would be involved, the jet pumps and instruments and so on. But where the velocities would be quite a bit less at the lower --

DR. BANERJEE: But is the steam dryer vibration or the acoustic wave dependent on the velocity?

MR. CASILLAS: No. Well, up at the top --

DR. BANERJEE: Do you know that?

MR. CASILLAS: At the top of the vessel, we have mostly steam flow and the steam flow is not changing. So a dryer --

DR. BANERJEE: Wouldn't matter. Because the 120 percent would give you the problem anyway.

MR. CASILLAS: Correct.

DR. BANERJEE: So that's why I was a bit confused about that.

MR. CASILLAS: But the vibration is in the internals.

DR. BANERJEE: It's a different vibration occurring.

MR. CASILLAS: Yes.

DR. BANERJEE: Not the steam dryer problem.

MR. KINGSTON: Right. All right. This is a typical BWR power flow map with the MELLLA boundaries shown. During a start-up, the plant would follow the red curve shown, would go up but low pump speed past the cavitation interlock and then go with flow up the curve and then the control rod motion, they would increase power and then continue with flow up to uprated power.

Now these are a little bit trickier. We adjusted these so it didn't look like people were going over 100 percent power. This is after you start it up, you have some equilibrium xenon burning in and you have a reactivity loss. So when you have the flow window available, what you can do is this red line is effectively a horizontal line because as your reactivity is decreasing you can increase your flow to stay at 100 percent power and that is much preferable to trying to move control rods at high power. It's a much smoother, much slower, much softer practice for the fuel.

Now the next one is where you have a power increase from Gad burnout. Now the BWRs have Gad aluminate in them and the fuel does get more reactive as you proceed into the cycle for awhile and this is the one that is drawn a little. As you would start to have a reactivity increase, you would move backwards along the flow line. Of course, you wouldn't go down in power, but as your reactivity increased you would back down on flow to stay at 100 percent power again using flow only, not having to move control --

This is reactivity loss from fuel burn-up which is much likely xenon burning in and you'd be going up in flow to compensate for the reactivity loss.

DR. BANERJEE: Plus what you are doing is you're adjusting your void fraction, right?

MR. KINGSTON: That's correct.

DR. BANERJEE: You're getting higher, higher and higher which is what brings up the issues related to the high void fractions.

MR. KINGSTON: That's correct.

And then even with the flow window, periodically you have to make a major rod pattern adjustment to keep the burn-up even in the core and in that case, you would come down this line in -- come down in flow along a rated rod line and then make your control pattern adjustment to gain your reactivity and then go back up to full power at flow. Without the window, you would have to be doing these in small steps to avoid getting into an unallowed domain and this makes life much easier, much safer, much more efficient for the plant operator.

So if you look at the 120 power uprate in MELLLA+, what's going on? What are the margins and why can you do it? The answer is really -- It's the fuel performance and what we have plotted here is some of the limiting factors in a power flow map and where you have them. These points are actual plotted data from our ATWS test facility and this shows the difference between this is steady state power/critical power ratio. This margin here is the margin that's used when you have anticipated operational occurrence and --

DR. BANERJEE: Can you explain the vertical spread of the points?

MR. KINGSTON: Probably Jens can.

MR. ANDERSEN: I can explain it because we have -- This is Jens Andersen from GNF. We have run tests at various subcoolings. We have run tests at various peaking distributions in the bundle. So these represent data with different power distributions inside the bundle.

DR. BANERJEE: Right. Now with the sort of power distribution that might obtain in a higher void core where you might have periods where the power has quite -- the distribution has quite a complex shift or maybe even a higher power region towards to the core exit at some point. Where would those points fall? Would they be on the lower side of this?

MR. ANDERSEN: When you are limited by critical power which tends to be towards the end of the fuel cycle where your power shape tends to be top-peaked, top-peaked power shape has a lower critical power than a bottom-peaked power shape and we test both power shapes.

DR. BANERJEE: So that would be the lowest. Would they be the lowest then, the top-peaked shapes?

MR. ANDERSEN: The top-peaked power shape would be at the bottom. The particular data that are shown here are for a mid-peak power shape. But the top-peaked would probably be along the bottom of the boundary of these data.

DR. CORRADINI: Could you repeat? You said it and I guess I didn't appreciate what you meant by it that the difference between, let's say, the 100 percent or the 120 and the lower limit line of all that critical power data is therefore and was it AOOs?

MR. ANDERSEN: Yes.

DR. CORRADINI: But I don't -- Could you kind of expand that just briefing so I understand what you mean by that?

MR. KINGSTON: We -- Part of the design criteria is that we cannot exceed 0.1 percent of the rods in transition boiling for steady state and for AOOs. And so this is the margin then between steady state and AOOs that we have.

DR. BONACA: But now you do have a trip set point, right? So that's just a margin for an overshoot? How do you get there? It's just simply margin.

MR. KINGSTON: If you have an anticipated operational occurrence, that is where you start eating into this margin and that's our delta CPR or above the safety limit.

MS. ABDULLAHI: This is Zena Abdullahi, NRC NRR for now. GDC-10 requires that the -- will not be violated during to steady state, normal steady state operation and anticipated transient operation. Therefore, during steady state, the critical power correlation predicts what's called a safety limit MCPR and those data are from the GEXL correlation data. They did testing at different power shapes so they can have the correlation that would allow them to calculate what the steady state value is where 99.9 percent of the rods would avoid boiling transition.

Now if you have a transient, then that delta is what will determine what your operating limits should be, so that if you do have a transient and the pressurization transient and the power peaks up, then your CPR should be such that you still do not violate 99.9 percent of your fuel rods should avoid boiling transition.

MR. KINGSTON: And that's why we do our calculations, to calculate what that operating limit delta is.

MS. ABDULLAHI: Yes. So basically that margin is not really a margin. It's meeting the delta CPR required to meet GDC-10.

DR. BANERJEE: So the margin under normal operating conditions.

MS. ABDULLAHI: Right.

DR. CORRADINI: It's a limiting condition. I mean, what I just heard the discussion say is that you have a particular event that occurs in the -- potentially once a year.

MR. KINGSTON: A range of events.

DR. CORRADINI: A range of events. Let's pick the pressurization event that when it occurs it creates essentially a change in pressure which creates a change in the CPR which means you have to stay where you are or else you're in trouble because you don't need your 0.1 percent.

MR. KINGSTON: That's right.

MR. ANDERSEN: That's correct.

DR. CORRADINI: Okay. Got it. Thank you.

DR. BANERJEE: Go ahead.

MR. KINGSTON: Okay. As you mentioned, Dr. Banerjee, the bypass voiding and core in it and the subcooling are controlling here at the 55 percent line. You see the steady constant decay ratio line as a region you want to avoid. And then, of course, you have the nodal heat limit, your heat generation rate limit, at the end here.

DR. CORRADINI: Which is "over here"

meaning to the flow -- I don't know what you mean by --

MR. KINGSTON: To the right.

DR. CORRADINI: Which implies what? Because we were just talking peak temperature? The linear heat generation limit is just essentially a temperature mode, yes?

MR. KINGSTON: It's temperature exchange in transient analysis, too. It's the strain, the center line melt.

DR. CORRADINI: Okay. Got it.

DR. BANERJEE: Thanks a lot.

DR. CORRADINI: This is very helpful.

DR. BANERJEE: Yes, it is. Now, this is sort of a generic case you've shown, right?

MR. KINGSTON: Yes.

DR. BANERJEE: I guess each plant will have different --

MR. KINGSTON: Depending on its geometry, its configuration, what generation of plant it is, what other options it has, how much bypass it has, all of those figure in the calculations.

DR. BANERJEE: In these operational transients, how close would you get in terms of, let's say, the horizontal part of the line to the CPR limit because it gets you to --

MR. KINGSTON: You're asking how close we make the delta CPR to the actual --

DR. BANERJEE: Yes, what is the delta CPR? At the moment, it's 1.5 or something, right, or 1.4? I don't know.

MR. ANDERSEN: Typically, you have a safety limit which is the margin you need to have safety limit minimum critical -- It would be somewhere in the order of 1.07 to 1.09 which means a seven to nine percent margin that you need to have to avoid one percent of the -- boiling sensation. Then as Rick mentioned, you analyzed all the events and you say how much change do you get in your critical power ratio during these AOO events and typically the limiting events are the pressurization events and that puts an additional delta CPR on top of the safety limit and that takes you maybe up to 1.4 which is a typical operating limit and so that's how much margin the fuel needs to have and it's designed -- the fuel and the core design are designed to meet those limits.

Now typically, plants like to have a couple of extra percent margin just to allow them flexibility in operations and they don't like to operate at the limit. The rest of the margin, if you have it, you can use to optimize the rate of your power distribution in the core which gives you better fuel economy.

DR. BANERJEE: But I think the thing to point out here is that while the safety limit CPR and the operating limit CPR is maintained, of course, much more of the core is at these conditions because in some sense the power distribution is really much flatter. So this one percent number, I guess, comes into that calculation, right?

MR. KINGSTON: 0.1 percent.

DR. BANERJEE: 0.1 percent, yes. Okay. I think we should continue.

MR. KINGSTON: Okay. As you mentioned, what's changed?

DR. BANERJEE: Can you just go back just for the record and state one thing.

CHAIRMAN SHACK: You're contradicting yourself here.

DR. BANERJEE: Sorry. I am.

(Off the record comments.)

DR. BANERJEE: But I think you should point out that, of course, the core is somewhat faster in some ways that adversely affects stability as well in this case, right?

MR. KINGSTON: Yes, the MELLLA+ does and, in fact, the DSSCD was developed to address an issue where MELLLA+ is having an adverse effect on the potential performance and we have that extra safeguard in place.

As I mentioned, the fuel performance is what's changed to allow MELLLA+. This table here is for GE fuel. The other fuel vendors have been increasing their performance with their fuel just as GE has. So the effects are comparable. You see what's happened. We've gone from an 8X8 lattice design to a 10x10 which gives us more rods, smaller diameter rods. It helps with cooling. It helps with surface area and heat flux. So it helps with your margin.

DR. BANERJEE: -- doesn't like this slide.

MR. KINGSTON: And you see some of the numbers higher there and how they've improved.

(Off the record comments.)

DR. BANERJEE: Carry on.

MR. KINGSTON: All right. Also on the pressure drops, essentially unchanged. From GE fuel, the stability of the two phase to single phase pressure drop, an introduction of parlene cross (phonetic) has also helped with fuel performance and we have a little excerpt from one of our documents here and the terms here are a little bit -- BOEC is beginning of equilibrium cycle, middle of equilibrium cycle and end of equilibrium cycle. This was done on an equilibrium basis and there is these decay ratios are essentially unchanged from the 8X8 to the GE14. Question?

DR. CORRADINI: So something magical happens there that I don't need to know about that the two phase pressure drop went down because you're upping flow.

MR. KINGSTON: Yes.

DR. CORRADINI: And everything all is hunky-dorey.

MR. ANDERSEN: I can answer that question. We introduced the --

DR. CORRADINI: I missed that. I'm sorry.

MR. ANDERSEN: In a 10X10 fuel we have about 14 -- at about two-thirds length. So you have increased flow area in your part of the bundle.

DR. CORRADINI: Okay. Thank you.

MR. CASILLAS: Let me clarify. The pressure drop change refers to the flow and the power for the specific bundle. So when we've had more rods you would expect more pressure drop. But we've decreased it. But in terms of power uprate if the bundle operates at a higher power, it will have higher pressure drop.

DR. CORRADINI: Okay. Fine. Thank you.

MR. KINGSTON: One of the concerns that was examined was potentially changing core condition as we move up the MELLLA+ line and here you can see a comparison of how the void fraction changes with different scenarios. The top scenario here is 105 percent power, 80 percent flow. That's like the stretch power uprate. Brian, maybe I'll have you --

MR. MOORE: This is Brian Moore. I can just try to talk through this. So you have a stretch power uprate at the MELLLA line and then if you proceed up the MELLLA line to an EPU condition, the changes that you'll see are that the core average voids are essentially unchanged.

Then as you proceed MELLLA+, you're starting to increase the core average voids. So in a whole, the void content in the core is higher. But because we are constrained in terms of bundle performance in terms of the CPR, the peak exit void fraction is bounded. So it cannot increase. In general, the core average void content increases, but on the peak bundle it does not.

You'll also notice that the potential for bypass voiding because you have reduced moderation because of the higher exit void fractions from the bulk of the core, you have more energy being deposited to the liquid that's between the channels. Therefore, the potential for bypass voiding starts to increase.

The other parameters shown, core pressure drop or inlet enthalpy and feedwater temperature, show that for different given scenarios we're not changing ultimately our departing drastically from our current database of performance either at the original MELLLA line or with the EPU conditions. So MELLLA+ does not introduce core conditions in general that are drastically different of what we have been able to support, to demonstrate that.

MS. ABDULLAHI: This is Zena. I just want to add here. I want to point out this. We didn't address in our slides later on that we'll cover. Because of the proprietary information, I have to omit it. I never thought GE would present these things and our slides basically because it's an open session did not bring any of this information back that we had during the subcommittee.

DR. CORRADINI: So this is one and only chance?

MS. ABDULLAHI: This is your chance.

(Off the record comments.)

MS. ABDULLAHI: I want to point out that the main thing to understand here is I guess that they're saying that assuming that my operating limit remains the same, that I don't change my operating limit, as from 105 to 120 to 80, that means then what bundle power can I operate under so that it's fixed in the operating limit. But that doesn't mean that when you actually operate and have an actual plant that wants to operate at that condition, they may have to change the bundle power.

DR. CORRADINI: So can I --

MS. ABDULLAHI: It's a constraint that is a design goal, but is not a constraint that you generally expect to happen. We went through in our section and said that there were cases where you had the bundle power increased in order to operate there. Go ahead.

DR. CORRADINI: So may I ask a question just to clarify. So let me frame it slightly differently but I think I get it which is they have some fictitious nominal reactor out there that they've done a calculation on. Any particular reactor may have to manipulate this to fit within their constraints of flow and bundle design, etc.

MS. ABDULLAHI: There's no limit on that.

PARTICIPANT: You can expect the same trends, whatever fixed --

DR. BANERJEE: The trick to keep this peak exit within the limits is you have a flatter core, right? That's the reason you can do that.

MR. CASILLAS: Yes, that's correct. In the case of the 105 percent power, it would be very easy to do. In the case of the 120 and 80 percent flow, it would be very difficult, it would be much more difficult.

DR. BANERJEE: Yes, it comes at the cost of stability with the flatter core, right? That's why eventually you have to put your --

MR. CASILLAS: Well, in the normal operation, the stability margins are the same as before.

DR. BANERJEE: Yes.

MR. CASILLAS: It's only if you depart because of a pump trip or something --

DR. BANERJEE: Sure. I mean, the stability point doesn't change.

MR. CASILLAS: Right.

DR. BANERJEE: But you come close to that.

Eventually, the core is more unstable.

DR. ARMIJO: All of these void fraction data are for the GE-14 design. Is that correct that's what we're seeing and if you had a different fuel design, say another supplier's fuel design, there would be different fractions here.

MR. ANDERSEN: I can answer that question. For the same power and fuel, you will get roughly the same void fractions and the reason is that if you compared all fuel design, the have roughly the same flow area in the bundles. They have roughly the same phenolic diameters. So for the same power flow conditions, you're going to get very similar void fractions.

DR. BANERJEE: But you know, we are going to -- for the committee, we are faced with Hope Creek and Susquehanna and Browns Ferry and they will have a mixture of GE and other fuel. So remember that.

DR. CORRADINI: So if I could just reflect what Sam said. So in your guys' subcommittee with Vermont Yankee, they have chosen not to do this because they have flexibility, a little bit of flexibility, in the 120 region. Is that what you said?

DR. ARMIJO: I said they are operating

right now.

DR. CORRADINI: Whether they choose to go forward or not but --

DR. ARMIJO: They would like to have more.

DR. CORRADINI: Their flexibility is on the higher flow side. Okay, thank you.

DR. ARMIJO: But my other question is really addressing other fuel designs because the difference is some -- I don't know if everybody has part link rods now, but you have that feature. You have water rods in some designs. You have water rods in other designs and so I'm trying to understand, is this viewed as fairly generic for the modern fuel that's out there today or is it just this is a specific design.

DR. BANERJEE: I think we'd have to consider it on a plant specific basis for sure.

MS. ABDULLAHI: Yeah.

DR. BANERJEE: Fuel design specific basis.

MS. ABDULLAHI: This is Zena. For the -- I don't think GE is telling you that every plant that they -- you know, every bundle will have a peak of 87.5. I mean, that is not what GE is telling you. I mean, I have a case of Brunswick data for EPU MELLLA and I had 93 exit void fraction. Okay, so what they're doing is if I reach the design goal, this is what I'm going to get is what they're going to say and this is what my voids would be.

Now, every plant, they have to analyze the -- simulate the core steady state condition, transient analysis, all of that would have to be done and then whatever comes out will come out. Regulatory-wise we don't calculate what the void is, we don't put a limit. We don't put a limit on the bundle. It's the calculated thermal and make sure you meet it.

MR. KINGSTON: And, of course, the MELLLA plus LTR is a process that you go through that includes these kind of checks to qualify and you know, the modeling would be --

DR. BANERJEE: Am I right that you're saying this only to give us an idea that you're not far outside what you're doing now?

MR. KINGSTON: That's right.

DR. ARMIJO: But a lot of these calculations have to be done every reload.

MR. KINGSTON: Yes.

DR. ARMIJO: So let's day you have a plant with a mixed core, how would you do these calculations?

MR. KINGSTON: Brian could probably answer that the best.

MR. MOORE: Yeah, this is Brian Moore again. During a vendor transition, we will be able to do a best estimate simulation of the other vendor's fuel in the same way that we're doing a best estimate modeling of our own fuel. So we get enough information from them regarding thermal hydraulic performance, nuclear performance, of course, we are modeling the exact design. We're not imitating or making approximations on what's happening in their fuel, but we're doing it to the best of our -- to the best of the ability of the methodology.

DR. ARMIJO: But how would you get information on CPR correlations?

MR. MOORE: As a part of the vendor transition, of course, we are -- you know, if we are not modeling the core, we must monitor to the thermal margin. So a part of that transition is getting information from the other vendor under protected terms and sometimes there's, you know, additional margin. They're not going to give us their critical power database. We have a method by which we're able to simulate the critical power sometimes involving us preparing and submitting critical power correlations specific to that fuel type to the staff for review.

So you'll have the information to monitor their critical power performance as well.

MR. KINGSTON: And as Brian mentioned, typically there's additional margin on that correlation compared to just a correlation. Some of the key safety analyses are shown here and a comparison is shown on what the impact of MELLLA plus is. On containment, there is no impact to the long term response. There's no change to the K heat and the small effect on the short term analysis.

DR. BANERJEE: Containment in the sense of loads during what? Is it --

MR. KINGSTON: LOCA loads.

DR. BANERJEE: LOCA loads, not ATWS loads.

MR. CASILLAS: Also ATWS loads. Containment. That's further down.

DR. ARMIJO: Now, when you say no impact, you're assuming you're already at the EPU level.

MR. CASILLAS: Yes, that's right.

DR. ARMIJO: You're just looking at the effects of flow.

MR. KINGSTON: No, the impact of MELLLA itself on the --

DR. ARMIJO: Right, MELLLA plus.

MR. KINGSTON: And the rest there you can take a look at and ask questions if you have them.

DR. CORRADINI: I'm trying to read your last one to understand it because that's the one eventually I want to understand better than the others, sorry.

MR. KINGSTON: We have another slide on stability. This item, as you know, was one of quite a bit of discussion two weeks ago and we've listened to the concerns, Dr. Banerjee's concerns. We have a slide on that. I will approach that. Are there any questions on any of these other impacts? In general, they're relatively small. Where this is an impact it's on stabilities, you know, we've gone to DSSCD to address that point.

DR. BANERJEE: With the backup safety.

MR. KINGSTON: Yes.

DR. BANERJEE: Was that offered by you or was that requested by the staff, the backup?

MR. KINGSTON: I don't know.

MR. CASILLAS: That was GE's. That was part of the design -- in how the design of MELLLA plus. We were very, very aware of this behavior.

MS. ABDULLAHI: Finished?

MR. CASILLAS: Yes.

MS. ABDULLAHI: Okay, what we said is that you can't have an inoperable system.

DR. BANERJEE: An automatic backup system.

MS. ABDULLAHI: We didn't tell them it has to be an automatic backup. It was a question of you cannot have an inoperable system because there's no time for operator action. And from there it was developed through the process was this backup an auto system was conceived, I think and then one plant cam up with the auto.

MR. CASILLAS: The CD was a GE system to go with MELLLA plus.

MS. ABDULLAHI: Right, yes.

MR. CASILLAS: Right, and the question is only what would you do if you don't have the CD system available for whatever reason. And the simple approach is you exit the MELLLA plus. You just do not operate that. And that's one. You can have also an automatic system also.

DR. BANERJEE: Are you going to address stability in your presentation?

MS. ABDULLAHI: Because this was one-hour open session --

DR. BANERJEE: Yeah, so you're not.

MS. ABDULLAHI: -- everything we covered in the closed for the sub, we didn't really -- we were just going to do an overview now but if you close any section we will be happy to pick up out old slides and go over it.

DR. BANERJEE: Well, I could, I think, tell the main committee that with regard to the stability issue, the subcommittee went over it in some depth and we can explore it if you like more. And I think which methodologies that were offered and all the CD plus the automatic backup I think we were quite relatively satisfied with that. I mean, we can reopen this at any point that you need.

DR. MAYNARD: I just have a quick question on the -- I'm not familiar with the margins, BWRs, the LOCA less than 100 degrees PCT change expected. How close to the limit is that? I don't know if 100 degrees putting it real close or whether you --

MR. GANT: You know, this was also presented at the subcommittee, some example results. You know, I think we see PCTs in the 1800 --

DR. BANERJEE: Quite a big margin.

MR. GANT: -- range. I mean, some plants can be higher than that, you know. Some of the older plants are LOCA limited so you would have --

DR. MAYNARD: Okay, I'm just not that familiar with the BWR operating margins.

DR. BANERJEE: The major issues that came up were, of course, uncertainty with minimum CPRs which the staff dealt with by adding some margin to the requirements. They'll probably speak to that. LOCA was not a big issue. There were some issues related to ATWS, as I said, plant specific issues which were resolved on a plant specific basis but really it was whether we can dispose of the ATWS instability on a generic basis is going to be something that you have to consider.

Now, we also have to consider all of the methods we can use in this. I mean, this is an enormous thing we are looking at on one hour.

MR. KINGSTON: Right, for the stability, the ATWS instability --

DR. BANERJEE: This slide we don't have it?

MR. KINGSTON: No, this was one we just -- we worked with Zena five minutes before the meeting. It looks like a paragraph. But you can read the option there. In effect, until there is a -- you know, the staff feels comfortable with the bounding generic solution, you know, there is a confirmation of what it is, we would do this, the instability on a plant specific basis.

DR. BANERJEE: Plant specific, yeah, are you asking for a disposition on at generic basis or on a plant specific basis? We don't have any problems with a plant specific basis.

MR. KINGSTON: Well, yeah, and what this is until we can get a generic disposition, we will continue on a plant specific basis and we'll continue to work you know with the codes and with the comparisons to generate a data set that we can bring to you and demonstrate that we do have a bounding generic case.

DR. BANERJEE: Yeah, sure.

DR. CORRADINI: But there's a set of conditions, if I remember, after all the discussion, there was a set of conditions of general principles, first general principles that must be mitigated. It can't be unmitigated. Right?

MR. KINGSTON: Right, that's right.

DR. CORRADINI: And then within the mitigated category, depending upon the plant, the specifics, you'd have to look at it, but no -- but isn't that -- am I remembering correctly?

DR. BONACA: Well, I thought that for the unmitigated case, we made a point of the frequency of this event being 10^6 or lower. And the fact that the

ATWS was really closed as a ISG because on a frequency basis.

DR. CORRADINI: The unmitigated.

DR. BONACA: The unmitigated, that's right.

DR. CORRADINI: But even the mitigated is a low enough frequency. It's not within the design base anyway, even the mitigated.

DR. BANERJEE: Well, ATWS is a special event anyway.

DR. CORRADINI: Right, but I just want to make sure I've got it right though, that unmitigated is off the table. Mitigated is what we're talking about and there it's on a specific basis, depending on how it effects that plant staff design in the MELLLA plus region.

DR. BANERJEE: Right, now.

DR. CORRADINI: Right now.

DR. BANERJEE: I mean, they may disposition it on a generic basis in the future, right?

DR. CORRADINI: Did I remember right?

MS. ABDULLAHI: Yeah, originally what NRC was willing to approve was it's low frequency and the assumptions in the mitigated -- there's no unmitigated anyway. There always is going to be -- unmitigated is more to see the variability of parameter changes and response. It's all let's say academic, to pick up those specific parameters that you want to assume in the mitigated as limiting parameters.

The agreement was they did one generic mitigated analysis. We accepted that generic mitigated analysis as telling us that they bound -- that it was bounding enough and that mitigation action was effective under MELLLA plus operation. There were some applicability ranges that they had to meet. If they don't meet those applicability ranges they have to reanalyze and applicability ranges were if we change the fuel design, because our position was based on G14 fuel design, generic.

If you change the bundle power flow ratio, the power density, so there were a certain set of applicability ranges that if in fact, a plant does not meet those, they would do an analysis. Other than that, we generically dispositioned.

DR. ARMIJO: Well, but hold on. There is nobody right now who is excluded by this 52.5 megawatts per million pounds per hour; is that correct?

MS. ABDULLAHI: That's per million.

DR. ARMIJO: What you're saying is that anybody who is using GE14 is generically approved; is that correct?

MS. ABDULLAHI: The way it was now, the way it was -- this limitation is new. This is new. It's being response to the committee.

DR. BANERJEE: To the subcommittee.

DR. ARMIJO: But the question is whether it really means anything.

MS. ABDULLAHI: The generic disposition?

DR. ARMIJO: Right, in the sense that if I read this, I would say anyone who is using GE14 is automatically covered by this generic analysis; is that correct?

MS. ABDULLAHI: Now it's slightly different. Now what it's trying to say is that you will do a plant specific analyses unless you could show, that was the intention now. This was supposed to be different.

MR. KINGSTON: The intent was you do a plant specific analysis until there's an approved generic.

DR. ARMIJO: Unless, you know, unless you have specific changes, but if you don't, you're using GE14 and everybody satisfies the 52.5 megawatts per million pounds per hour, then you don't have to do anything.

Mr. Marche-Lueba: This is Jose Marche-Lueba. The language in the red sentence says each -- the red sentence over there says, "Each plant safety analysis report". It means each plant application must include a specific analysis. So they will do at least one per plant. Now, what they are trying to say is that after the 10th plant, maybe plant 11 we have enough information to know that plants of this type don't need to do it any more. That's the way we intend that to read.

DR. BANERJEE: Yeah, I can tell you what the concerns of the subcommittee were in this just to summarize it. If you look at one of those -- it's not here but you have a line which was a red line on one of the slides that somebody showed. You were in an ATWS instability situation in an area of domain, if you like, where you would expect because of this MELLLA plus operation, that your instabilities grow faster, will come more rapidly, whatever and the subcommittee was concerned, even though this was a very low frequency event, to dispose of it generically without having more experience in running this and seeing what effect the mitigative actions would be.

At the moment it looks like the mitigative actions can be done within two minutes, then it's fine. But we don't know if this had to be done in 30 seconds or 40 seconds, what it would be on a plant specific basis. Even though we agree that some of these calculations were done conservatively, nonetheless, you know, this is in a regime where these codes have not been tested all that much. We don't understand this regime very well. I have a paper on reflux which I'll give to Jens which shows that the rewetting velocity goes down by a factor of two when you have these oscillations. Okay, so it's an open issue still in my mind. So I think if you're going to do a plant specific analysis, fine.

DR. ARMIJO: Without further specificity as to the conditions at which this specific or plant specific calculation would be done, I don't think this means anything because I can always select the conditions at which I do this calculation and show that I can satisfy the acceptance criteria.

You have to specify the limiting conditions at which this calculation needs to be done.

MS. ABDULLAHI: Okay, if you would notice the applicability ranges, I'm not going to tell you that these words are perfect. This is we were all scrambling the last minute, okay, but I can tell you what are the conditions that we find important.

One these are fuel design -- number one cause is M+SAR must include ATWS instability analysis that satisfies the ATWS acceptance criteria. That is the beat. Maybe we should put that first. That is the new important one.

DR. BANERJEE: No, you can view that second. The intent is important so it satisfies Said with the rewording. We don't want to waste much time.

MS. ABDULLAHI: Well, we would leave that first but the list that you have underneath there, the one, the two, the three, the four, the five, these are parameters that we wanted to be checked in general, okay. It's anybody's turn -- after a certain time you way that I need the auto analysis for Type 4 plants, okay, and that has been provided. These are what we think are important parameters that would give them the checklist that they are okay.

Axial power radial distribution effects the ATWS stability, so they would have to show that the assumed cases meet that. They would have to show the bundle power flow ratio, that they meet that. So this is really not -- this has increased our applicability ranges today also, okay, or whatever analysis is accepted in the future. And I would also like to --

DR. BANERJEE: Zena can you do this?

MS. ABDULLAHI: Separately.

DR. BANERJEE: Yeah, separately because we don't have the time right now.

CHAIRMAN SHACK: Yeah, we're at 11:30 already.

DR. BANERJEE: Yeah, so we need to finish this presentation and between whatever is needed, I mean, when we write the full committee letter, we would need to have an understanding of what is the limitations.

DR. ARMIJO: And we'll get a copy of this?

MS. ABDULLAHI: For the record, what I understand you're requesting is that we clean it up, make it more clear, provide you a written -- proposed written ATWS instability limitation that would be clear enough that an ATWS instability analysis would be to follow on a plant specific basis.

DR. BANERJEE: Yeah, and I don't know what Bill wants to do, whether this can be just something that can be given to the committee at the time it's considering its letter or it's up to you how you want to deal with that.

CHAIRMAN SHACK: Well, I mean, if we feel this is necessary, we can describe in the letter that this limitation has to be applied. I mean, I'm not drawing any conclusions at the moment.

DR. BANERJEE: Yeah, we don't know.

CHAIRMAN SHACK: But if we have this, we can certainly include the restriction in the letter.

DR. BANERJEE: Okay, let's move on. Okay, thank you. Maybe this next Slide 12 is useful, yeah, we want to talk about that, yeah.

MR. KINGSTON: And Brian, I'll let you take this one.

MR. MOORE: Sure. The -- as we're calculating all these different conditions and events for MELLLA plus, the question arose first by GE, is your methodology capable of analyzing these conditions? And the staff was also very uniquely interested in this. And particular attention was paid, attention to void fraction, bypass voiding, handling of uncertainties relevant to this condition, and other items. And in the end, there was a request by the staff for a particular set of validation data pertinent to operation at EPU and MELLLA plus and GE was able to provide information relevant to many of them and others we did not have readily available. So what we were able to do is encoded in the LTR and also was presented to the subcommittee was determine reasonable assurance by increasing your uncertainties what is the additional margin that you would want to add.

And for instance, for the safety limit, you know, that analysis concludes you need about a .01 to address those uncertainties. In the end we landed on a .02 which, you know, is sort of double the margin, there's plenty of margin there to address EPU condition and also to address, for instance, questions of on the void correlation, a .01 operating limit or additional margin was provided.

For MELLLA plus, again, since we don't have plants operating there yet, additional margin, what this does is pushes the fuel farther back from the expected conditions of where you would, you know, if you were operating on the limit and had your worst case transient, et cetera, you're pushing that off and providing additional --

DR. BANERJEE: The .03 is because of the lower flows in the MELLLA plus projection with the same power? I mean, just a physical reason for it?

MR. MOORE: Well, I think because we don't have a lot of benchmarking, if you consider it in steps, you go to EPU and then you -- most of the time you go to EPU and then you go MELLLA plus, we don't have some of this benchmarking data yet at EPU conditions. So we're obtaining that now. Once we get that, then you can say that perhaps, we can reduce the margins down to that incremental additional -- the staff is being prudent here to say there's plenty of margin that needs to be provided for that --

DR. ARMIJO: But for a plant like Vermont Yankee at EPU conditions, if they decide to implement MELLLA plus, the impact would be only at .01 change in the safety limit MCTR.

MR. MOORE: Because they already have under their EPU license approval they already have a .02 additional margin.

DR. ARMIJO: So that's what this means.

MR. MOORE: That's my understanding, yes.

MS. ABDULLAHI: Excuse me, say that again.

MR. GANT: It would be a .01 on the safety limit and an additional .01 on the operating.

DR. ARMIJO: Not the way I read this. We're talking about a plant like Vermont Yankee that's operating at extended power uprate. If they were to go ahead and implement MELLLA plus, the impact would be just simply a change of .01 in the safety limit and

CPR. That's it.

MS. ABDULLAHI: The thing is, when we reviewed the Vermont Yankee, we had a .02 applied but we didn't have the .01 for OLMCPR applied at the time.

DR. ARMIJO: Oh, I see, so this is --

MS. ABDULLAHI: So what I mean, they come for MELLLA plus if the data is all fixed up. They will get .01 from EPU to MELLLA plus and they will get a .01 on the OLMCPR which comes --

DR. ARMIJO: So if they come back for a reload analysis, you will catch them with this additional .01 operating limit?

MS. ABDULLAHI: No, the --

DR. BANERJEE: MELLLA plus.

DR. ARMIJO: No, without MELLLA plus.

MS. ABDULLAHI: The reload, we don't do anything. The reload is approved in GSTAR 2 which is GE goes off and does the reload on their own. Only when we have an application in-house can we do the regulatory.

DR. ARMIJO: I want to make sure I understand. If GE had and provided all these other data where there's mikes, would these MELLLA plus limitations disappear or be reduced?

MS. ABDULLAHI: They can go or they can

come back higher depending on what the data tells us.

DR. ARMIJO: Right assuming the data -- the other thing is, are those blanks, do they mean that you're -- the staff is never going to see that data or that GE is going to provide it later?

MR. KINGSTON: No, no, that means we left it as a blank. It means something we owe and we're going to bring to the staff to review. And these are all, you know, underway. We're gathering gamma scan data and this other data at plants, you know.

DR. ARMIJO: So that's within some time period that you would come back to the staff with the data.

MR. MOORE: Yes, we've committed to the staff to get them a good portion of the gamma scan data and on pressure drop and some information on void fraction by the end of this year. The data that we've obtained so far which was presented to the subcommittee indicates that there's no need for additional margin, so it's a good result, but we're continuing to pursue, you know, getting this and it will be then evaluated by the staff for the final determination.

DR. BANERJEE: Okay, let's move on. Did you want to say anything about the bypass voiding or you can summarize it then?

MR. CASILLAS: If you have a question on it.

DR. BANERJEE: No, no, I don't.

MR. MOORE: We're just simply saying that there are other limitations with regard to the methods that are included in the safety evaluation and you know, many of those are GE specific process items. The awareness of bypass voiding and what it does or needed to bound it with your coritizon (phonetic) on a regular basis and addressing calibration issues for stability set point determination, there's other items as well. I didn't want -- feel it was necessary to list them.

DR. BANERJEE: No, I think it's fine. We asked you to focus on two or three of the major limitations.

MR. KINGSTON: Just recapping the MELLLA plus flow window, it's very beneficial in needing to efficiently operate the plants at EPU power levels and again, we're seeking the ACRS acceptance of the use for the methodology in the MELLLA plus report and the supporting topical reports in the plant-specific application for EPU and MELLLA plus.

DR. BANERJEE: Okay, thank you very much, a nice presentation. We'll turn it over to the NRC now.

MR. CRANSTON: This is Greg Cranston again. The NRC, for this next portion it will be the NRC staff presentation. The lead reviewer is Zena Abdullahi. And she has assistance from Oakridge National Laboratory consultants and Jose Marche-Lueba.

DR. BANERJEE: Are we in open session or closed session now?

MS. ABDULLAHI: Open.

DR. BANERJEE: So please, Zena, try to finish by 12:15.

MS. ABDULLAHI: Okay, I'll speak faster. Jose will speak even faster.

DR. BANERJEE: No, he can't speak faster. As it is we have trouble understanding what he says.

Mr. Marche-Lueba: I'll tell you what, I'll stay quiet.

MS. ABDULLAHI: Okay, this is an open session, so what we did is we -- since the data doesn't belong to us, we are presenting basically a much more overview than we did in the subcommittee meeting but I believe we provided you with also the subcommittee slides and so we have also provided you with an ATWS instability proprietary version and a non-proprietary version. We may cover the non-proprietary but the proprietary we cannot cover or talk of it unless GE does a waiver again and I don't think they will in this case.

Okay, I think GE on the -- before I go into the detail, I want to point out that these topical reports had an extensive number of people reviewing it. We spent a lot of energy and I think GE also spent a lot of time and energy as well, and one of the reasons we did this is because we felt that as you can see from the out-power flow map, the plant was designed initially within the blue -- within the green zone of what was called the original license thermal power 100 and 100.

And it progressively changed and each progression had some impact. So when we went through the EPU we thought that, oh, okay, this is a major impact, let's pay attention, 20 percent above. And now we're talking about 20 percent above the original license thermal power and then the core flow, lower core flow. So we took this LTR quite seriously.

What we are approving is revision 2 of the LTR which means revision 1 took into account many, many REI changes and incorporated and methodology changes. So what we're coming to you to ask you for approval, we're telling you that we have spent -- we have taken it seriously and there is sufficient changes made within the process being asked that plants will implement when they do EPU. So -- and we have -- we have -- NRR now feels there is sufficient assurances that plants can meet the regulatory and safety requirements.

DR. BANERJEE: but you have also put a fairly large number of limitations.

MS. ABDULLAHI: We did.

DR. BANERJEE: And the subcommittee saw a certain set of limitations but I now notice that there is a document saying -- are there any changes to these limitations that you've made since the subcommittee meeting?

MS. ABDULLAHI: No, this document, actually we sent you May 23rd, and I think our meeting was May 24. And the reason we sent you this is -- I'll give you a little bit of background. I'll speak fast because we don't have much time.

In general, whenever we write an SCR, that SCR is issued to the vendor for comments, both proprietary or technical comments. That's one aspect. Another aspect is that from the Maine Yankee lesson learned, you want to make sure that licensees and fuel vendors understand how they apply that limitation. So there has to be a resolution and understanding on both sides.

Limitations were issued to GE. GE had sent us a large number of comments. We have reviewed those comments. We agreed on some of them which is just a question of clarification purposes. Some cases we have been at it for a long time and GE can attest to that. And but since these agreement was done after we issued you the SCR, we felt it's important that we give to you the changes, submit the changes to you.

DR. BANERJEE: But since the subcommittee meeting there have been no changes.

MS. ABDULLAHI: No, but there are one particular limitation that we are still working on but I don't think that particular limitation will effect the conclusion.

DR. BANERJEE: Is that tech spec?

MS. ABDULLAHI: Yeah, it's mostly tech specs.

DR. BANERJEE: Is that a tech spec related to ATWS?

MS. ABDULLAHI: Yes.

DR. BANERJEE: We would like to be informed of that if there's any change because we are very interested in this.

MS. ABDULLAHI: We could do that by submitting it to you or do you want us to give you an idea now, because it's a question of timing?

DR. BANERJEE: No, just carry on your presentation. We'll come to this at the end.

MS. ABDULLAHI: Yeah, but the only thing, that limitation was giving it to you because we made changes which differs in Chapter 12 of the SCR, so you needed to know, that's all.

DR. BANERJEE: We'll revisit your limitations at the end.

MS. ABDULLAHI: Okay, this is the inter-related topical reports that support MELLLA plus. MELLLA plus had an impact on instability. As a result of it, GE had developed a specific methodology called DSSCD in which stability is detected and suppressed. Because in order to demonstrate that when stability occurs the safety limited minimum critical power ratio would not be exceeded, GE also submitted TRACG G for DSSCD. TRACG G is actually --

DR. BANERJEE: So we never reviewed that?

MS. ABDULLAHI: Yes, yes, Dr. Banerjee, right. Those two topical reports were approved but you haven't --

DR. BANERJEE: Without review by ACRS.

MS. ABDULLAHI: Without review, however, the person who approved it and reviewed it was Tai Han, who is not here. However, Jose, who was the technical had, during the subcommittee provided you with any information. This is the reason why we included in the subcommittee meeting the second on DSSCD.

DR. BANERJEE: But I think this is important enough that things like this have to come to ACRS.

MS. ABDULLAHI: I think that's a management issue.

MR. CRANSTON: This is Greg Cranston, Branch Chief for systems.

DR. BANERJEE: How are we going to deal with this otherwise?

MR. CRANSTON: Yeah, we can do that if you desire. We also made a brief presentation, it was very brief, in conjunction with the standard review plan that had to do with reactor stability where we covered a general overview of this approach.

DR. BANERJEE: Yeah, I remember that, yeah.

MR. CRANSTON: So if the ACRS would like

to see something --

DR. BANERJEE: These are pretty major items, you know. And I was just going through it to understand what converting studies have been done with TRACG G. Whether it was explicit, what the Courant numbers were. There were a huge number of issues there which should have been -- perhaps you dealt with it, we never saw it. I mean, if we had access to it, we would have gone over it with a fine tooth comb for sure.

MS. ABDULLAHI: I think that's a comment for the record, and NRR.

CHAIRMAN SHACK: That's up to the Committee to decide whether we can proceed without doing that, so just go ahead at the moment.

MS. ABDULLAHI: Yes, we did cover, because we knew it was important, we included in our subcommittee meeting. Now MELLLA+ LTR defines the scope of work and the analyses that will be provided on plant-specific basis. In the subcommittee, I provided you with a table that specified with fuel-dependent analysis will be provided on plant-specific basis. I could not present it here, because that would be proprietary information. But if you look to the subcommittee, you will find out.

Plant-specific application, as mentioned earlier, will, in fact, be submitted, and it will come to the ACRS member for each plant. So if Brunswick decides to implement MELLLA+, Brunswick application to MELLLA+ will come to the subcommittee, and then approval will go through that process. So you will be able to look at it and decide from there.

And now, the interim methods LTR, NEDC-33173P, supports both the plant-specific MELLLA+ topical report, and the EPU applications. So that is how they are all interconnected, and this is what this slide is trying to explain.

Now MELLLA+ approval is contingent upon compliance with the limitations specified in the Staff SER approving the latest versions of the three LTRs, basically.

DR. ARMIJO: The yellow box for the interim methods invokes the earlier approval of TRACG?

MS. ABDULLAHI: No. Say that again?

DR. ARMIJO: It invokes the earlier approval of TRACG for stability calculations that ACRS had not reviewed.

MS. ABDULLAHI: You mean the TRACG for DSSCD?

DR. ARMIJO: Right.

DR. BANERJEE: No, he's talking about interim methods.

DR. ARMIJO: These interim methods that are supporting these applications.

MS. ABDULLAHI: Right.

DR. ARMIJO: This NEDC-33173P.

MS. ABDULLAHI: Yes.

DR. ARMIJO: Implies prior, or invokes prior approval of TRACG.

MR. MARCHE-LUEBA: There are TRACG calculations which are included, to justify the conclusions from that LTR. So you are correct.

DR. BANERJEE: That's what my concern was always.

MR. MARCHE-LUEBA: Now the TRACG report that you did not get to review is this one right here.

DR. ARMIJO: Correct.

MR. MARCHE-LUEBA: 33147P, that's exclusively for use with the DSSCD application. There are other reports on validations of TRACG that allow you to use with ESBWR, there's another report for ATWS instability calculation. There's another application for calculation of the divom curve for TRACG. So the only TRACG LTR you didn't see is four calculations specifically for DSSCD.

DR. ARMIJO: Okay.

DR. BANERJEE: Which is a very important part of this.

MR. MARCHE-LUEBA: It is. That's why -- we even though these reports have already been issued and approved, we intended to present to the subcommittee because we thought you would be interested. The judgment from the staff point of view, from the DSSCD point of view, is a minor incremental change versus solution three.

DR. BANERJEE: But we understand because you're adding CD to it.

MR. MARCHE-LUEBA: Right. Solution III+, and, therefore, at the management level, we decided that ACRS probably doesn't want to be bothered with this minor incremental thing. TRACG, they should have noticed that you would -- we agree with your statement.

MS. ABDULLAHI: Okay. What I tried to do overall here is just basically define with MELLLA+ is. I'll skip that part at this point because he has the right, good job of that. And the SC covers all this information. I'll just present what fuel dependent analysis that are affected, the details of that we covered during the subcommittee meeting, and I believe that slides are available.

We were going to discuss ATWS instability impact, but I suppose we could skip that for now. And then we'll cover some parts of the interim methods. I'll pass power flow map, slide four, pass slide six, let's go to slide 7.

From our review, we found that yes, MELLLA+ does affect fuel dependent analysis. And one of the reasons it affects, obviously, is because of the fact that MELLLA+ would be EPU++ in a sense that you would be at 20 percent higher power level, and then you would have a lower flow conditions. So, in a way, we thought about it as EPU++, so anything that deals with fuel dependent in terms of a rod lining, or in terms of bundle conditions, then it would affect.

Some other effects are impact on stability response, impact on ATWS response, impact on ATWS instability response, impact on the ECCS-LOCA response, and the impact on the SLMCPR. These are just some of the main ones.

Now for the stability response, you have the DSSCD protection system specifically designed for MELLLA+ operation, and we found that that was very acceptable. The ATWS response was a very big review, and there's been --

DR. BANERJEE: Let ask you something here. Did you -- were you able to use something like TRACE to look at the stability, as well? I'm sort of accepting that TRACG is okay, since you approved and we've never seen it.

MS. ABDULLAHI: I had --

DR. BANERJEE: But did you do anything else?

MS. ABDULLAHI: I had an ISL report that was supposed to circulate. Did you see that one? I made one colored copy, and it was supposed to move from member to member. But I gave you a CD, and that CD contains actually the ISL report.

DR. BANERJEE: But what the -- there was confirmatory analysis done of this?

MS. ABDULLAHI: Yes. And I could jump to that.

DR. BANERJEE: That's all right, but say yes or no.

MS. ABDULLAHI: Yes.

MR. MARCHE-LUEBA: Not necessarily TRACE. You also use frequency Domain Lapulco for stability, outside the ATWS domains.

MS. ABDULLAHI: For the record, that is the ISL report we received, and with effort we tried to do a confirmatory. Our intention in SOW included instability, and included ATWS isolation, isolation ATWS.

DR. BANERJEE: And what code was used here?

MS. ABDULLAHI: TRACE-PARKS, PARKS-TRACE.

DR. BANERJEE: Successfully coupled for this, but not for ATWS?

MS. ABDULLAHI: No, it was ATWS, and it --

DR. BANERJEE: Why wouldn't it work for ATWS instability then?

MS. ABDULLAHI: At the time, okay, we were told that in order for it to model ATWS at the time, it would need to be perturbed. We had to put in the power perturbation from some other code.

DR. BANERJEE: And if it's coupled to PARKS?

MS. ABDULLAHI: At the time, PARKS was not settling in --

MR. MARCHE-LUEBA: Research has been doing some research on Purdue, use of Purdue at Penn State on getting TRACE-PARKS to work for stability, and they have had to -- they have several versions of TRACE that are able to do it. And we do have some slides that shows the --

MS. ABDULLAHI: Yes, we can handle that.

DR. BANERJEE: Let me ask you this question; imagine that we are going to be faced with MELLLA+ for different plants with maybe mixed fuels, and all sorts of things in the future. How are you going to do confirmatory analysis?

MS. ABDULLAHI: We have a slide on PARKS-TRACE. You told us to go to Research, find out what to do. We went, we talked, they gave us information, so if we go through this, we'll go to those slides.

DR. BANERJEE: Okay.

MS. ABDULLAHI: And you should have those slides there.

We haven't performed ATWS confirmatory analysis, and the intention at the time was to see what was the impact on isolation ATWS. And we have determined a couple of very important things at the time, which is the operator actions was not being modeled by the code that was being used, and the resolution was that GE would actually use a TRACG calculation to model the depressurization if the heat capacity temperature limit is reached.

We have also reached -- actually, I think we made it a lot more safer in that GE has agreed -

now I don't know, this is proprietary, it's one of the limitations. Randy, is it proprietary, heat load?

MR. GANT: No.

MS. ABDULLAHI: Okay. Good. We had to write a letter recently on proprietary, things we believe, so I'm being careful.

One of the many important things that we have come through this review with GE is that the actual boron concentration will be increased so that --

DR. BANERJEE: Enriched.

MS. ABDULLAHI: Enriched, Boron-10, so that the heat load will remain the same to the original license thermal power.

DR. BANERJEE: That's been agreed on. Correct?

MS. ABDULLAHI: We agreed on that.

MR. MARCHE-LUEBA: For the plants that need it.

DR. BANERJEE: For the plants that -- they're not --

MS. ABDULLAHI: It's an option for plants.

DR. BANERJEE: Okay. Can we move on?

MS. ABDULLAHI: Okay. Well, we covered all of this issue in the subcommittee, and we satisfied ourselves that with these changes, that would work. I only want to add a few things in conclusion. One of them is that we did perform a comprehensive review, because of the reactor condition and plant response being outside the current experience base. We had some significant findings. We have proven Version 2. We have performed confirmatory analyses, where feasible. And we also have looked at the methodology being used in order to get assurances --

DR. BANERJEE: Before you go off so quickly for the main committee, I'd like to say that the reactor physics confirmatory analysis was quite comprehensive and excellent. The thermal hydraulic confirmatory analysis was not.

MS. ABDULLAHI: TRACE doesn't work at the time.

DR. BANERJEE: Well, something has to be done about it.

MS. ABDULLAHI: It works now. Let me run to that particular TRACE --

MR. GANT: We have some slides on that.

MS. ABDULLAHI: That was supposed to be thermal hydraulic. The staff concludes that the expanded operating domain defined by the MELLA+ upper boundary does adversely impact fuel dependent analysis. However, without plant modification, some BWRs cannot implement MELLLA+ operation and meet the safety and regulatory requirements.

What that means is, if you have a peak pressure, and you don't have enough SRV capacity, then you would have to do some plant mod, increase the throat of the SRV, put another SRV in, or whatever you have to do to be able to survive. Other thing is, the option available to them increased the boron so that you would not have early shutdown.

Now the extent of the expanded operating domain, BWRs can implement and meet the safety and regulatory requirement will be highly plant-specific; which means, that if you have a plant that is going back to Otto's last question, is LOCA-limited. Okay? And LOCA is impacted by the low flow condition, maybe would not go all the way. You may have to go less to maybe 90 or 80. If the plant -- and another thing is, while they are design goals, it's possible that plant when you have this high operating domain with much lower flow conditions, that that particular plant may not be able to operate at that power level, so that it can hit that bundled condition, and meet the operating limit, so that it may have to reduce it. So there are a lot of plant-specific conditions.

The main objective of our review was to define what analyses are affected, are we going to get it on a plant-specific basis? First, we want to get a feel of what the change impact would be, and then are we going to get it on a plant-specific basis? And, basically, MELLLA+ operation is acceptable with the limitations specified in the Staff SERs.

Now for the methods, we also have done quite an extensive review of the methods.

DR. BANERJEE: So I think for the committee, the issue will be do we want to write one letter, two letters, one on methods, one on MELLLA+. Look at it from that point of view.

MS. ABDULLAHI: Yes. The method is basically ensuring that when you predict a certain calculation, you predict that the PCP is this amount, or you predict that your SLNCPR is this value, how much can you rely on that?

I'm going to skip fast to Item 13.

DR. ARMIJO: I have a question.

MS. ABDULLAHI: Yes, sir.

DR. ARMIJO: If we're going to write two letters, why would we do that? Are there two applications, or just one application?

DR. BANERJEE: Well, let Zena speak to that, maybe. I have a view of this, but I don't --

MS. ABDULLAHI: Go ahead.

MS. HONCHARUK: This is Michelle Honcharuk with NRR. We do have in-house two separate applications for review. The interim methods came in under one cover letter from GE, and the MELLLA+ came in under another, so we've been tracking them with two different review schedules, two different tag numbers, and whatnot.

As far as a preference, whether one or two letters, if you're able to issue one letter in a timely fashion that covers both, that's fine. But if there is some sort of holdup on one or the other because of some outstanding issue, then we would request that you do separate them out, so that we can move along closure path for the one where there aren't any issues.

DR. BANERJEE: Right. We may write a letter on methods, if we wish, and not on MELLLA+. Or we could write two separate letters, whatever. Any combination is possible.

MR. CRANSTON: This is Greg Cranston. The other comment I wanted to make, too, is that there's plants that are submitting applications where if the methods was approved, we'd be using that in conjunction with their EPU. They may not be going for MELLLA+ right away, and, therefore, if we had the methods through the process, and there was something associated with MELLLA+ that we wanted to pursue longer, then that wouldn't hold up any of those plants.

MS. ABDULLAHI: In the methods review, we basically looked at extension of the neutronic methods to high void, impact of bypass voiding on the reliability of neutron monitoring systems, adequacy of available correlation, and model qualification databases.

We did do a confirmatory code-to-code comparison, both on the thermal mechanical. We did a FRAPCON calculation on thermal mechanical, and then we also did the HELIOS comparison on the code-to-code.

DR. BANERJEE: Are you going to talk about the FRAPCON results, or give some indication --

MS. ABDULLAHI: Roughly, I do, but we did have a section, a thermal mechanical section during the subcommittee.

DR. BANERJEE: I mean for the full committee.

MS. ABDULLAHI: Yes, I have some vague

part -- the SC has a whole section on the FRAPCON table, and data, and everything else. So the conclusions of our review are basically, there would be a .02 applied to the SLMCPR, and a .03 will be applied for EPU, and a .03 will be applied to the MELLLA+.

DR. CORRADINI: These are -- just to be back to when you discuss at the subcommittee, these are additive.

MS. ABDULLAHI: These are additive. On cycle-specific basis, the SLMCPR is calculated on cycle-specific basis.

DR. BANERJEE: They're like a Delta CPR in some ways.

MS. ABDULLAHI: Right. It's after you have your cycle-specific value, you'll up this adder. And we think this is quite significant margin. And licensee, I'm sure will be happy to tell you that it is --

DR. CORRADINI: Too much.

MS. ABDULLAHI: Yes. But it's based on some sort of a judgment, and data, looking at old data, picking up 95 of that data, perturbing it in single parameter, pin peaking, and bundle peaking, and then coming out with a .01 from there. And then that's how we -- it's not like pick it up from the lower kind of parameter.

DR. BANERJEE: There were some Monte Carlo calculations done or something. Right?

MR. GEHIN: This is Jess Gehin, Oak Ridge. A part of this came from the code-to-code confirmatory to get some basis on the possible errors introduced from the high void fraction operation, without the lack of the data that staff would like to have to get a basis to see -- to feed those uncertainties into the calculation of the Delta CPR to come up with these. So there's a process that was followed to quantify these SLMCPR adders. And then, actually, the values were actually increased over what came out of that process.

MS. ABDULLAHI: Let me add a clarification, since this is an important part. What you have is, in the SLMCPR process, you would have - the core will be modeled at certain steady state conditions, where you would model at the beginning of cycle, middle of cycle, end of cycle. And there's quite a lot of statistical involved. Among those are uncertainties, specific uncertainties that you apply, which are pin peak and uncertainty bundle, bundle uncertainties, four bundle uncertainties, core flow uncertainties, and you perturb around the steady state condition, and then you see how the number of -- whether you would meet 99.9 percent of the fuel bundles were not experiencing void and transition.

Within those you have a case where you have a certain uncertainty in the bundle and the pin which you would obtain from gamma scan, and it was obtained from gamma scans in the past. So those were not available, and GE then did a conservative approach, which is okay, gamma scan will take a while to obtain for GE-14, for the new fuel design, the new peak and clad factors, all these other things that affect the SLMCPR. Am I proprietary?

MR. GANT: Yes.

MS. ABDULLAHI: Am I getting close? Back-out, then. You want to go ahead and do it?

BM: Yes. We would like you not to discuss the process --

MS. ABDULLAHI: Which you came up with.

BM: That's correct.

MS. ABDULLAHI: I close it at that point. All I'm saying is that we did come out through a process how we achieve this .01 and .02.

DR. BANERJEE: Yes, the subcommittee understands that, but unless we're going to --

MS. ABDULLAHI: Thank you. Yes, so now we also looked at the Findlay-Dix correlation, we went to the source document, and we looked at the conditions that we have today in the core.

DR. BANERJEE: You know our concern about that, of course.

MS. ABDULLAHI: Right.

DR. BANERJEE: Because this is a drift-flux correlation.

MS. ABDULLAHI: Right.

DR. BANERJEE: Which is being used outside its development range physically, so there's no physical basis for this. This is purely --

DR. CORRADINI: Mathematical correlation.

DR. BANERJEE: It's purely a curve fit, at this point.

MS. ABDULLAHI: Right. And the data is -- we found it quite limited, and so GE and the staff agreed that assuming a certain percent of uncertainty, and then propagating that uncertainty over, then we came up with this adder.

DR. BANERJEE: Well, this has more implications than that, because it goes into the ODIN code, which is used for ATWS. So I think we shouldn't pass over this too lightly.

MS. ABDULLAHI: Pass over? You mean, explain it?

DR. BANERJEE: Yes, because it is not -- something like TRACG does it more mechanistically, and this -- I'm more concerned about things like ATWS.

MS. ABDULLAHI: Okay. Well, this .01 is applied to the operating limit.

DR. BANERJEE: Yes, that's right.

MS. ABDULLAHI: And as a result of it, you are getting not only a margin on the safety, you're also getting a margin on the operating limit through the void reactivity coefficient. You're saying if I am off my voids fraction by this amount, how does that affect my reactivity, void reactivity?

DR. BANERJEE: What correlations are you using for the bypass voiding?

MS. ABDULLAHI: Calculation of the bypass voiding?

MR. MARCHE-LUEBA: Same separation.

DR. BANERJEE: But you can also do bypass voiding with TRACG. Right?

MR. MARCHE-LUEBA: That's correct.

(Simultaneous speech.)

MR. MARCHE-LUEBA: Dix-Findlay is used for ATWS, is used for most of the AOOs, and is used for a steady state in PANACEA to calculate, so when you're talking about a CPR correlation, CPR does not involve a fraction, but a calculation of CV in PANACEA is --

DR. BANERJEE: It fits back into all the reactor physics. Right?

MR. MARCHE-LUEBA: It fits into the reactor physics. Correct.

MS. ABDULLAHI: And there are RAIs that staff is reviewing in sufficient detail TRACG right now, and that issue of the coupling with Findlay-Dix is being reviewed there.

DR. BANERJEE: There's been a remark made - I don't know, public or not - but that this is straining the database that was existing in the 70s and 80s, and the correlations perhaps beyond their breaking points. And I don't see that 60s or 70s or reflux models that Graham Wallis and Novak Zuber developed was state-of-the-art then, necessarily need to be applied to something else, sort of crucial right now, where your reactor physics becomes very dependent on what's happening there.

MS. ABDULLAHI: I think in terms of thermal hydraulic and conversion to TRAC -- a couple of comments I want to make about this now. Because of MELLA+, we did this detailed evaluation. And because of MELLLA+, now GE actually has taken a big effort of gamma scan data that it's developing and getting, and it's already showing us some preliminary data, so I consider that a positive.

Secondly, in terms of the transition, most BWRs who go to MELLLA+ may probably transition to TRACG. And, in fact, I think we had some limitation, or some discussion of that in the SC, because they get a margin. It's a best estimate. ODIN had some, how do you put it, conservatism. It has some conservatism in - can I discuss the conservatism? I don't know. But it has some conservatisms. All codes were not as good, but they used to have a lot of conservatism applied. New codes you refine, and you reduce the conservatism, so many plants will probably transition to TRACG.

DR. BANERJEE: There's a good physical reason for doing it?

MS. ABDULLAHI: Yes, but there you want to have the benchmarking to be improved, as well. So the void quality correlation, basically, our conclusion is a .01 will be added until we resolve the data supporting the correlation. And now, the thermal mechanical, I did not --

DR. BANERJEE: How will you get this data, because at this high void fractions, making measurements is extremely difficult. It's like Heisenberg's Uncertainty Principle. I don't see how you can get the data, unless you use neutron scattering, or something.

MS. ABDULLAHI: Well --

DR. BANERJEE: Will you submit the data to us to look at with a critical eye?

MS. ABDULLAHI: Actually, if a review - any review you suggest to get follow-up, I think you have the right to --

(Simultaneous speech.)

DR. BANERJEE: GE, can you speak, please, what you can tell in open session about this?

MR. ANDERSEN: Okay. The question is on the void fraction?

DR. BANERJEE: Yes. How do you get it?

MR. ANDERSEN: Well, the void fraction data, I mean, we presented some of it at the subcommittee, and the proprietary information were presented. The void fraction data would derive from bundled data. We have 4X4, 7X7, 8X8 bundled data, most of these data were taken using gamma attenuation. Some data were taking using quick closing valves that measured the liquid content between two different valve locations. The range of the data is large enough to cover current operation.

It is correct that we don't have any void fraction data for 10X10 fuel, but if you look at the range of the parameters that exist in the bundles, it's not significantly different from the range that was used in the original data.

MS. ABDULLAHI: I think I totally disagree, obviously, as the staff. We went through -- extensively gone through the source documents, and we looked at the type of data. We're talking about the raw bundled data, we're talking about the CHEESA data, we're talking about data that even when you do have data, the parameters which those data are based on are not lined up. It's like you may have a void up to 95, but the flow is this amount, and then here might be equivalent raw diameter here. You don't have it all lined up. We even went out of our way to look at the world data and try to check if the Dix-Findlay data fits the world data.

DR. BANERJEE: But I think the main thing is that high void fractions, you're really looking at the liquid fractions, because that's what is doing the moderation. And, of course, also the bypass. But in this case the issue is what is the uncertainty in the liquid fraction, and that is substantial, of course, because even with quick closing valves, if you close one valve slightly differently from the other, you capture quite a different amount of liquid. And gamma at this range is very insensitive, so if you are going to fill in this database, that's why I was saying it's a little bit Heisenberg's Uncertainty Principle - how are you going to do it? I mean, the only way that I know of to do it is by using either neutron scattering, or neutron absorption in this range. I know of no -- you may know other methods, but I don't know of any other in this high void fraction, so how are you going to fill it in? Maybe you should just take this and say forget it. We'll never be able to do anything with it.

DR. ARMIJO: That may be a practical option, because it may be less -- you're going to spend a lot of time and money chasing this, and it may not work.

DR. BANERJEE: I know, and what is sort of worrying is that you guys have been dismantling your facilities. You had this beautiful facility that maybe with neutrons you could have done something. But now, what are you going to do? Do you have an answer?

MR. ANDERSEN: Well, I can't make any specific commitments for GE. And while there is some disagreement as to what is the adequacy of the range, we do agree that if you account for the additional uncertainty that Zena is discussing, that would be covered by the .01 increase in the operating limits. And so we have agreed to take that additional margin until we obtain such data to justify a removal of that margin.

DR. BANERJEE: The question was, how do you get the data, if you try to get it?

MR. ANDERSEN: Well, that's a different issue. What we do do, is that we do perform full-scale data of the pressure drop, which is what allows us to know what the flow distribution is in the core. We do perform full-scale data for the critical power, which is what allows us to determine the margin to thermal limits, and we do do the gamma scans, which provide us information on the power distribution uncertainties. And that is what you need in order to justify your margin to the thermal limits.

Now you could postulate that there are compensating errors, and your void fraction may be wrong, so that's why we agreed to stay with the additional margin of .01. That's how we get additional data.

MS. ABDULLAHI: Yes. And, in fact, we did ask GE, actually, and they are working on and submitted some information we asked them to do, to back-calculate from their pressure drop data low flow condition to back-calculate what the void fraction would be, and then get it on an axial level so we can see how at low flow condition they -- Dix-Findlay performs axially, not average, so we see what impact a half part would have, et cetera. And so, they may do stages in their submittal.

What we did in the thermal mechanical is, we performed the FRAPCON calculations, and the staff -- of a GE-14 fuel design. We looked at the internal rod pressure, and the thermal overpower, which is the fuel center line -- affects the fuel center line melt acceptance criteria. And the mechanical overpower, which the acceptance criteria is that you would meet the 1 percent geometric strain acceptance criteria.

Now on a separate review, the Staff in the ESBWR had actually found out, also, that they -- that GSTRM under-predicts by as much as, if I recall correctly, 425 degrees the fuel center line temperature. They also found that the FRAPCON calculation in their case was consistent with a prime, which is a new GE methodology.

DR. BANERJEE: That's not being asked to be approved in the methods. Right?

MS. ABDULLAHI: No, we're not approving it. This is just to tell you that anything that will change the method in the future, we will just let you know now so that what you approved, if we amend, or change, we have given you a forewarning that this is what we'll do. That's all the purpose of GSTRM work.

DR. BANERJEE: But is GSTRM in the package of methods that you're asking us to approve?

MS. ABDULLAHI: Yes, it is.

DR. BANERJEE: So what --

MS. ABDULLAHI: What conclusions did I reach?

DR. BANERJEE: Yes.

MS. ABDULLAHI: The conclusions we basically reached is that a fuel center line temperature - a couple of conclusions. Let's go to the next slide. Did you get there?

The fuel center line temperature, we found that their uncertainty treatment compensates for it. Therefore, we're not going to take any further action. We also found that their qualification database here is very limited in that especially, the internal rod pressure data is up to 20, I think, gigawatt days/metric ton. Fuel center line temperature was only up to 30, and the data itself is 25 years old, and it does not represent what you expect the fuel rods to be today.

DR. BANERJEE: In fact, your consultant, Carl Beyer, was at pains to point this out to the subcommittee.

MS. ABDULLAHI: Right. We pulled him in because when we saw that, we asked them to do a Part 21 evaluation, they came back with an answer to the Part 21 evaluation. We were not comfortable with the conclusion of it, so then we pulled Carl in to weigh-in on his outlook. And he confirmed that, in fact, he had concerns also, from what he saw.

The conclusion is Part 21 will be reopened. We'll ask them to reopen the Part 21. We will write them a letter. We feel, at this point, the concern lies on two-fold. One is the rod internal pressure calculation not under-predicting at the end of the life. The second one is that GE needs to update its gamma scan, or raw puncture, but their internal rod pressure calculations, benchmarking has to be done and updated. We have commitment from GE, and some conversation back and forth since 2005 on this.

DR. BANERJEE: Shouldn't they be comparing this with --

MS. ABDULLAHI: World data?

DR. BANERJEE: Yes. More modern data.

MS. ABDULLAHI: That is another issue that came up, is that they take GSTRM and they go back -- since the gamma scan or whatever data they're going to take will take a while, that they take GSTRM and, in fact, compare with the data they're using now for PRIME and re-evaluate, re-benchmark using new data. So that's --

DR. BANERJEE: PRIME replaces GSTRM. Right?

MS. ABDULLAHI: For MELLLA+, it's required that when NRC approves limitation, and this is how limitations work, it's like when NRC approves PRIME, which is the new code, then the plants will transition to PRIME. So that is the long-term solution for EPU MELLLA+. On the other hand --

DR. BANERJEE: So what is the limitation on this currently, that they have to have a certain very conservative calculation?

MS. ABDULLAHI: There's nothing on it right now on GSTRM, except the transitioning, and the commitment to perform benchmarking. But it's going to be addressed in this Part 21 follow-up work. That's why we present it to you, because the SC does not contain this, in terms of how we concluded in our review.

DR. BANERJEE: Well, what does ACRS do with the methods part of it?

MS. ABDULLAHI: The methods we have --

DR. BANERJEE: This will be excluded from that, until you resolve Part 21?

MS. ABDULLAHI: Yes. We have a statement in there, I think we have a limitation in there dealing with a Part 21, which says the conclusion of the Part 21 will be applicable. There is a little clause in there that we may have to work with it, but there is some discussion. We discuss the Part 21, but it says that we're expanding. Now we are closer to --

DR. BANERJEE: So what you're saying is if we concur with the staff SC on this, including the limitations, then this issue will be handled under that limitations.

MS. ABDULLAHI: Yes, separately. It will be concluded separately, but we will provide you with whatever conclusions we reach.

DR. BANERJEE: Right. Right, eventually, but right now, we have two letters to write. Right?

MS. ABDULLAHI: In terms of your letter right now, this Part 21, already there's a limitation there that says the conclusion of the Part 21 will be applicable.

DR. BANERJEE: Okay.

MS. ABDULLAHI: And what we presented to you is what we think our conclusion is right now, as of now.

Staff reviewed the applicability of GE methods to EPU and MELLLA+. The staff determined that some of the analytical method used to predict the EPU conditions need additional validation data. Hence, additional margins were applied in some of the methods as an interim. And, basically, that concludes my overall slides. If we have time, we would like to go to the TRACE-PARKS discussion.

DR. BANERJEE: Can you do it in five minutes?

MS. ABDULLAHI: Jose, speak fast, faster?

MR. MARCHE-LUEBA: I can only show you some plots, so if you wanted to see data - we can skip the word slides, go directly to the plots. So thanks to Tony Ulses, which got a degree from public university was ready for the -

DR. BANERJEE: Who is this?

MR. MARCHE-LUEBA: Tony Ulses made this calculation.

MR. ULSES: Of the Office of Research, I actually ran this calculation within the last week since we spoke last, I guess a week and a half since we spoke last.

MR. MARCHE-LUEBA: Okay. And so --

DR. BANERJEE: And you had a Ringold's deck.

MR. ULSES: Yes. We had a Ringold's deck that we've been using.

DR. BANERJEE: Okay.

MR. MARCHE-LUEBA: Research has been doing some work on developing this. And you used a special version of TRACE. Right?

MR. ULSES: Well, we're using a version of TRACE, I don't want to call it a special version of TRACE. I mean, as we look at these things, if we have a question about a model, I mean the code, we'll have to take a look at it, obviously. Right now, we took the version of TRACE that we are currently evaluating for ESBWR applications for AOOs, I guess the short answer to that question.

DR. BANERJEE: Okay.

MR. MARCHE-LUEBA: The purpose of this slide is to show you that TRACE can't do the job. It still has not done the job. This is the first step into the ATWS stability transient that we were talking about.

DR. BANERJEE: Can you show the earlier part of it?

MR. MARCHE-LUEBA: Yes.

DR. BANERJEE: So you get into fairly severe oscillations within very -- which is what I would have expected.

MS. ABDULLAHI: This is all original license thermal power. This is not MELLLA+ or anything.

MR. MARCHE-LUEBA: 150, 200 percent, which is not --

DR. BANERJEE: Right. That --

MS. ABDULLAHI: Compared to a thousand.

MR. MARCHE-LUEBA: Yes, we worry about the one thousand.

MR. ULSES: Well, the point I want to make here also on this calculation, Dr. Banerjee - I mean, this again, this is not MELLLA+. This isn't a U.S. design BWR. I mean, this is actually -- I think this is --

DR. BANERJEE: I realize this is just stability.

MR. MARCHE-LUEBA: Yes. In this part, you will have gotten a SCRAM up here on all high power, right in 10 seconds, 10 seconds from the -- I wanted to -- this is a blow-up of that figure that shows the nice behavior of the limit cycle, so TRACE is doing a decent job of modeling this. It has the proper numerics, it has the proper models to do the job.

DR. CORRADINI: And is that one curve or two curves?

MR. MARCHE-LUEBA: This is only one curve.

DR. CORRADINI: One curve, so what's the effect -- I'm sorry for asking a detailed question, but I see a dark blue line, and a thin blue line. Is it just my eyes?

DR. BANERJEE: It's your eyes.

MR. ULSES: It's the resolution.

DR. CORRADINI: Okay.

DR. BANERJEE: You've got two minutes to finish.

MR. MARCHE-LUEBA: This is what the flow did after - following the pump trip. And if we didn't blow-up, but you can see the quality of the flow and the flow outer face as they're supposed to be, and it follows isolation. So that was basically what we wanted to show you, that we did spend a week trying to get the stability case running. To do it right, our estimate is it would take six months.

DR. BANERJEE: It's a question of we're getting a lot of these -- this is not going to be disposed of generically, so in a sense --

MR. MARCHE-LUEBA: That is correct.

DR. BANERJEE: -- by the time you start to get plant-specific applications, we should be in the position to the consummatory analysis, I think.

MR. MARCHE-LUEBA: It takes a lot of time to do plant-specific data, it doesn't take us much to run it.

DR. BANERJEE: Well, you know what the plant-specific applications are that's coming in. Right?

MR. MARCHE-LUEBA: We would have to be --

DR. BANERJEE: There are three or four of them. Right?

MR. MARCHE-LUEBA: We'll have to start working on them.

DR. BANERJEE: Yes. Anyway, let's -- do you have any last parting comments to make? Thank you.

MS. ABDULLAHI: The comment I have is, the Brown's Ferry Deck is here. And if you notice, we are recommending that research assessment include reactor core fuel performance analysis at MELLLA+ condition. Okay? We, or the staff, or the reviewer of this generic analysis do understand that, and anybody who is doing an analysis would like to see the actual analysis confirmed. And the tool I think we do recommend that we do get those analysis provided, and research, instead of worrying - this is now personally speaking - instead of worrying about new reactors that we don't have it, a bird in the hand is better than two on a tree.

DR. BANERJEE: We understand.

MS. ABDULLAHI: We should spend time on operating reactor. This is a deck of Brown's Ferry, deck, and I would like to see that effort be done so that staff have good confidence and a code be frozen for operating BWRs. That's my two-year, three-year frustration talking. And I would also like to recognize that the TRACE work was also done by a lot of other people with Research, with Tom Downer, and Joe Stodemayer. And who were the other involved? You were involved.

MR. MARCHE-LUEBA: The University of Penn State have been working on this for the last year.

DR. BANERJEE: Well, Downer has left Purdue right now.

MR. MARCHE-LUEBA: Yes.

DR. BANERJEE: They've self-destructed at Purdue.

(Laughter.)

DR. CORRADINI: You're on the record. Let's just leave it, that he's left Purdue.

CHAIRMAN SHACK: Can we move on?

MS. ABDULLAHI: I'm finished. Thank you very much.

DR. BANERJEE: Thank you. Thank you. All right. So I guess the Full Committee will have to consider whether to write two letters or one letter, whether we feel MELLLA+ is ready for a letter, even, right now.

CHAIRMAN SHACK: Well, it's hard to write a letter on MELLLA+ without approving the methods that you're using to analyze.

DR. BANERJEE: We have to start with the methods. The issue is, of course, that there are -- we've not even really touched on the limitations, that there's been a lot of discussion of that in the subcommittee meeting. So the Full Committee will have to decide whether they want to go forward with all these limitations, and all these things with MELLLA+, as well as the methods.

With regard to the methods, I think the reactor physics stuff was pretty well verified and confirmed. You got a good warm feeling about this. I don't know if the rest of the subcommittee felt that way. We found that staff had done really excellent work on confirmatory analysis.

With the thermal hydraulics, I think GE presented a fairly convincing case about TRACG, by and large, but there was very little confirmatory analysis done, which probably is frustrating to the staff. They would liked to have done it, but they couldn't do it.

And then with regard to the fuel, the staff started to do some confirmatory analysis. They recently only brought in Carl Beyer to look at this, and did some FRAPCON runs and things like that. If that is excluded in some way, you'd have to look at the language in detail. Then the sense of it is they've got that handled in some way right now. So you have to decide, and we can have a separate discussion on this.

Are there any issues and questions you'd like to bring up, either for GE or the Staff right now?

CHAIRMAN SHACK: On that fuel thing, I mean, I do read the thing that when they include the uncertainties, they get an adequate prediction. I mean, you may have desires for a better model, but living with their penalties, they seem to get acceptable results. Is that a correct conclusion?

MS. ABDULLAHI: Yes. These are significant margins that is included. And the reason is because of the fact that we're going outside the experience base, that we're taking these prudent approaches.

DR. BANERJEE: And the other thing which we should consider is that the staff and GE didn't speak to it, but some of these events like ATWS, which is outside the design basis, are also very low probability, but they did speak about this in the subcommittee meeting.

All right, sir. I'm going to turn this back to you.

DR. MAYNARD: I have one - and I apologize if I missed this. Implementation of MELLLA+, does it result in any set point changes? Do we reduce reactor trip set points, add run backs or anything?

DR. BANERJEE: Zena or Jens?

MS. ABDULLAHI: Set point changes in -- yes, there would be scram set point changes, there would rod block set point changes. There would be -- I suppose other issues that we were bringing up is they may even have to deal with changes on the SRVs. But when you design the core, you want to operate at that bundle of power, you do the analysis to support it, and you find you can't meet the requirement, then you have to make changes. What I believe it doesn't need is changing your turbine. They've already done that. In other case, the EPU part was mostly done, is the impact of the reduced flow that they have to deal with now.

DR. ABDEL-KHALIK: But that's an output of the plant-specific analysis.

MS. ABDULLAHI: Yes.

DR. BANERJEE: However, as was mentioned, the methods part of it impacts all the EPUs. I mean, we really need to deal with that. MELLLA+ maybe is going to come along a little bit later, but EPU is right on top of us right now.

MS. ABDULLAHI: In terms of set point, I was talking about flow dependent scram set points and stuff like that. GE, do you want to comment on that?

DR. MAYNARD: My question on set points, I know you would have to change some set points just to actually take advantage of MELLLA+. I'm talking about for safety margin, are we changing some set points to gain some margin outside of just actually what it takes to physically be able to operate in those conditions?

MR. JACOBS: This is Randy Jacobs. No, we primarily need to change the flow biased set points to move them away from the power flow map boundary, so we can extend it. But we're not trying to reduce set points to get better margins that way.

DR. ABDEL-KHALIK: The language that the staff and GE agreed to with regard to the plant-specific ATWS stability, is this going to be made available to the committee before we start deliberation?

CHAIRMAN SHACK: Yes.

MS. ABDULLAHI: On NRC's part, yes, we'll work with GE to get there. And I suppose GE agrees with me on that.

DR. MAYNARD: Again, I think we can also have -- if we don't have that, that could be something we could specifically put in our letter, that that's what we would expect.

CHAIRMAN SHACK: We want it to say, whatever it does say, we can put in what we want it to say.

DR. BANERJEE: Okay.

DR. BANERJEE: Okay. Then I think we can finish this session. Thank you very much for your patience and very good presentations. I read the transcript of the thermal hydraulics meeting. That must have been an enjoyable event.

(Laughter.)

DR. BANERJEE: How did you read it? I just got the transcripts.

CHAIRMAN SHACK: I got it from Zena. Well, her summary, I should say, or Ralph's summary, whoever put it together. It was an excellent summary that came out very quickly, so I appreciate that very much, because it sort of got me a little bit ahead of the game here.

I'd like to break for lunch. If can come back at 1:30, for our PHEBUS presentation.

(Whereupon, the proceedings went off the record at 12:35:31 p.m., and went back on the record at 1:31:28 p.m.)

CHAIRMAN SHACK: Back in session. Dr.

Kress.

DR. KRESS: Okay.

CHAIRMAN SHACK: That was quite a protracted introduction.

DR. KRESS: Yes, aren't you going to tell everybody what my qualifications are, or anything?

CHAIRMAN SHACK: No, they might leave.

(Laughter.)

DR. CORRADINI: I can tell he doesn't like people on the right.

DR. KRESS: This briefing is what it is, and there's no letter or any obligation we have. What it's for --

DR. APOSTOLAKIS: Except for paying attention.

DR. KRESS: Yes, pay attention, definitely, because you'll find out this is very, very interesting stuff. I don't think you will --

DR. BANERJEE: And also because you're spending a lot of money.

DR. KRESS: Yes, that's right, but it's well worth it. This is a remarkable program. I would characterize it as a severe accident source term program. Those are hard to do, not many of them left. This one has been going on for a number of years, and

NRC is a participant in this international program being conducted at Cadarache. They're finding out some very interesting things about source term, and I think this is mostly for getting us up to speed in the severe accident area, so that we can be aware of what's going on, and what the new results may be telling us.

So with that non-introduction, I'll it over to Richard Lee.

MR. LEE: Well, thank you, Tom. And I also have the pleasure to introduce to you Bernard Klement from the Institute of Radiological Protection and Nuclear Safety from France. And Bernard has been involved with the PHEBUS project since inception, the design of it, the conduct of experiments, and also analysis, so he's basically know practically all the things happen in the experiment, as far as all the analysis that has been done. So thank you for showing up.

DR. APOSTOLAKIS: Is he spending some time with you?

MR. LEE: No. He came in for a different meeting, the discussion on the following project that you will hear at the very end of this meeting here.

DR. KRESS: You don't want anything out of us, like a letter, or just a name --

MR. LEE: No, I just wanted to make sure Mike pay attention, that's all.

DR. APOSTOLAKIS: Even if the letter says this is the greatest thing the NRC ever did? You still don't want a letter? That's putting you on the spot.

(Laughter.)

MR. LEE: Okay. You can ask Farouk, then. I think we also sent the committee a short write-up about a month ago, and I think all members have received a copy of it. You will see that the introduction gave a quite lengthy introduction to severe accident your agency has undertaken since the TMI, to set background so you know why we participate in this project.

Now following the TMI accident, we found out that TID-14844 source term that was developed back in 1962 really did not give the results that when we compared the predictions from the TID source was and what we find at TMI are completely different. For example, the iodine release was very, very low. If you use the TID source term, that is not what you will get.

And then the Commission then asked

Research, can we develop a more realistic source term? And then if this source term can be smaller, and can be used for reactor licensing. And the answer from the Research staff is that we don't have enough information to develop this source term, but it is possible to develop such a more understanding on the source term itself, and the Commission told Research to do so. And at that time, Chairman Ahon directed Research to proceed with the research on source term. And at that time, the budget estimate was about $50 million that the Research told the Commission, but they said no.

(Laughter.)

DR. CORRADINI: That was in 1950 dollars?

MR. LEE: This is 1980s.

(Off the record comments.)

MR. LEE: For example, the PBF and so forth are very, very expensive.

DR. APOSTOLAKIS: What does system-level modeling mean? The very last sub-bullet.

MR. LEE: Basically, is that, for example, I'm going to go into more of this. We can talk more on the phenomenological, separate FAC test.

DR. APOSTOLAKIS: Can you remind me the first bullet, the mechanistic understanding did not exist.

MR. LEE: Because in the TID-14844, it's basically some very crude experiment that we did using fuel fragments and look at the releases. And the development was based on that, and the TID source term for determining the iodine release. Most of them are in gaseous form. So you have a very large gaseous iodine going into the containment, and the aeros form is very small, and you will see that later in the 90s when we revised the source term, that composition change based on further understanding, based on the research we had done subsequent to the TMI.

Now to put it in perspective, at that same time, after TMI there was a Sandia siting study was done, and it was NUREG-2239 published in 1982. And then, basically, that study was undertaken to answer the questions that if we really know the source term better, can we do the consequence analysis better? And for that study, what they did is that they assumed a very large source term, they assumed a very low source term, and then looked at the consequence. And, of course, the results show that the source term affects the consequence. So that is nothing surprising, but this also tells you that it's worthwhile to undertake severe accident research. And as you know now, that siting study was coded by people taking parts out of it, depends you pick the worst 95 percentile of the releases, worst source - how do you call it, the source term so you can calculate very large postulated debt, so the Commission, as you know now, has directed staff to redo this analysis based on 20 years of --

DR. APOSTOLAKIS: So what did NUREG-1150 use, the Sandia study?

MR. LEE: No.

DR. APOSTOLAKIS: It was a different evaluation? What --

MR. LEE: It was a different evaluation. You will see that.

DR. APOSTOLAKIS: No, it was more than that.

MR. LEE: It's more than that. The source term code package after the TMI, we developed a source term code package. So, basically, the source term code package linked between models to examine the releases, the transport in the primary system into the containment, so you have different modules now. It's the first set of things that we linked together all the source term calculation into containment, and into the --

DR. APOSTOLAKIS: So when you refer to the source term package, and you're saying 14844, is this a stylized source term for licensing purposes?

DR. KRESS: Is no longer exists, George.

DR. APOSTOLAKIS: What?

DR. KRESS: It no longer exists. He's giving you history.

DR. APOSTOLAKIS: I understand that.

DR. KRESS: It's been replaced by MELCOR.

MR. LEE: Yes. It's a computer code for calculation, so you can systematically calculate different sequence for --

DR. APOSTOLAKIS: That's what it was, for licensing.

DR. KRESS: No. No.

MR. LEE: It was used for NUREG --

DR. KRESS: It was part of the NUREG-1150 background.

DR. APOSTOLAKIS: What was part, the --

MR. LEE: This code was used for the analysis of source term.

DR. APOSTOLAKIS: 14844.

MR. LEE: 14844 is a report, based on sudden experiment. There's no analysis. It's not a calculation.

DR. APOSTOLAKIS: And that was for licensing purposes, or what?

DR. KRESS: They used it for siting.

DR. CORRADINI: That is the background document for current plant siting, is it not?

DR. POWERS: Nearly all of them are licensed originally on 14844.

DR. APOSTOLAKIS: Okay.

MR. LEE: That's what it's for.

DR. APOSTOLAKIS: Okay.

MR. LEE: Original licensing.

DR. APOSTOLAKIS: Okay.

MR. LEE: And plants now can use that model, or they can use the new one.

DR. KRESS: And they talk about -- George, when they talked about the fission products that go into containment, that you have to meet 10 CFR 100 at the site, that's what they originally used.

DR. APOSTOLAKIS: Exactly.

MR. LEE: Correct. That's what it is, for Part 100.

DR. APOSTOLAKIS: And now they have the option to use MELCOR.

DR. KRESS: 1465.

MR. LEE: 1465.

DR. KRESS: Is the option. No option to use MELCOR.

DR. APOSTOLAKIS: Oh, no option.

MR. LEE: No.

DR. KRESS: Well, they might want to if they want to do a risk --

CHAIRMAN SHACK: Yes, a full-fledged Level 3 PRA.

DR. CORRADINI: You're talking only siting.

DR. POWERS: It's used in an awful lot of things.

DR. KRESS: It's used for containment.

DR. CORRADINI: Maybe I -- I didn't mean to phrase it that way, but I guess what I was saying is that for an advanced plant, ESBWR, 1465 is the equivalent of 14844.

DR. KRESS: Yes.

DR. CORRADINI: For that application. And your point is, there are other applications that 1465 is useful for.

DR. KRESS: Exactly.

MR. LEE: Yes. We're going to go into that a little bit. So after the source term code PakNet was developed, we use it for the 1150.

Actually, a lot of results were used to synthesize the NUREG-1465 source term, as well, too. Okay? And if you look at the next viewgraph, compared to the WASH-1400 study, you will see that this is the -- WASH-1400, these are the points. And you will see that for PWR, is basically -- the WASH-1400 envelope this uncertainty that you see from the 1150 studies. Okay? And you can see that a group of different isotopes, classes that are predicted for --

DR. APOSTOLAKIS: So in a sense that was more conservative. Right? The reactor safety study was more conservative.

MR. LEE: Yes.

DR. APOSTOLAKIS: But not really outrageously conservative.

DR. KRESS: It depends on where you are on that uncertainty band.

DR. APOSTOLAKIS: Well, I'm mean they're consistently above the 95th. I mean, it's not that they're way out there. They are conservative.

DR. CORRADINI: One is the upper limit --

DR. POWERS: It's the wrong scale, George, so being a little bit above is a factor of three. Above the 95th percentile.

DR. CORRADINI: I should know this, but I can't remember. So everything from yellow to red is the various release categories, so PWR-1 release is equivalent to -- I should know that, but I'm not asking that right now. In the reactor safety study, the little triangles that you point out there is the highest release category, because there were nine release categories in the reactor safety study, were there not?

MR. LEE: I believe that is the --

DR. POWERS: Yes, this particular plot comes out of NUREG-1150, and they're trying to compare similar categories.

DR. CORRADINI: So this was a similar release category?

DR. POWERS: Right.

DR. CORRADINI: Okay.

DR. POWERS: The way they bin things up.

DR. CORRADINI: Okay.

DR. POWERS: I mean, the issue was at the time people thought that the reactor safety study might have been overly conservative. And, certainly, in the case of the PWR, for this particular category, and it turns out for all the categories - yes, you could argue the reactor safety study was pretty conservative. It turns out not to be the case with

BWR.

MR. LEE: And as you can see, the next one, as Dana said, you can look at the -- because in the BWR there's a lot of zirconium, so there's huge source term releases at the expense of part of it, so you see that WASH-1400 is over here, and the spread is pretty big.

DR. APOSTOLAKIS: What's the reason for that, again?

MR. LEE: In most of the coding, so when you develop the source term code package, when you do the calculations you melt and freeze the lower head, and you go out into the containment, you have melt-proof core-cooling actions, and it's a very vigorous in action, so you have more fission particle releases from the expensive part of it.

DR. KRESS: It's like I said, it was the bad actor, and core is zirconium, not fission products. It drives the steam oxide reaction that melts the core, it drives the core-concrete interaction, and creates the potential for FCI. This person would know if it's -- so bad actor, so as long as you don't get that zirconium down to the core.

DR. CORRADINI: So you said it, and I just want to make sure. This is release into containment.

DR. POWERS: No, these are releases to the environment.

MR. LEE: These are into the environment.

DR. CORRADINI: Oh, excuse me.

MR. LEE: This is environment.

DR. ABDEL-KHALIK: And where do these big bars come from?

DR. KRESS: This is expert elicitation results.

DR. ABDEL-KHALIK: Okay. So there is no data, so far.

DR. KRESS: Well, it's based on data to a large extent.

DR. POWERS: These are all mechanistic calculations done with a source term code package for NUREG-1150, where they propagated the uncertainties in key parameters through the calculation, and you get -- the result is an uncertainty band.

MR. LEE: That's what you did.

DR. POWERS: And it shows you the magnitude of the uncertainty at conclusion of 1150.

MR. LEE: That's what it is.

DR. APOSTOLAKIS: But a good part of it is expert judgment.

DR. POWERS: Whether it's expert judgment, or -- depends on what -- they identified lots of key uncertain parameters, both in the accident initiation, and in accident progression. They assembled panels to elicit information. Now what the panelists did, some cases they used their expertise. Be generous and say they used their expertise. In some cases, particularly in the source term panel, there were extensive -- Dr. Kress was on it. I mean, there were extensive analyses done, both by the industry and by the non-industrial experts that results in distribution functions that were actually propagated to the 1150 calculation.

DR. CORRADINI: So I guess just to clarify for Said, so since I was in the middle of it for the containment one, Dana's point is, let's pick something - let's take core-concrete interactions. So in core-concrete interactions, there might have been an uncertainty on the heat transfer between the molten material and the concrete. So they got a bunch of people in a room, and we argued for an extended period of time. People ran away, did their own calculations.

DR. POWERS: Three days worth of arguments.

DR. CORRADINI: Three days, and then came back with their own calculations, argued some more.

And basically came to a range of values for what that heat transfer coefficient would be. That that went in in a regimented way into the source term code package, which then computed the effect, and then all the down stream effects for source term blah, blah, blah, blah. Is that approximately --

DR. POWERS: Yes. What they used the source term code package for was to create a response surface. And then the PRA generates what? I think typically they ran about 2 million sequences for each reactor, something on that order, and they could locate them on this response surface. And then they would subsequently bin them, and all the magic stuff that gets done in these things. And come back and, presumably, identify which of those parameters really made a difference. And needless to say, source term issues just came up bingo, right to the top of the list.

MR. LEE: Okay. So that's why NRC undertook a very extensive research program in many, many areas and phenomenologically look at the type of experiment we have done, steam oxidation of cladding, fuel melting experiment at PBF, very expensive experiment. They also did the full length heat transfer experiment in Canada, so we're looking at 12 foot long rods versus a 3 feet long rods that are used in PBF. The core debris interactions with concrete experiment was done at Sandia, of course, at Argonne, too. And hydrogen research at Brookhaven. We did a lot of work with the Russians, and then development of models, I did Corcoran, Vanessa and so forth.

The direct containment heating was issues that were resolved in the 90s. We did a lot of separate effects experiment, and integral effects experiment, as well at Sandia, Argonne, and Purdue University. And we are -- most of these issues has been basically - as far as U.S. is concerned, is finished.

And this is also - if you look at the phase diagram research that was done, basically, it's telling you that before that, the melting temperature is very high, like 3100 degree K. And we found out that the experiment shows that these points are not lined up in these lines here, as we predicted. The mixtures melting temperature is much lower, so currently, for example, in MELCOR using for the fuel melting is like 2800, fuel relocation is like 2500 K. And these experiments carried out not just in many other -- for example, this is -- particularly, this measurement is at the Transuranic Institute in

Germany, and this plot is developed by the FCK.

Now we also know that the core melt progression is not a uniform, when we do the source term code package. In general, the core melt progression is very uniform, but TMI showed that this is really not the case. And, also, that the number of nodes you use affects how the melt progression, progress. For example, the source term code package at that time was a March code. And usually, we melt the core in about 30 minutes, now they use the melt core calculations, takes hours, three, four, five hours before the core melt.

DR. APOSTOLAKIS: Between what and what?

MR. LEE: From the onset of the falling down the core.

DR. APOSTOLAKIS: So core uncovery?

MR. LEE: Core uncovery to melting the fuel.

DR. APOSTOLAKIS: The full core?

MR. LEE: Yes, relocating it into the lower plenum. Now we did -- if you look at some of the experiment, we show you one of this experiment that was done at Sandia. You will see the aerosol production. There's a lot of aerosol experiments were carried out in different area, different labs, too.

And you can see from Sandia's, that you can see gas generation here. You can see the aerosol here, and you have see melt expulsion.

The recent experiment that we are doing now at Argonne, you cannot see it because usually they are not visual-type experiment, you cannot see the MCCI phenomenon. So we're just showing you what it looks like in one of the old experiment that was conducted at Sandia.

Now, basically, by the time we conclude the NUREG-1150 report in 1990, that we know that the fuel melt releases from fuel for fission products, we cannot use trace-irradiated fuel, or dosimenons that we put into fresh fuel and try to do the releases measurement. The Germans have undertaken such experiment, and we found out that when we did it with the irradiated fuel, the behavior is completely different because when you dope the fuel, the initialization of the fission products where it's located, it's very different. Also, you don't have the network of power for fission products come up when you have irradiated fuel. So we know that the kinetics are higher in irradiated fuel.

We also know that molten cladding and actions with fuel. And in the past, we have ignored the retention of fission products in the cooling system, but in the one we're doing, NUREG-1150, we do know that we have to take that into account. We also know that the retention, whatever chemical species or fission products deposit in later time can also come up.

In term of aerosol physics area, I think the NRC research really set the stage for the aerosol physics monitoring for the whole entire field, because before that, they were using the Mormon methods. And if you look at the aerosol behavior, you have a fresh aerosol coming out. There's aged aerosol which is starting to grow, so you really have a bi-modal distribution. But if you use the Mormon method, and you combine the super position, the highest maximum value is the middle of the distribution, and actually, there's no aerosol size in that range. So went to a section of methods, and subsequently the aerosol where were used in the chemistry, in the chemical industry or other application, they adopted that method. So NRC set the stage for aerosol physics.

DR. BANERJEE: What is new about this? What was the innovation?

MR. LEE: The innovation is that we found out the methodology how to model aerosol physics has to be changed from the old method.

DR. BANERJEE: What is the old method, and what is the new method? Just a matter of interest --

MR. LEE: The old method is a moment method, so basically, it's waiting -- if you have a distribution look like this, and you have a distribution look like this.

DR. BANERJEE: Right, right.

MR. LEE: So you add it up, it's in the middle. But in the containment, the fresh aerosol has a size distribution, and you look at maximum, it's at the lower end. We have one in the higher end.

DR. CORRADINI: It would be the equivalent of energy groups in neutron in reactor physics. In the original aerosol physics, they had essentially --

DR. BANERJEE: Friedlander was doing this a long time go.

DR. CORRADINI: Right. But they essentially had -- in the old days, they essentially had one -- the equivalent of one energy group, or two energy groups. And now the sectional method is they have 100 energy groups, or 1,000 energy groups, so they have 1,000 length scales, and they track the length scales and all the physics that goes with the length scales. Basically, that's it.

DR. BANERJEE: It's been in the literature for a long time.

DR. CORRADINI: It's harder with all the chemistry, it's quite harder.

DR. BANERJEE: You mean John Seinfeld and people like that weren't doing this before?

DR. CORRADINI: I don't know those people, but I think I know who Richard is speaking about, Profession Lioka, a number of people that were at Sandia. I'm trying to think of the gentleman who wrote MEROSE for MELCOR.

DR. POWERS: Gil Barden.

DR. CORRADINI: Gil Barden.

DR. APOSTOLAKIS: Friedlander from UCLA was part of it.

DR. CORRADINI: Right.

DR. BANERJEE: Yes. Shelley was doing this stuff a long time ago. But, nonetheless, you adopted it for use.

DR. POWERS: To be absolutely accurate, they just revolutionized the field.

DR. BANERJEE: They did?

DR. POWERS: Oh, yes. Yes, I mean the whole business of calculating the dynamic equation, everybody was using moments methods in the past, and now nobody uses moments methods. Though, interestingly, I saw a paper trying to resurrect it just recently, but --

DR. BANERJEE: I guess if you get enough moments, you get the same thing.

DR. POWERS: Well, no. You almost never can because we always have situations of fresh aerosol coming in, and it does just what Richard says, is the moments method puts the mean right where you have no particles.

DR. BANERJEE: Right.

DR. POWERS: So you always get the wrong answer.

DR. BANERJEE: But if you get higher and higher moments, eventually you get the --

DR. POWERS: Yes. This is whether it's convergent or not. And they're never convergent.

MR. LEE: I think this is akin to in the thermal hydraulics area when we are doing Appendix K, and as you embark on developing all the tools for instrumentation, because there are no instrumentation out there that can measure the superheat, for example, that we developed at Lehigh University, other laser other of these are methods that we look at droplet sizing and so forth. And the drag test that we use in measuring the moment of flux going through the bundle and so forth.

DR. BANERJEE: There were a lot of experiments.

MR. LEE: It's a very intensive experiment that we did and depending on the minor that one. And this is one area in severe accident that NRC took the lead, and other people adopted our work.

And also, in iodine behavior, we know that particulates as was a gas, both of those exist, so you have to deal with both --

DR. APOSTOLAKIS: Which isotope is this?

MR. LEE: We're talking about iodine.

DR. APOSTOLAKIS: Which isotope?

MR. LEE: 131. And then we talk about -- we know that in the area of revaporization and resuspension of materials, of deposit materials, we know that you can have prolonged releases of fission products during the late in-vessel part of it. And I am sure that PHEBUS is still looking at that at this time.

DR. KRESS: It might be of interest to note that with respect to the aerosol physics, the only code that doesn't use that method is the MAPP code, which is used by everybody in industry to do the calculation.

DR. CORRADINI: Which is a moment.

DR. KRESS: No, it's more of an empirical method.

DR. CORRADINI: But isn't it derived or calibrated --

DR. KRESS: It's related to the moment method. It's not a bad -- I don't mean to be derogatory. I can do a pretty good job.

DR. CORRADINI: We didn't sense that.

DR. KRESS: It can do a pretty good job, actually.

DR. POWERS: Provided you have the answer.

DR. KRESS: Yes. Provided you already have the answer, right.

MR. LEE: And MAPP is also used extensively in Europe's nuclear industry, over there at the utilities.

Now also, experiment was done at Sandia looking at Cesium Hydroxide interaction with Stainless Steel. And noted that at high temperature, even though you have a protective layer, it does not prevent the Cesium to crack the stainless steel. But, of course, in the inert atmosphere argon, you don't see any attack.

DR. ABDEL-KHALIK: What do these pictures show? What is it that we're looking at here?

MR. LEE: The Cesium, this is the initial Cesium. These are some -- Dana, these are --

DR. POWERS: They're small stainless still coupons in the pathway.

MR. LEE: And you expose it to Cesium Hydroxide under certain temperature, and the flow comes in here, and they expose it. These are excess temperatures here with steam. And you can see this one here at high temperature, start to -- the stainless steel start to degrade. And this is under inert conditions.

Just telling you that there's a lot of experiments to study about different fission products interaction with surfaces. Stainless steel is one of it. I don't know whether they have done any on Inconel. And this is showing how the Cesium and Silicon interactions in the layers of the Stainless Steel. You can see that here, Cesium forms this Cesium Silicate Oxide, and they also found the same type of materials compounds at the TMI.

DR. ARMIJO: Is that an appreciable amount of Cesium, or just a small amount of the total that can get tied up with the --

MR. LEE: There's plenty of Cesium in the system, so you can tie it up with it.

DR. POWERS: Probably about ten times over --

MR. LEE: Ten times more than --

DR. POWERS: More Silicon than what you need to have for Cesium.

MR. LEE: The next viewgraph show you that our predictions of aerosol versus data. And these are very large scale multi-component containment models, and you can see that the predictions versus the data show that we did very well.

DR. ABDEL-KHALIK: And these are totally a priori calculations.

MR. LEE: Yes. As a matter of fact, these are blind calculations. And as a matter of fact, the characterization of the aerosol that was introduced in the volume was not quite well characterized, but despite of that, you can see the prediction versus the data. So just telling you that our modeling of the aerosol calculations are pretty well. And the other one is another multi-component showing you at different compartments, the MELCOR prediction versus the data. And, Randy, I don't remember what CSE --

MR. GANT: Containment Spray Experiments, I think is what that stands for. Very old test facility.

DR. CORRADINI: These are the old Hanford tests.

MR. LEE: Okay. Now we come to 1995. We published NUREG-1465, alternative source term to the TID-14844, and the synthesis of those thing was based on, we used a lot of analysis that was done back in using the source term code package. And still some additional MELCOR analysis, too, but not that many to synthesize this source term. And you can see now there are different pole phase of it. There's a gap release, there's in-vessel release, and ex-vessel, and the late releases that are coming from revaporization of fission product that were deposit onto the circuit.

DR. CORRADINI: Can I ask a question that's a little bit off topic, but just so I understand? So just to link back to MELLA+, stay with me. My question really is, is there a difference in assumptions? So in their case, when they were going over their critical power ratio, and if .1 percent of their rods went above critical power ratio, they assumed fuel failure. What was released? Just the gap release?

DR. ARMIJO: Yes.

DR. CORRADINI: Okay. That was my question.

DR. ARMIJO: Nothing melted.

DR. CORRADINI: Nothing else.

DR. KRESS: I'd like to point out that putting together this NUREG-1465 out of the NUREG-1150 results was done to a great extent by our good friend, Hossein Nourbaksh. You did a fine job, Hossein.

MR. LEE: And then we also did research at -- Tom Kress, at that time, was at the Oak Ridge.

DR. KRESS: Who?

MR. LEE: Someone.

DR. POWERS: You were saying he was still useful in those days.

MR. LEE: We were looking at the chemical form of the --

DR. KRESS: I did real work back then.

MR. LEE: -- of the gaseous iodine. We did a lot of calculations. We synthesize this last statement over here, the 5 percent gaseous iodine was being gaseous, and 95 percent being particulate. And there is a separate report that was published for this conclusion here. So, actually, 1465 really entailed many, many research put together into synthesizing the source term, the so-called alternative source term.

This is just showing you one of the samples from the boiling water reactor. Okay? And you can see there's a duration related to the full phase of the releases. These first two columns here actually used in the Reg Guide 1.83 for design-basis source term analysis to comply with the siting Part 100. These are -- for PWR there's another table for that, and these are the one that they're using.

DR. CORRADINI: And if you lined up 14844 along that, if I remember correctly, noble gases were 100 percent, halogens were what, 50 percent, or 25 percent?

MR. LEE: I think --

DR. KRESS: Fifty.

DR. CORRADINI: Fifty?

DR. KRESS: I think it was closer to --

DR. CORRADINI: And all the solids, all the lanthanides, alkaline metals and such were 1 percent, or of that order?

DR. KRESS: Yes.

MR. LEE: The TID don't have too many specifications on that.

DR. CORRADINI: So except for the alkaline metals, which is higher here, everything else here by investigation has been reduced as an alternative source term. Is that --

MR. LEE: I think basically, the total amount really don't differ that much between the TID and this one. What's important is the timing part.

DR. CORRADINI: Right. Yes, I understand that part. I understand. But the way you phrase it, I just wanted to make sure it's in that same bin, is that if I did it for siting, it would be the sum of the first two columns. And that would be compared to 14844, which --

MR. LEE: That's the one they use. Correct.

DR. CORRADINI: Thank you.

MR. LEE: You can use that. You can grandfather it, you don't have to do anything with that. You can stay with the 14844 source term, or you can use this one. It will be the first two.

DR. CORRADINI: But or the advanced reactors, they have no choice. They will go with this.

MR. LEE: I believe that's what I was told, yes. And this is -- a lot of people -- I mean, some utilities are using this for many relief from the tech spec requirement and so forth. Changes were made after this publications for the diesel generator start-up time. Remember, that we give them relief in that area, starting very fast, we said now you can delay it longer, so it's better for the equipment's performance, and probably improve the plant safety.

DR. CORRADINI: If I might ask just one other connected question. Then the signing criteria is such that you still must assume a certain leap rate, which is the same.

MR. LEE: Those are the design, whatever the plant is. Dose remain the same.

DR. KRESS: Remember this is in design-basis space.

MR. LEE: These are design-basis accident --

DR. KRESS: You do something different in PRA space.

MR. LEE: We're talking about design-basis accident. These are used for design-basis accident. But for MELCOR example, we don't need to use any of this. We calculate - it depends on the whole sequence so we have all the phenomena that we can calculate.

So at the completion of 1150, at that time we said the understanding of severe accident is adequate for regulatory needs, but we need to refine more in terms of laboratory analysis, that we need to know more about specifics area.

Now we also found out that we were doing all these in-pile testing, they are very expensive, so we couldn't afford to do too many of those tests. Now if you look at the Sandia experiment that we done with Cesium, you can put Iodine, and then you have a surface, but there are so many combination you can do that it's not possible to do all the chemical species that you know that can exist. So it's really very intensive, so we couldn't do all the separate effects experiment.

Then we went into doing -- we developed a Victoria code as you remember back in the 90s. We look at the calculation, there are so many chemical species that the code is predicting, we don't know which one is more important than the other, so basically, we need to have some guidance on what are the prototypic source term you can find. We should be focusing on for the system level code by MELCOR. So it came up, and what came along back in the '89 time frame is that the French invite us to join 2:10:46) project. So we saw the opportunity that we would be able to get some prototypic data from that facility, so we at least know what type of chemicals form off the fission products, and what are the ones that we should focus on for the code.

If you look at the current strategy now, if I may go to the next one, this show you the programs that are involved with this past many years. Some of them are coming to conclusion, like this one here is finishing up this year. And what is the output from this program, and what we use it for validation, and what it is used for application. So this show you the experiment, the validation, and the application.

PHEBUS is the one that we were constantly talking today. The OECD MCCI is still ongoing at Argonne. This one came to a conclusion, and this one already finished. And there are two codes that we are maintaining now, is the MELCOR and then we have for new action is the TEXAS code. And the usage of this thing is shown here for the ARTIST. For example, we are using it for the auxiliary test action, and we are concluding that part very soon. So today, I'm going to only talk about the PHEBUS part of it.

I think based on the information I've sent you, I think you pretty know what the PHEBUS facility is about. Am I correct? The facility is located in Cadarache in France, south of France. And the main objective of this, the test is really looking at the source term and fission products behavior in containment, that is the main focus. But we also got a lot of information about fuel degradation, because of the tremendous amount of measurement that they did after the test was completed. And you will see in later part of the presentation.

There are certain -- the way that the PHEBUS project ran, there was very extensive number of people involved, different groups of people involved with the analysis for a very long time in order to understand what's happening. And it turned out to work very well in terms of what we have observed throughout this past 15 years of our involvement with the project; even though a lot of meetings, sometimes you have no idea where it is going. Many, many presentation that has no bearing on any of the analysis they were doing, but you have to sort through those. In time, things start to fall out, and you have some idea where it is, what the conclusions are.

There is a steering committee meeting, a committee in charge of -- it's a management board, basically. They are a scientific working group that specialists in certain area that focus on certain aspect of the experiment. Like, for example, the bundle interpretation, they focus on degradation of the bundle, looking at the behavior of the experiment. The prediction versus actual what happened. Because before the test, they do a lot of cold calculation to see what the outcomes, how much melt you will have in this bundle, because they also need to go to the regulatory bodies to get approval for the tests before they're conducted.

And there is a whole group looking at just containment chemistry. And then another group look at the circuit which is the primary system, and the containment aerosol, what does it mean the results? And there are two meetings per year. The steering committee, the management will only meet once a year to approve all the recommendation that come out from the other groups.

And this is the facility. It's 1:5000 scale of the French 900 megawatt electric PWR.

DR. KRESS: You don't want to know what the scaling parameters were, Sanjoy?

DR. BANERJEE: I want to know.

DR. CORRADINI: We were waiting for this.

DR. BANERJEE: Tell us.

MR. LEE: Okay. But now you can elaborate on it.

MR. KLEMENT: Yes, there are several parts that are scaled on this factor. First, the amount of fuel, and that's also the amount of fission products that are in the fuel. For the containment part, what is scaled down at this factor is volume of the atmosphere. The calculation between the atmosphere and the sump water, and also, I need to explain maybe with that - of course, for the scaling, the volume is too small as compared with the surfaces here, so we have introduced these cool surfaces here on which the incoming steam will condense on these surfaces. And this is scaled down to the same factor. These surfaces here are slightly overheated to prevent any steam condensation.

There is another part that is scaled down at the factor. Here is the model of a steam generator U-tube. While given the number of U-tubes you've got in a steam generator, here it was scaling down terms in one single U-tube here of 20 millimeters in diameter. The height is not to scale down. We have seen that most of the fission product deposition is in the rodding part, so it was not too tight around the U-tube like that. This is basically how it was done, the scaling.

DR. CORRADINI: So to summarize, a typical containment is 50,000 cubic meters divide by 5,000.

MR. KLEMENT: Yes.

DR. CORRADINI: So that's the volume scaling. But all the other scaling that they've been doing is mainly time scaling, trying to get it from Point A to Point B in approximately realistic timing for fission product deposition.

DR. BANERJEE: But also, for surface area per unit volume is important. Right? As well as transit time in this, probably. What are the non-dimensional groups that arise?

MR. KLEMENT: Okay. We have performed five experiments. Okay?

DR. POWERS: You're eminently predictable.

MR. LEE: Okay. You can answer this.

MR. KLEMENT: Okay. We have performed five experiments. Okay? Imagine all the number of reactor sequences with different configurations for the transport. We do not want to simulate that, so we have always simulated one kind of sequence here for the circuit, for the hot leg, steam generator, and the cold leg, corresponding to a large cold leg break. So it is also a sequence for which the retention in the primary circuit Particulate system is not so high. Most of it is in the steam generator, so we didn't attempt to simulate everything that was happening in the reactor cooling system.

DR. BANERJEE: The steam generator has a realistic surface to volume ratio.

MR. KLEMENT: Yes. And these, in fact, are only transfer lines. Okay? And, in fact, it appears that most of the deposition is here in this part. It's really small here, very small here, so the reactor transfer line, and there are also deposition here just above the core where all the fission -- the logic part of the fission product emitted as vapors condense to aerosol. But this also happens in the reactor core, in the upper plenum of the core. But these are only transfer line with low deposits, so they are not scaled down.

DR. BANERJEE: So why doesn't things deposit in those lines?

MR. KLEMENT: Well, they are heated.

DR. KRESS: And they're high flow.

DR. POWERS: And particles don't like to settle very fast.

DR. KRESS: No.

DR. CORRADINI: But there is no -- I guess the other thing, I was reading the summary that was provided to us, and I couldn't remember. There is no carrier gas once you get out of the degradation state of the test bundle, and you come into the red area. You add no carrier gas, it's just the steam and --

DR. KRESS: Steam and hydrogen.

DR. CORRADINI: -- and hydrogen that carries it out. Okay.

DR. KRESS: And fission gases.

DR. CORRADINI: Right, and fission gas.

MR. LEE: And, of course, the facility is extensively instrumented. And they tell you that the very concentrated point is at Point C because this is the point before you enter the steam generator, and the point it exit the steam generator into the containment, so they tried to characterize these two points as much as they can. Of course, there's a lot of other instrument in the containment, as well.

And this is about the size of the cup over there, is about the size that you are contain, 21 rods. There are 20 fuel rods here, and there's a control rod in here. These are several cadmium or is a boron carbon rod. Except one test that's not of the bundle, is a derivative test so none of these thing apply.

This is showing you the camera denseotometer measurements looking into the containment vessel.

DR. BANERJEE: So what does the denseotometer show there?

MR. KLEMENT: The mass spectrometer.

DR. BANERJEE: Spectrometers.

MR. KLEMENT: Spectrometers, on line gamma spectrometers.

DR. BANERJEE: So you actually know what species are deposited by their gamma signatures.

MR. KLEMENT: Yes.

MR. LEE: It depends, right. Different one.

DR. BANERJEE: I was wondering what a denseotometer was.

MR. LEE: Is not denseotometer. I'm sorry. Is a gamma --

DR. KRESS: Well, we have gamma denseotometers to measure the aerosol concentration.

DR. BANERJEE: They do?

DR. KRESS: They do, yes.

DR. POWERS: Optically.

DR. KRESS: They use optical, that's right.

DR. BANERJEE: Gamma denseotometer wouldn't show much with an aerosol.

DR. KRESS: No.

DR. POWERS: You can -- I mean, we often do it.

MR. LEE: What do you say?

DR. POWERS: I mean, we've done gamma densesotometry on aerosol.

DR. BANERJEE: Well, if the aerosol is emitting a gamma, that would --

DR. POWERS: Yes, to look at the attenuation in some circumstances. We've done that. It's easier to do optical, but it's --

DR. BANERJEE: Yes.

DR. POWERS: But some cases, you have to use gamma.

DR. BANERJEE: I should get you guys to use some other methods than gamma. Anyway, carry on. There are fairly high atomic number aerosols. Right?

DR. KRESS: Some of them, yes.

DR. POWERS: You betcha.

MR. LEE: Yes.

DR. BANERJEE: So the gammas would be --

DR. CORRADINI: Like Uranium. That's the one that comes to mind.

MR. LEE: And this is -- also, you can see that the extensive sampling of Maypack and impactors, filter, and all sort of things that measuring. When they go into different phase of the study of the aerosol behavior in the containment, you see these are instrumentation. These are the listing of all the -- I think, did we miss anything on that?

In terms of the test, these are the five tests that has completed. The last test was deleted because of there was not enough budget to do it, so this test was deleted.

DR. CORRADINI: Can I ask a question there, because that wasn't listed on the table of the report. Number 5, but was -- is now the current test series concluded, and you've now moved to separate effects test? Is that they way I read the report?

MR. LEE: Correct.

DR. CORRADINI: Okay.

MR. LEE: What happened is now these are integral tests, so basically, there's a lot of the so-called phenomenological - you cannot unfold all the findings from PHEBUS, so they need to characterize this more, so we've moving to the separate effects test to understand better the characterization and so forth. We will discuss those later.

DR. CORRADINI: Thank you.

MR. LEE: This first test is using fresh fuel, and then irradiated for, I think, was it two weeks or ten days?

MR. KLEMENT: Ten days.

MR. LEE: Ten days. And this show you different condition about the steam flow rates, what type control rods we use, and what is the sump pH control of different tests.

DR. ARMIJO: Were the fuel rods in the high burn-up, were they pre-irradiated in power reactors, and then refabricated?

MR. LEE: These came from the PWR, yes.

DR. ARMIJO: So they were not refabricated. They were segments.

DR. POWERS: They were the actual fuel.

(Simultaneous speech.)

DR. POWERS: Yes, they start off at the right length.

MR. LEE: They are all one meter long.

DR. ARMIJO: Yes.

MR. LEE: Yes, so they just it out from there. And these are the burn-up when they took it out from there. And then were irradiated for about seven days, ten days, depends on -- put back all these short life isotope, iodine especially into the -- so you can do measurements.

DR. ARMIJO: And the one test you did with boron carbide for the control rod, was that sort of like a BWR-type of --

MR. LEE: It's supposed to simulate the BWR, but this applicable for the PWR, as well, too, because lot of PWR are moving into 4C instead of using the cadmium rod. But the intent is to try to give some idea about boiling water reactors. The French don't have boiling water reactors, so whoever thinks they're going to get it, they're going to be disappointed.

The irradiation, as I mentioned to you around eight days. There are many temperature plateaus for calibration before moving to active degradation. And usually, the degradation phase takes about one to two hours. And then they will terminate the test, shut off everything, and then move into the extensive modeling and measurements in the containment vessel. The aerosol phase is about a day, sometimes it's longer. And then they do a very short washing phase to remove the aerosol deposit close to the bottom of the containment vessel, and the chemistry phase takes in usually about two, three days.

Now if you look at that, these are the plateaus that I'm talking about. You have calibration plateaus. I think they stay there to look at the coupling between the powering, the driver core power versus the -- a lot of calibration that they were doing before they moved to active degradation phase over here. And you can see the temperature escalation at different level in the bundles are shown here. And this is the transition. And then after this part, that's where the driver of the reactor core shutdown, but not at this point. I think you isolate the bundle from the --

MR. KLEMENT: I would note it's after one hour or something like that, that it is isolated.

MR. LEE: After this part.

MR. KLEMENT: Yes. This part, between the reactor shutdown, and the isolation is in this part, during which we can see revaporization of fission products from the deposits, for instance. Because we still have some steam flow, no more fission product emission from the core, and in this period of the test we can evidence what happens as revaporization of deposits in piping.

MR. LEE: Okay. And you can see here the oxidation, the hydrogen production coincides with the cladding oxidation. And you will see condition of oxidation into relocating of the debris. This is for the first test. These are tomography --

DR. ABDEL-KHALIK: If you go back two slides, the red graph where the clad oxidation takes place, where the peak is, is this an exothermic reaction that starts at 1500 C?

DR. POWERS: It's a very exothermic reaction.

DR. ABDEL-KHALIK: That starts at 1500?

DR. POWERS: Well, I mean, exothermic reactions are going on all the time, and it's only a matter of rate. Okay? You can detect it here, manifestly detect it. But, I mean, the oxidation of Zirconium goes on at any temperature above zero degrees Kelvin. It's just at a rate --

DR. ABDEL-KHALIK: Right. But, I mean --

DR. POWERS: There's no magic threshold.

DR. BANERJEE: But it's accelerating after the --

MR. LEE: We see.

DR. ABDEL-KHALIK: All right. It should be thinking of the 1200C.

DR. BANERJEE: Yes, 1100 it's starting to accelerate.

DR. ABDEL-KHALIK: Okay. Thank you.

DR. POWERS: What happens, it starts going so rapidly at those spikes that now the rate gets limited by your ability to supply steam, and not any chemical kinetics going on at the surface.

DR. ABDEL-KHALIK: Okay.

DR. POWERS: And it's literally cooking itself, you get this tremendous spike.

DR. ABDEL-KHALIK: Okay.

DR. ARMIJO: Isn't the steam ballooning at the same time?

DR. POWERS: It has done big balloon.

DR. ARMIJO: It's already --

DR. CORRADINI: Ballooned a long time ago, yes.

MR. LEE: These are tomography that was done for each of the tests. Initially, it looks like the bundle, and you will see that at the end FPT0, 1, 2, 3 - do you have some for four? Okay. We didn't show it here, and you can see that FPT0, that was the first test they did. They really melt the heck out of it.

(Laughter.)

MR. LEE: There's a huge void in the middle here, and then they pull back. The next test is like this, and this one here, the melt, some of them actually reached almost to the foot valve that isolate this loop from the driver core, because you don't want anything to melt through the foot valves. It will melt and go out into the --

DR. BANERJEE: The colors indicate density? And this is after the experiments.

MR. LEE: Yes. They pulled the bundle out very slowly, and then they measure it. And this is basically -- how do you call it, reconstruction of the tomography, that they will take slides after slides and you'll see.

This is also a tomography of the bundle.

DR. BANERJEE: This is a tomograph. Right?

MR. LEE: Reconstruction digital, digitally put together. I think at one time, a few years ago, they show you they can rotate this whole thing. I didn't have that.

DR. CORRADINI: So instead of a body, you took a fuel bundle.

DR. BANERJEE: What's interesting is that you've got a computer program that renders the colors, as well. Right? So that it's shining on top and stuff like that.

MR. LEE: Is that right?

MR. KLEMENT: No, this is just to show to people who don't know how it looks like after an experiment.

DR. BANERJEE: Yes, but you got reflected light.

MR. KLEMENT: Okay. Just a computer program, yes.

DR. BANERJEE: That's a rendering program.

MR. KLEMENT: Sure.

MR. LEE: This is a computer reconstruction. This is actually the slides that they took at different elevations. And the elevations start from low to high, and this corresponds to over here. By looking at the color, you can see the voids, what are the mass related to it, and you can even see the semblance of the fuel rods and so forth. And, basically, they took all these to do the other compositions.

And here it shows you something about Uranium and Zirconium interactions. Okay? Basically, you can see that these are no longer a circular, I mean sharp interface between Zirconium and Uranium, so you can see that they're interacting. This didn't show up too well. This is supposed to show the march into the Uranium, so it's lower than melting temperature of the fuel. And these are gamma measurements here?

MR. KLEMENT: Gamma measurements, yes.

MR. LEE: Okay. These are gamma scanning of the bundle afterwards, and they're looking at whether Iodine is remaining in the bundle. And you can see that in the lower part here, if you look at the core, power is a cosine shape. You will see that most of them are retained over here, this part here, but all these move out, and some of them deposit here. This is the top of the fuel bundle, and this is the space before we go out into the circuit.

DR. BANERJEE: That's quite a soft gamma, so it comes through?

MR. KLEMENT: Yes.

DR. BANERJEE: And you actually see it?

MR. KLEMENT: Yes. You have to make the measurement a short time after the experiments.

DR. POWERS: That's not all that soft.

DR. BANERJEE: No, it's not. But soft compared to what we --

DR. POWERS: Yes, it's not like Tritium.

MR. KLEMENT: Okay. This for the Cesium, and you can see that a lot of them are deposit over here. It's not as volatile as the Iodine, that we see the deposit is much larger here.

DR. BANERJEE: This still has a harder gamma than this, doesn't it?

MR. KLEMENT: Harder gamma and longer half-life.

DR. BANERJEE: Yes.

MR. KLEMENT: Much better for the measurement.

DR. BANERJEE: Yes.

MR. LEE: There's a two Cesium peak. Right?

MR. KLEMENT: No, only one.

MR. LEE: Only one? This is --

MR. KLEMENT: Two for Iodine.

MR. LEE: Two for Iodine, yes. Sorry. And this one show you the Ruthenium, but what we need to point out here is that Ruthenium did get released from the fuel, but again all deposit on the top over here. So 100 percent of that remains inside this fuel bundle, and the top part of the bundle.

Basically, if you look at this one, it's pretty flat. So, basically, whatever release from the fuel get deposit very close to where the release is, and keep on going. But after here is all captured. So we like to look at how the cold prediction versus the experiment --

DR. BANERJEE: What's the volatile species of Ruthenium?

DR. KRESS: Ruthenium oxide.

DR. CORRADINI: It goes to the oxide it's what?

DR. KRESS: It's volatile.

DR. CORRADINI: Oh.

DR. KRESS: Ruthenium itself is not very volatile.

MR. LEE: The metal is not volatile, it's the oxide. This is a prediction of what observed in PHEBUS versus MELCOR. And I don't remember which test this is for, but in general, you see the prediction is pretty reasonable.

DR. BANERJEE: So what algorithm does MELCOR use? Is it just some sort of cuff fit, or is there some --

DR. CORRADINI: I feel the audience ready to pop up, the audience getting nervous.

DR. KRESS: It gives you three options.

DR. BANERJEE: All right.

DR. CORRADINI: Good, better, best.

DR. KRESS: One option is a strictly empirical one, was the original one. It's not real good. One option came out of VICTORIA, that looks at araneus-type behavior. And another option was one called the Bridge --

MR. LEE: Was it causal booth you're talking about?

DR. KRESS: No, I was thinking about the --

DR. CORRADINI: There's somebody behind you that can help you.

MR. LEE: Okay. Randy Gant is here.

DR. BANERJEE: So when you said araneus that means there's some kinetics there.

MR. GANT: Yes. I'll just add a few words. My name is Randy Gant. I probably did that calculation, but I don't remember, but we routinely -- as someone mentioned, we have -- Tom mentioned it. We have several options in the code, but the option we generally exercise routinely, because it's a little more physics-based, is the so-called booth diffusion.

DR. KRESS: That's the one I was trying to remember.

MR. GANT: And it includes a diffusional component, which transports through the fuel grains. And there is also a volatility component that basically looks at the assumed vapor pressure of the volatility of the thing that's being released. And that's what was done here.

DR. ARMIJO: What's your starting point on, let's say, for Iodine and Cesium in the pellet before the experiment starts? Is Cesium Iodide or Iodine and Cesium separate, or what?

MR. GANT: This is quickly going to get very detailed, and it kind of addresses some of the limitations in the model. And because the model doesn't have extremely elegant speciation capabilities, based on what we're seeing from the PHEBUS tests, we make an assumption about the speciation in order to capture the right volatility of the material. And so, for example, when we look at Cesium and Iodine, I can tell you, that was released under the assumption of Iodine would be assumed to be pretty much Cesium Iodide.

Cesium, the balance of the Cesium based on our observations from PHEBUS, is assumed to be Cesium Molybdate, which has quite a bit different volatility from either Cesium Hydroxide or Moly-metal. And we find that from the distribution of these things that they've been observed in the PHEBUS test, that is our strongest suspicion, that Cesium and Moly are combining, at least on release. And there's some evidence that late in time any deposited Cesium Molybdate might be respeciating to come off as the Cesium coming back off again as Hydroxide if there's steam around.

DR. ABDEL-KHALIK: If you're making assumptions about speciation based on experimental observations, would you consider these calculations to be a priori?

MR. GANT: Well, I think we assume that these experiments are producing pretty prototypic conditions here. There are regions of the test bundle that are steam rich. There's regions of the test bundle that are bathed in Hydrogen, and that on the net what we're seeing is on average what you're going to see being released from the core. And absent a dynamic speciation model like VICTORIA, that's pretty much what we're left with, is to make an assumption on what that basic speciation is going to be.

DR. BANERJEE: If you married VICTORIA to MELCOR, would you get roughly those numbers?

MR. GANT: Well, I would hope so. I mean, we're matching the observations, so we hope we wouldn't deviate much from that. There are other models, perhaps ELSA - Bernard might speak to this. There are other models that are not as numerically burdensome as a full-blown chemistry model, such as VICTORIA. And I guess these are some of the things we'll be contemplating in terms of --

DR. BANERJEE: Well, let's put it another way. Does VICTORIA predict the sort of speciation that you see in the experiments?

MR. GANT: I'm going to pass that to Dana, because I'm not sure that all of the chemical species are in VICTORIA to capture this.

DR. POWERS: Yes. Well, VICTORIA would calculate this test very well, as far as the speciation. The question you're really getting at -- let's start back at Ground Zero with Sam's question. The presumption is that within the fuel grain you have atomic species, and those diffuse to the surface. And then they respeciate at the surface of the grains. And it's that vapor species that transport through the pore models. So VICTORIA makes an assumption, doesn't make an assumption, makes a calculation of what the oxygen potential and the chemical potentials are at the grain surface. And to be honest with you, we used to inhibit the Molybdenum potential deliberately because we kept predicting the Cesium Molybdate, and they did the experiment. We said well, let's not do that any more, so it will predict Cesium Molybdate for these experiments.

Now you asked me, what if I did a different kind of experiment, say one at 100 atmospheres instead of 2 atmospheres. And suppose I was in an environment that was very Hydrogen rich, would you predict the same speciation? No, VICTORIA will give you different speciation there. But then you emerge from the fuel region into the transport region where all these things kind of mix together. They go right back to the Molybdate.

The question we're wrestling with now is, does it do further changes, and we rather suspect yes. And Richard will talk to you more about the separate effects experimentation to talk about the further change.

DR. CORRADINI: So I guess that kind of was maybe the wrong question. When I was reading the report, what you gave us, and then kind of a couple of summaries, it seemed that there was a surprise about the - was it FP-3? I wanted you to kind of try to explain that, because I didn't understand it. You had -- was it essentially BWR control material, and there was a big change into -- now I'm going to have to look it up. The Iodine release. Can you kind of explain, because the way -- there was a summary paragraph that said this was like remarkable, or surprising, or there's some word that you seldom see in a research report.

MR. LEE: What happened for that one with the B4C, is that the Boric Acid from the B4C was steam and turned into Boric Acid, so it's basically capture all the sites that Iodine can go, so Iodine has no place to go, so they found a gaseous iodine, so that's what they see during the degradation phase of it, they see a very large gaseous iodine going into the containment.

DR. CORRADINI: So now that led me to my question about scaling, not scaling in terms of length scales or time scales, but scaling in terms of compositional. Was that experiment over-rich in B4C relative to a typical core, or is that something -- because the one thing you started off with in terms you led with, was is geez, Iodine isn't where it used to be. We think it's here now, but that one test showed a totally different shift. And I was curious about was there some distortion in that experiment that you then would say well, that was just a distortion relative to the chemical amounts available. Do you see my question?

MR. GANT: Richard, can I take a first

shot at that and point out; before you go generalizing that particular result to American BWRs, it's a bit of a mistake to characterize --

DR. CORRADINI: I wanted to understand what was happening. I thought there was just too much B4C.

MR. GANT: The physical form of these B4C is not at all like in the American boiler with control blades and the steel tubes. And this is more along the lines of the new fuel control materials that they've been using in Europe. I believe this is coming into use in American PWRs, where the control material is not silver-ended Cadmium, but it's a pretty chunky lump of Boron Carbide, quite a bit more robust than the typical boiler blade arrangement. And so, this pellet of Boron Carbide will have a tendency to stand in hot steam a lot longer than you'll see in the BWR blade. And that's producing a lot more reaction with the steam. And then I just wanted to --

DR. CORRADINI: No, I understand.

MR. GANT: I kind of wanted to clarify that, because it's not really a BWR test. It's --

DR. CORRADINI: Advanced control material.

MR. GANT: Advanced control material.

DR. ARMIJO: But there's a lot more Boron in some of the modern PWR fuel. They put zirc diboride on the pellets. Would it behave in a similar way, do you think?

MR. LEE: I think, but not to allude to you the scaling aspect of the B4C, because we have a lot of discussion about it, what is it really scaling in terms of was it a BWR, was it PWR?

MR. KLEMENT: Yes. Before performing the experiments, we have a lot of discussion about scaling of this test with Boron Carbide with three different aspects, so as compared to the amount, you choose the amount of Boron Carbide, of course. And, also, the amount of Boron Carbide as compared to the amount of stainless steel, because here you have a very different ratio between boiling water reactor with much more steel than in pressurized water reactors. And the effect of that, you will have more dissolution of Boron Carbide by steel, and more liquid metal going down in the core before having oxidation by the Boron Carbide.

So the test was the pressurized water reactor situation, then the boiling water reactor situation. The other point is the ratio between the Boron Carbide and the fuel, so the ratio between the Boron Carbide and the fission products.

And if I remember well, we are here for the scaling in-between what is the ratio in an assembly with control rods, and what is the ratio for the in-between this bundle. But, anyway, if you look at the amount of Boron that is emitted, it is largely nexus, as compared with the amount of fission products.

MR. LEE: So it's very large, and I think people shouldn't jump to conclusion that what we see in the very large gaseous Iodine, release in the containment is not the prototypic expectation.

DR. CORRADINI: That's fine. That helps. Thank you.

MR. LEE: Okay. Because this is a very small bundle, it's very peculiar for that part.

DR. BANERJEE: But your Iodine release numbers are significantly higher than the prediction. Right?

MR. KLEMENT: No, it's not.

DR. BANERJEE: No?

MR. KLEMENT: No.

DR. BANERJEE: Why don't you just predict 100 percent?

DR. CORRADINI: Okay.

DR. BANERJEE: What difference would it make?

DR. CORRADINI: From a licensing standpoint, I think that's the background that Richard was showing in terms of what is assumed, which is an upper limit. This they tried to drive out the material.

MR. LEE: Yes. This earlier Dana alluded to. There is also optical transmission measurements. It's a qualitative measurement on the aerosol coming out of the pipe. I believe it's in the point C area?

MR. KLEMENT: Yes.

MR. LEE: We install a so-called optical - what is it?

MR. KLEMENT: On-line.

MR. LEE: Is on-line aerosol monitor that was developed at Idaho, and we installed it to look at the aerosol transmission, interrupting the optical transmission. And you can see that it's qualitatively coincide with clad ruptures. You will see the signal goes down, with the control rod this go down, too, and the clad oxidation where there's a lot of aerosol comes out, but it's a very qualitative instrumentation.

This show you something that the transport is really occurs mostly after the excursion in terms of the aerosol got into the containment, and you will see the high radiation that was caused after this peak over here, because you need to have time from the circuit, so it will carry into the containment before you see the radiation, that will increase this.

The other one, it tells you what PHEBUS finding, very important point, has to do with the aerosol. One of the crucial assumptions that we use in aerosol calculation is that we don't make any difference in terms of looking at different type of aerosol. They're just using it pretty much the same. We see that it all put together. This is what PHEBUS is showing.

DR. KRESS: Is that log-normal?

MR. LEE: This is a --

DR. KRESS: It's its own --

DR. POWERS: Kind of. There don't have enough data points there to fit log-normal.

CHAIRMAN SHACK: Or you have little enough data that a log-normal will fit.

DR. POWERS: Or you can take that point of view.

MR. LEE: So, basically, for most element, all the aerosol behavior are pretty much the same. So this is a very fundamental assumption we make in aerosol calculation.

DR. BANERJEE: What is with the microns?

DR. ARMIJO: I'm sorry. What's an aerodynamic diameter, as opposed to just a diameter?

DR. POWERS: That diameter that's here with the same aerodynamic properties and unit density.

DR. KRESS: I think aerodynamic diameter means how does it fall, how fast does it fall, compared to a sphere of the same density.

DR. BANERJEE: It must be based on some measurement. Right?

DR. KRESS: Pardon? You have to measure it, yes. You can measure it, though, with an impacter, specially made impacter.

DR. POWERS: The only way you can collect the aerosol, you're going to collect it based on aerodynamics.

DR. KRESS: Yes.

DR. BANERJEE: The usual devices which --

DR. KRESS: Yes. Whatever you get --

DR. BANERJEE: We use the --

DR. KRESS: Also back out of that the aerodynamic behavior.

DR. BANERJEE: Separational spray dried stuff.

DR. KRESS: The sizing actually has built into it, the aerodynamic behavior.

MR. LEE: Yes. It's just that in heat transfer we use the diameter, which show you the surface because we're interested in how to --

DR. CORRADINI: This is that?

MR. LEE: Yes, and also that. But in aerosol, they use this definition. But this show you multi-components aerosol. They all mixed together, and from PHEBUS we find out that these are the distribution. And I think we use that in the code.

So, in other words, what we are showing you here is a very, very small fractions of the data that are coming out from PHEBUS. The data is really extensive, and the analysis takes a long time. And if you look at some of the reference we give you in the publication of the design, the conclusion that they have reached many years ago on PHEBUS was FPT-1 and FPT-0. I think when we get to the end of the program, we have to re-evaluate the entire set of data, maybe we come to different conclusions. So I'm just telling you that interpretation of it has not ended. It's still going on.

DR. BANERJEE: But what is the sort of take-home message. Looking at the data you've shown us, it suggests, at least, that your first approximately, everything up to Moly is more or less released. Maybe it's half, maybe it's two-thirds, but roughly all of it. Is it that most of it is not or whatever on the steam generator tubes, and the top of the core, in the dry regions? What are you seeing, in broad terms, the overview.

DR. KRESS: Most severe accidents don't pass through the steam generator tubes.

DR. BANERJEE: That's what you see?

DR. KRESS: Most of them -- so you've got to discount that as where most of the stuff goes. A large break, or a medium-size break may occur in the hot leg or cold leg, and it may go through the steam generator, it may not.

DR. BANERJEE: It may not.

DR. KRESS: So you have to look at where it goes.

DR. BANERJEE: So what you're finding is that quite a bit of it comes out in the upper plenum or something?

DR. KRESS: Well, I think the finding is that the release equations that are in MELCOR are reasonably good.

DR. BANERJEE: Right.

DR. KRESS: And that you can use those

then to determine what goes in containment. And I think they're also finding out that their containment behavior, with the possible exception of Iodine, is pretty good for the aerosols.

MR. LEE: For aerosols physics that we have now, these are very good, whatever we --

DR. KRESS: And I think one thing that's a little question is the speciation of Iodine.

DR. BANERJEE: But, Tom, to a first approximation isn't all the Iodine being released? I mean, otherwise, you're just asking --

DR. KRESS: No, no. It depends on the --

DR. POWERS: Why don't you go ahead. He'll show you what happens to it.

DR. BANERJEE: All right.

DR. KRESS: And a full core melt is not exactly like these, so you're thinking most of the melt down scenarios to get 20 percent, 30 percent. But if it progresses to core on the floor, then you might get a lot more of it.

DR. CORRADINI: But, I guess another way to say it to Sanjoy is that, I guess the reason I asked the question about FP-3, and these guys explained what I missed was just the way the Iodine was released is very big, is a very big deal. So what they're concluding is to how it's partitioned, even if 100 percent got out and you cooked the core for God knows how long, how it comes out chemically is very important.

DR. BANERJEE: As to where it goes.

DR. CORRADINI: Yes. Yes.

DR. BANERJEE: Okay.

DR. KRESS: The longer you cook the core, the more gets out. And the faster -- paradoxically, the faster you can eat up the melt, the less you're going to release.

MR. LEE: Okay. This show again about MELCOR comparison with hydrogen production, so you see that it's really not bad. See non-releases --

DR. ABDEL-KHALIK: I guess I have a question about integral experiments of this type, in general. They work great when they work, in a sense, when your results match the model. But let's say you did this, and MELCOR was way off from the experiment, how would you use the results of this experiment?

MR. LEE: I think, basically, you need to understand what the experiment is showing you first. And, also, the use of the MELCOR itself also make a big difference in terms of the user, how good are they in doing modeling. For example, when we were looking at the CSI FET-1 standard exercise, there was a group of user from Sandia and the European, German, all these, and they used the MELCOR code. And you will see the trends going one way, and then later during the exercise, some eastern Europeans joined, and they used MELCOR, and the prediction from MELCOR went completely in a different fashion. So it has user effects, you have to understand what you ask, your assumptions. First, of course, you need to understand what is happening in the test. I will say that not every prediction shows perfect things. I selectively show you the good ones.

DR. KRESS: The other thing --

MR. LEE: There are many -- there are some didn't do as well, but we have to understand why.

DR. BANERJEE: Right.

MR. LEE: Showing all the one that predicted well, but understand why we did it.

DR. POWERS: But I think save setting up your follow-ons, I mean, there are things that happen in the test that you can't explain. And you can run the MELCOR code until you're blind in the face, if it doesn't have that physics, it's not going to predict it.

MR. GANT: Richard, back up a slide, and

I want to make a point that bears on your question. That particular signature of the integral, integrated release of hydrogen. To get that right, we had to get a lot of things right. We had to get the oxidation kinetics right. That's number one. We have to get the bundle heat-up right. That's number two. A curious -- when you see that signature kind of roll-over, there's another thing you have to get right, and that is the thing that is oxidizing, actually is molten Zirconium trapped behind the oxide shell that's forming. And it's the breach of that shell, and the release of that molten oxidizing metal that actually starts that curve rolling over. So you've got to get that modeled right, and then you see out at the end where it starts to pick up again. That's due to a resumed oxidation down low in the bundle that is precipitated by relocating hot material from up high in the bundle down low, and re-igniting that Zirconium. So in order to get that, we had to look at a lot of things, timing of fuel rod degradation, the arrival of hot molten material in the bottom of the bundle, many self-consistent signatures. And when you start to get all of those right, things fall into place. No way to get that integral curve without getting a whole lot of other things straight.

DR. ABDEL-KHALIK: Right. I mean, in my own mind, what's the process? Do you do the separate effects and understand all the details first, and then do an integral experiment that hopefully works, and then we tell you, yes, you've done it right. You understand the --

MR. GANT: It is hard-fought ground.

DR. ABDEL-KHALIK: But if you do the integral effect experiment first, and if it misses, then you're lost.

MR. GANT: Yes.

DR. ABDEL-KHALIK: You have no way of using that information.

DR. BANERJEE: Sometimes you can figure it out. I mean, I remember these loft tests where each time we did a pre-prediction, we would always miss it. And we got it perfectly in the post-prediction.

MR. GANT: Well, this type of thing was preceded by scads of work on oxidation, of cladding, of material interactions between molten Zirconium and Uranium and Zirconium Oxide. There's tons of supporting separate effects phenomenological insights that had to come together before you could build an integral model like that.

DR. BANERJEE: So let me ask you, is this a pretest or a post-test?

MR. GANT: Oh, I'll tell you. That's a post-test.

DR. BANERJEE: Post-test. What was the pretest like?

DR. POWERS: Actually, it was very close to this.

DR. BANERJEE: Okay. Then you will -- there is no unexpected phenomenon.

DR. POWERS: Despite Randy's claim of all the work he did, this is one of the easiest things to predict.

DR. BANERJEE: What is the hardest one?

MR. GRANT: Easy for him to say.

DR. KRESS: That's easy for you to say.

DR. BANERJEE: What's a hard one?

MR. LEE: Well, this is the Iodine predictions. I'm sure there are many other things. There's tons of them.

DR. POWERS: There you go.

MR. LEE: Look at the Cesium deposit.

DR. BANERJEE: I was going in the wrong direction.

MR. LEE: And this is the Cesium deposit in the steam generator. Are those things that come down and so forth.

MR. KLEMENT: The peaks.

DR. ARMIJO: The wiggles.

MR. LEE: All those wiggles up and down.

MR. KLEMENT: No, this is just because the steam generator tube is gamma scanned after having been cut, and this is the location of the cuts. That's all.

DR. ABDEL-KHALIK: Is the location of what? I'm sorry.

MR. KLEMENT: Of the cut.

MR. LEE: They cut the steam generator to --

MR. KLEMENT: The pipe like that, it's too long to be gamma scanned, so we cut it in two pieces, and these are just the location of the cuts.

DR. ABDEL-KHALIK: So these sharp peaks are not real.

MR. KLEMENT: No, forget about those sharp peaks.

DR. ABDEL-KHALIK: Okay.

MR. LEE: So, in general, you can see -- we're just looking in general at the shape of the deposit, was more than just --

DR. BANERJEE: What's the most interesting is when your calculation doesn't agree with your data, because then you haven't really figured out why. Is there something like that --

MR. LEE: Well, they spent a lot of time on that, really. And that's why it took a long time, and if they keep on calculating --

DR. ARMIJO: Were there any other codes or event used in Europe or elsewhere that did similar, or better than --

MR. LEE: I don't know about better.

MR. KLEMENT: Well, there are many other codes, which some of them also calculate the whole sequence of the experiment, such as MELCOR, that equates to the equivalent of MELCOR that is AZTEC in Europe. Some other codes are only able to calculate fuel degradation, a number of codes. And what is interesting, which I mentioned, that there was an international standard problem on this test, PHEBUS FPT-1, so it was a post-test calculation. And we have had interesting figures. For instance, for fission products transport in the circuit, we have, I think it was responsible for this exercise, something like more than 12, maybe 15 MELCOR calculations by different user. And the same with AZTEC, it was different users. So we are really able to look at the ability of the code, looking at the best calculations. And, also, you have a kind of measure of the user effects, which was really interesting.

DR. KRESS: This is an indication of aerosol deposition, rather than chemical interactions.

MR. KLEMENT: Yes.

DR. KRESS: The temperature is decreasing as you go along.

MR. KLEMENT: Sure.

DR. KRESS: But the temperature doesn't matter that much, because it's --

MR. KLEMENT: So that aerosol, that's aerosol.

MR. LEE: Because the Iodine behavior shows that it's a mixture, because you see there's a slope here this way, and there's another slope. And if you go back to the other one, basically, is as exponential decay, basically is telling you that this form is mostly the aerosol Iodine, which is this one.

From the PHEBUS, we found that the fuel relocation takes place at the lower temperature. And I believe we have also adjusted for that for our code, so did other codes. There was -- Randy, when did we do that, four, five years ago?

MR. GANT: Yes. That's been at least four years ago.

DR. KRESS: And it's now 2600 K?

MR. GANT: We liquify fuel at 2800 K respecting the eutectic between Zirconium Oxide, Uranium Oxide. But we failed the fuel rod, that is, change it from a fuel rod to a slumped geometry at 2500 K, representing this kind of non-equilibrium interaction of Uranium, Zirconium, and Zirc Oxide.

MR. LEE: And we found our codes, including other codes tends to over-predict the deposition in the circuit. As I mentioned, the finding for the aerosol tells you that the models we use are very good. That is a very important finding that is size-independent.

DR. KRESS: That's really helpful.

MR. LEE: Yes. Tells the fundamental assumptions are correct.

DR. POWERS: What you develop is an acute suspicion of the CFD which the codes do better than the CFD codes.

DR. BANERJEE: Anything is better than that.

MR. LEE: And in MELCOR, and I believe in AZTEC, and also -- we use very large nodes for the containment. It appears that you look at the previous predictions, calculations are pretty -- calculate the PHEBUS containment very well. You also see that PHEBUS using two or three million nodes CFD analysis for containment, which we don't know why, but it's telling us you really don't need to do those type of calculation.

We know the effects on Iodine behavior in the sump, shows what we have learned previously. We also know that Cesium formed is not Cesium Hydroxide, is mostly Moly, and we adjusted for that. But also, the Cesium eliminate the deposit at a later time when the steam comes, we may have Cesium Hydroxide come out from the system.

We have evidence of revaporization, but this part is a difficult problem to study. I think your -- after you terminate your driver core power, and I don't know how much, how good is this part of the data coming out from this, because you need to do more experiment on it to find --

DR. BANERJEE: Are the French -- they have their own codes. Right? The AZTEC.

MR. LEE: The AZTEC is the code now.

MR. KLEMENT: Yes. In fact, AZTEC is the code that is jointly developed by the French and

Germans. And now it's used in European projects and European networks. It's becoming the European code.

DR. BANERJEE: And what is the basis of the code?

MR. KLEMENT: Well, it's a system-level code, so the -- I would say the requirements are, which is the same for the MELCOR, and the capabilities are roughly the same. Being different from one thing to another, but they are roughly the same.

MR. GANT: They're very similar in capabilities. One difference I could say is that the AZTEC code is a -- I don't want this to sound bad. It's an amalgam of many codes that have been -- that they use the data -- it's like source term code package in a way, but it's a much more sophisticated method of integrating the database of these different tools. And so, that's kind of how AZTEC is put together, compared to MELCOR; not that MELCOR is not an amalgam of various separate models, but very similar capability.

DR. BANERJEE: So what are the -- is there some basic model which is different, different physics, different understanding?

DR. POWERS: I would hope the physics are about the same.

MR. GANT: I'm having trouble thinking --

DR. BANERJEE: That's what I'm trying to probe.

MR. KLEMENT: For example, for aerosols, the basis is the same. The basis is what is in there for instance, so the same basis. For aerosol physics --

DR. BANERJEE: Simply a matter of style, not of substance.

MR. KLEMENT: There's one difference about chemistry in the primary circuit, where we have calculation of chemistry in AZTEC, as it was in VICTORIA, that is not in MELCOR. This is one difference, for instance.

DR. BANERJEE: So it sort of is an amalgam of MELCOR and VICTORIA?

MR. KLEMENT: This part was not coming from VICTORIA, no. It's not amalgam. It's --

DR. BANERJEE: Oh, so it's an amalgam of -
-

MR. KLEMENT: Yes.

DR. BANERJEE: -- whatever,

MR. LEE: Similar type.

MR. KLEMENT: Yes.

MR. LEE: Treatments of chemicals.

MR. KLEMENT: VICTORIA.

MR. LEE: But we don't put that in our code.

DR. BANERJEE: And the numerics are the same?

DR. POWERS: I think the numerics are very different, very different.

DR. BANERJEE: You use two million nodes for the containment.

MR. KLEMENT: No. Never.

But, you know, many people make -- there are many partners in the PHEBUS FP program, so many people make calculations, and sometimes we see some calculations in the containment. And we see very detailed calculations that are of no use.

MR. LEE: Just lots of calculations, and even some of them use a parameter code, but using one million nodes of --

MR. KLEMENT: Not one million, five hundred.

MR. LEE: Five hundred.

DR. BANERJEE: Five hundred million? No.

MR. KLEMENT: No.

DR. POWERS: Five hundred, for a lump

node.

MR. LEE: For the lump parameter type codes. But the CFDs are in the millions. Okay. And one big observation that we found out from test after test from FTP-1, except FPT-4, which is the test, there is a steady state gaseous Iodine appearing in the containment throughout these four period. I mean, this period. Look at this one here. In the aerosol phase, and in the chemistry phase. And if you go back here and you look at the -- if you look at back of the test matrix, they are tested some acid, doesn't matter if some of them are basic. One of them is basic, three of them acid. Some of them have silver, one test doesn't have silver because it's Boron Carbide. There are cases that the sump is condensing, and some cases the sump is evaporating. And FPT-3 as earlier we mentioned, very large amount of gaseous Iodine came in the containment, but if you look at the later part here, in the aerosol phase and chemistry phase, you see a steady state. So our expectation is that if you have good, high pH, if you have silver there, you should not be seeing a steady state gaseous Iodine. So we came to realize that this gaseous Iodine steady state that we're observing is coming from a source that has nothing to do with the sump. So the pH controlling the sump doesn't do anything here, because if you look at the condenser up there, the Iodine goes to the condenser. It can come back out from it, depends on the conditions that is occurring in the containment. If you have evaporation from the sump, there's a higher rate of flux, so you remove the Iodine, and you deposit it back onto the condenser. So you have a situation that we observed that the steady state gaseous Iodine is coming from a source that is not from the sump.

DR. KRESS: But, eventually, that Iodine that's airborne would make its way to the sump. There are processes that would carry it to the sump, and so it may make a difference whether the sump is acid or basic in a very long time. Because if it does make its way to the sump, it acts like a little bypass cleanup system to the containment. And you would expect to see eventually, it all end up in the sump.

DR. POWERS: Eventually, you'll see it all decay.

DR. KRESS: It decays faster than this little thing -- that may very well be.

DR. POWERS: Notice the time scale over there.

DR. KRESS: Yes, it depends on the speed.

You're right. Thanks for pointing that out.

DR. CORRADINI: So not being that good at source term, that seems like a big deal considering all that was said about what happens. So what was going on in TMI that isn't occurring in FP-1, 2, 3? In other words, I thought TMI had an enormous partition of a gaseous Iodine, versus what was in the water.

MR. LEE: I think in the TMI most of the Iodine went into the water.

DR. CORRADINI: Right.

MR. LEE: And then transmitted from the tank into auxiliary feed building.

DR. CORRADINI: No, I understand that. But the partition -- I mean, unless I misunderstand what you're telling me, one in twenty is still sitting inside the atmosphere.

MR. KLEMENT: No.

MR. LEE: This is percent.:

DR. CORRADINI: Oh, this is percent. Excuse me.

MR. LEE: It's percent.

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

DR. BANERJEE: So maybe .2 percent, at most.

DR. CORRADINI: But what was the partition at TMI, though? I thought it was like 100,000.

DR. POWERS: It was all in the sump.

DR. ABDEL-KHALIK: So if you're thinking about the chemical effects of the sump blockage issue, what would you advise people to do?

DR. KRESS: Get rid of the --

DR. POWERS: Get rid of the buffer.

DR. ABDEL-KHALIK: Right?

DR. KRESS: Yes. Does it make any difference?

MR. LEE: I think our opinion now is that from the onset of the accident, you really don't need the buffering. Maybe in the late phase, much longer time. And if you want to spray the containment, the question remain is that whether you need to add the buffer into the spray or not, and what effects that has on the -- is long-term evolution of gaseous Iodine in the containment.

DR. BANERJEE: There could be other reasons you need the buffer, as they pointed out.

DR. POWERS: Like what?

CHAIRMAN SHACK: Unless you like to make Calcium Phosphate.

DR. BANERJEE: One of the things that came up at the meeting was, why don't you just remove the buffer? And there were people from NRR who said that all the implications of that have to be assessed, because --

CHAIRMAN SHACK: Well, I agree with that.

DR. BANERJEE: It's not that straightforward, they explained to us.

DR. CORRADINI: But isn't the buffer for the containment spray the only purpose is to remove Iodine from gaseous Iodine?

MR. LEE: Is the retention of gaseous Iodine.

DR. CORRADINI: That's why I'm having --

(Simultaneous speech.)

DR. CORRADINI: I don't mean to -- this is what my question was about. I thought at TMI they sprayed the beJesus out of it, and that was one of the reasons it stayed in the sump. Am I off base?

DR. POWERS: No, it went into the water immediately. TMI, all the Iodine release was through the water filled pressurizer.

DR. CORRADINI: Oh, right. Okay.

DR. POWERS: It wasn't released to the atmosphere.

DR. CORRADINI: So the containment spray, although on, would have had no effect.

DR. POWERS: Been no effect. Cleaned up the -- made it nice, and took all the pollen out of the air.

DR. BANERJEE: So one of the sump screen solutions has been one of the plants is turning up their spray. We had five plants present, and each had a different way to - or four plants. Each had a different way to handle the problem, all very creative, by the way. Hopefully, they'll appear and present to the Full Committee, maybe in July.

DR. ABDEL-KHALIK: But this is a very significant finding. I mean, this is --

(Simultaneous speech.)

DR. BANERJEE: I think they know some of this, though.

MS. HART: This is Michelle Hart. I'm with NRR. Mike Scott, who's the head of the branch is doing GSI 1.91 did have to leave, but we are aware of these responses of this result. And, of course, it does cause issues in my particular, I'm the dose analyst. Because all of our current guidance, Reg Guide 1.183 is based on NUREG-1465, which says well, your pH has to stay above seven, that's why the species are the way they are. So we are interested in seeing what happens with the follow-on results to make sure we understand this fully, and we can model it correctly, because currently we don't model it with a steady state Iodine concentration in the containment. Our models aren't set up that way.

And for the near-term, GSI 1.91 does need to be resolved by the end of the year, including chemical effects, and so this will not be able to be figured out within that time frame, is our thinking.

DR. CORRADINI: But if I understood what you just said, you're saying because you don't understand the physics behind what you see from the four tests, one doesn't want to jump to make a change in another issue?

DR. POWERS: The problem --

MS. HART: That's part of it. The problem is also that when we say okay, take the pH out of the sumps, then they're all going to come in with license amendments, and we have no way to evaluate whether they've calculated the re-evolution, or the amount of Iodine in containment correctly within the next five months, six months.

DR. POWERS: The problem is inherent to, this is a phenomenological experiment. Somebody has to take this result and say now, what do we get a real reactor accident? The problem is, steady states are lovely. You love to get them. They tell you that you have a source, and you have a sink, and they're operating at the same rates. Unfortunately, they don't tell you anything about the sources and the sinks. You cannot find -- the problem is a steady state obscures information, so we don't know what the sources are, or what the sink is. We're pretty sure the source is not the sump, because we've perturbed in just about every way you can think of. We made it acid, we made it base, we put silver in it, we evaporated, we cool it down. Yes, we do see some fluctuations in the steady state due to things like changing the evaporation and the condensation, and we think that has to do with the flux of steam taking Iodine on to surface as we're pulling it off.

Now you have to take that phenomenological result and say what happens in a reactor accident. We don't know how to do that right now. And this comes back to Said's point, is that when you do an integral test, the problem is you can't do enough perturbations to tell you what is mechanistic, or give you a handle on what the mechanisms are. And so that leads to the next slide, and I'll let Richard pick up from there.

MR. LEE: Just a year or two ago, I think, they launched a follow-on program to PHEBUS because there's findings from PHEBUS that we could not sort out because of the integral nature of it. The EPICUR program was the Iodine chemistry, and we think that is essential for us to answer the questions related to that so-called steady state Iodine behavior that we see in PHEBUS. And there is also another program that's been launched by OECD, has to do with ECL, another Iodine program that they want to do measurements. So we are trying to make sure that these two programs gave us enough information for us to validate the model that we already put together, because, for example, the -- if you want to do the analysis of the steady state Iodine behavior, the paint behavior, and so forth, we don't have the information in order to validate the model that we have developed at this time.

And, also, there are some disagreement between, or maybe different view between the French and the Canadians about how Iodine evolved from surfaces and paint. One thought it was a surface effect, one thought it was more of a - how do you call it - atmosphere effect. Right? So we need to sort those out.

DR. BANERJEE: So which are the ACL tests?

MR. LEE: None of the ACL. These are all the French follow-on.

DR. BANERJEE: Only the French.

MR. LEE: But I'm just pointing out to you that currently, the OECD launch another program based on the Canadian testing. Canadian has done a lot of Iodine chemistry area for -- I mean, 30, 40 years, so they know - they have the view about how Iodine behave. And they are very strong in the Iodine modeling and experimentation area, so we have to pay attention to what they're doing, because we tried to see, to make sure that these two views are --

DR. BANERJEE: What is their view?

MR. KLEMENT: Anyway, because the Canadians are participating to this program, and we, the French, are participating to the Canadian programs.

MR. LEE: So maybe you can talk about your view on the paint behaviors, versus the Canadian view.

MR. KLEMENT: Well, there is one thing that we have in our models, is just when you have inorganic Iodine in the atmosphere, we consider an absorption of this inorganic Iodine onto the surfaces. Then chemical reaction on to the -- with the surfaces, and the absorption of organic Iodides is being a reaction on the surfaces.

There is one point that may be solved by the Canadian experiments, too, that is the influence of steel, and whether the surface was wet before being dry because it seems that could have an influence. So this will be part of the Canadian experiments, and so on. But, basically, for us, it's more surface reaction. Then you can also imagine that your solvents, you're getting solvents that come out in the boundary layer that react with Iodine, and so on. That's when the modeling at the end, once you have understood probably one single, simple model will be enough, if you are sure you are not missing anything to be put in AZTEC or MELCOR, or something.

MR. LEE: Basically, the Canadians put a lot of -- they think the solvent in the paint is very important in terms of Iodine behavior.

MR. KLEMENT: We don't say it is not important, but we say -- we are trying to model it more, in a more full manner, without going into the detail of the reactions.

MR. LEE: So it's the degree of modeling, there are differences between the two. So we want to test out the way that they did it, the way the Canadian does it, and see which one is the one that we should adopt, so we can do the analysis to understand what happened in PHEBUS. And then we can use the model to extrapolate to the full size plant. So we can look at what is the steady state Iodine that can develop in a prototype reactor, under prototype reactor conditions.

DR. POWERS: It's interesting, if things go as we currently think they'll go, subject to change based on the experiments. If the steady state Iodine concentration goes up in reactor accidents relative to what you see in the experiments.

DR. BANERJEE: Have the Canadians done any reactor tests with NRU loops?

MR. KLEMENT: Have done reactor tests, but not --

DR. BANERJEE: Not on --

MR. LEE: They did --

DR. POWERS: They have done irradiated tests. In their RTF program, they would irradiate solutions with a Cobalt-60 source and look at the Iodine vaporization, and how it interacted with surfaces. That's not what they're proposing to do here. It was a more microscopic test, more mechanistic test.

MR. LEE: They also did some fuel release tests, too, in the --

DR. POWERS: Well, they did fuel release tests, and quite a few things like that.

MR. LEE: A few of them they did. We worked closely with them at the time when we were developing the VICTORIA code. The Canadian with also with UK, very closely.

The CHIP program that's shown here is really to look at the release of gaseous Iodine from RCS. Remember, I guess - I don't know whether you recognize it or not, the PHEBUS piping is really not stainless steel, it's Inconel. So we need to ask a little bit questions about the scaling aspect of that, so we want to look into that a little bit more, so it's stainless steel versus inconel. And then on the other one, those are - they want to look at the Boron Carbide stainless steel behavior, basically looking at the control rod. The MOZART test is looking at the cladding oxidation in air, is basically they are trying to expand the database that low temperature experiment that we have done at Argonne a few years ago. They want to do some experiment to overlap the range, and then did some more in that area. What have you done recently?

MR. KLEMENT: Well, we had done most of

the experiments on Zircaloy-4, and we will start experiments on Zirlo.

MR. LEE: Okay. And then the last facility is the replacement for the test that was -- is located in Grenoble. They shut down all those facilities, or they're building a new facility. The CEA is building at Cadarache, so they're going to want to do some MOX fuel, and also high burn-up fuel, similar to the HIVI-type tests, but it's for high burn-up, is for MOX, and also for high burn-up. This won't start until 2009 and 2010.

DR. KRESS: I may still be around.

MR. LEE: Sure. So in summary, you will see that I think PHEBUS provide a lot of information for us to validate the code. And then the follow-on program will provide even further information to sort out all the findings from PHEBUS try to untangle at this time. And, of course, NRR is always interested in what does it do to the alternative source term they use in the DBA analysis, especially the -- is there anything changes this, does the Cesium form different, the Iodine, the Iodine behavior in the containment. And then we need to sort out the steady state gaseous Iodine behavior in the containment. And I told you that we have models developed based on the -- we are waiting for the results from the EPICUR tests to give us some additional data for validation of the models. Once we put it together, we check the results using PHEBUS, and then we're going to extrapolate it to the prototype reactor so we can tell where there is a problem or not for us.

So I think that's about it. And these are references for study. We can summarize it for you the next meeting. Those are the references I believe that you have been provided.

DR. KRESS: Your engineering.

MR. LEE: I'm telling you all these --

DR. APOSTOLAKIS: Not any more.

DR. KRESS: Oh, he doesn't have it any more?

DR. APOSTOLAKIS: The European thing, but Theo was involved, but not any more.

DR. KRESS: Not any more.

MR. LEE: At one time was the editor. Right?

DR. APOSTOLAKIS: One of the editors. He has some classrooms now.

(Simultaneous speech.)

DR. APOSTOLAKIS: Do I want to hear it?

MR. LEE: That is the end. Do you have

any questions?

DR. APOSTOLAKIS: It's a very good job.

DR. KRESS: Yes, thank you very much.

DR. CORRADINI: Very good.

DR. KRESS: Appreciate that. Any questions anybody? I'm about to turn it back over to our esteemed Chairman.

DR. MAYNARD: Just a comment, not so much on PHEBUS, but to some of the results. I'm glad to see that the NRR staff responsible for generic issue 1.91 is following this, and paying attention to it. I think it is extremely important that we do all that we can. I know the constraints, I know we have some requirements to resolve it, GSI 1.91 by a certain date. I understand some of the issues that Dana was talking about. There is also some of the regulatory aspects, if we go to removing requirements to have this. But the bottom line, I think we owe it to the public that we do everything we can to make sure our solution to 1.91 doesn't decrease safety, if we have information available to us now that could enhance that resolution, so I think we really need to work hard on that.

DR. KRESS: On this gaseous Iodine steady state, I would be tempted to think it might be coming off of the condenser, and I have asked the question, how long does the water stay there before it drops off into the pool? And if it stays there a significant amount of time, and it's not prototypic of some of the real reactor conditions. I don't know where else it would come from.

DR. CORRADINI: Because it would rain out.

DR. KRESS: It's a question of a film, and how fast the film flows down. And I don't think you have the equivalent condition in the containment.

DR. ABDEL-KHALIK: That is very, very short compared to the 100 hundreds or so that you're talking about here.

DR. CORRADINI: Well, I guess, Dana, you said something, I didn't remember how you finished the answer about it. You said you've done some estimates, and you would guess that it would be higher in containment. And I don't remember why you -- what the reason was.

DR. POWERS: I didn't tell you my reason.

DR. CORRADINI: Will you tell us?

DR. POWERS: No.

DR. CORRADINI: Proprietary.

DR. POWERS: It's what you would expect at this point, Mike, because I'm just guessing at what's going on. But, essentially, it boils down to the fact that no matter where I inject the containment, I have a much more torturous path to get things down to the sumps, than I do in the PHEBUS experiment, so I have far more material loaded on more surface area in the reactor. So I have more source, about the same sinking, because I'm sinking largely by homogenous destruction, the Iodine, so it's about -- my sink term is about the same as in the reactor, but my source term is a little bigger.

DR. CORRADINI: But then that means that in all the models to-date, once you split out was is gaseous versus what is tied up with Cesium, or whatever, there's no physical model that trades that out.

DR. POWERS: We trade it.

DR. CORRADINI: Oh. So then -- but the gaseous -- the way you're explaining it, I'm just trying to understand, the way you're explaining is, it's in solutions sitting on some wetted surface, and it's, essentially out-gasing.

DR. POWERS: In my modeling it didn't have to be wet.

DR. CORRADINI: Oh.

DR. POWERS: Okay? And that's one of the

key issues that's going to be looked at first and foremost in the ACL experiments, because they're going to look at surfaces as a function of the ambient humidity. And that's one of the contentions on whether you get irreversible deposition, or reversible deposition on dry surfaces or not.

DR. CORRADINI: In these experiments, is there going to be some sort of active spraying to look and see if you actually try to remove it with some sort of --

DR. POWERS: We presume we know how to move Iodine gas with a spray droplet.

DR. KRESS: Is there going to be any consideration of radioactivity --

DR. POWERS: Oh, the self-dosing effect? No, I think we -- certainly, the experiments they do at Cadarache are irradiated solution, and they can even irradiate it. The Canadian test will probably not do that. We haven't really designed that.

DR. CORRADINI: So let me just ask one other question. If .1 percent became 1 percent, is it worth having the containment spray have the sodium hydroxide there to knock it down? How large would it have to get that you actually cared about having the sodium hydroxide in the water?

DR. POWERS: It's not the level of concentration in the atmosphere. It's the magnitude of loading on the surface, because if I pull it out of the atmosphere, then I turn the spray off, it just comes right back in until I depleted my sources.

DR. CORRADINI: Right. But since it's gaseous, and it's not being tied up chemical -- I guess what I'm still back to is, I'm trying to understand, if it's not being traded off and getting held by some other chemical -- by chemically reacting to something else, you're saying either I put it there and it re-evolves, if I stop doing whatever I'm doing.

DR. POWERS: I think it's very difficult to get things from the sump back to the atmosphere.

DR. CORRADINI: But once you put it there --

DR. POWERS: What's on the surfaces, and the amount of loading I have there, it's going -- again, this is totally speculation on my part. How much I put on the surfaces early in the accident, if I spray those surfaces, or spray that atmosphere and take out some of the gases there, doesn't matter, come right back up, as soon as I stop spraying.

DR. CORRADINI: Right.

DR. POWERS: And it will keep going that

until the combination there of decay and depletion reduce those sources.

MR. LEE: Basically, if you deplete, make the concentration over the surface to balance it. That's what we think we're observing in PHEBUS.

DR. KRESS: PHEBUS didn't find anything on the containment walls, did it?

MR. LEE: No, containment walls is heated, so you don't see anything on the containment deposited. Right?

MR. KLEMENT: We have seen some Iodine coming out from the steel walls, yes.

DR. KRESS: You think that might be the source, as opposed to the condenser?

DR. POWERS: It is not a source that you can discount. You can't throw it away. And, in particular, up in the particular locations, flow patterns up there during the injection phase is very complicated. After injection, it's even more complicated, so you can't throw it away.

DR. KRESS: It's not necessarily true --

DR. POWERS: I don't think that's --

DR. KRESS: It's not necessarily true that the condensation carries everything.

DR. POWERS: But I think if you're going -

- the smart money is going to bet on the condensers. But you can't throw it away right now.

MR. LEE: So, basically, we said that the sump in PHEBUS has great access to the containment, and we see that the sump is not active in doing the Iodine partitioning stuff. Other things it's doing. And for comments related to working with NRR, research work, we work very closely with NRR and NRO now, because they split. Closely with on site since the inception of it.

DR. KRESS: Did you actually have measurements of how much Iodine is in the sump as a function of time?

MR. KLEMENT: Yes.

DR. KRESS: You have to be able to calculate potential source, back into the atmosphere from --

(Simultaneous speech.)

DR. KRESS: It may be really small, like you say.

DR. POWERS: What they do, they have a very nice setup. They have a gamma spectrometer looks through the solution. They have one that looks at the bottom, and so when the silver iodide precipitates down, they can see that, and they can see the depletion from the solution. It's actually pretty good.

DR. KRESS: May be useful to --

MR. LEE: They will see the Iodine when they wash it from the elliptical surfaces into sump, you see it actually goes out. You can correlate those directly.

DR. KRESS: That was that little blip you had on the end.

DR. POWERS: That has more to do with, in that particular test, they dropped the temperature of the sump, and so there was less vaporization from the sump, so there's less flux putting it back under the condenser. So the steady state concentration crept up, and they've done it the opposite way, and it goes down.

DR. KRESS: I see.

MR. LEE: And you see one test that the evaporation rate is high, the rate goes down, so you see that it adjusts itself, basically.

DR. POWERS: You know, you try to pull things out of these integral tests, but in the end stage, right, integral tests are a long way to go to separate effects tests, like EPICUR.

DR. KRESS: They're there to tell you if

you're missing something important. And maybe this steady state Iodine tells you you might be missing something.

DR. POWERS: Well, it told us we did miss something important. I mean, it's not that we didn't know the paint was important, we didn't know it was this important.

MR. LEE: So, basically, I think we're looking for between a year or two we're going to sort out this stuff.

DR. KRESS: Sounds good.

CHAIRMAN SHACK: Well, again, thank you very much for the presentation. We're going to take a 15-minute break, and come back at 4:00.

(Whereupon, the proceedings went off the record at 3:42:56 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 543rd Meeting

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.

The Phébus-FP Project presented to the Advisory Committee on Reactor Safeguards June 6, 2007

Richard Y. Lee
Office of Nuclear Regulatory Research

Bernard Clement: Institute for Radiological Protection and Nuclear Safety.

Jay Lee: NRO

Outline

- NRC research on severe accident phenomena
  - History
  - Current Strategy
- The Phébus-FP project and the follow-on efforts
- Summary

History

Following the TMI-2 accident

- It was evident that a mechanistic understanding of radionuclide behavior under accident conditions did not exist
- The Commission directed the staff to develop a better understanding of the reactor accident "source term" of radionuclides to the containment and to the environment
  - Replace the TID-14844 source term
- Nearly $0.5 billion dollars were spent
  - Phenomenological experiments
  - Separate-effects experiments
  - Phenomenological modeling
  - Systems-level modeling

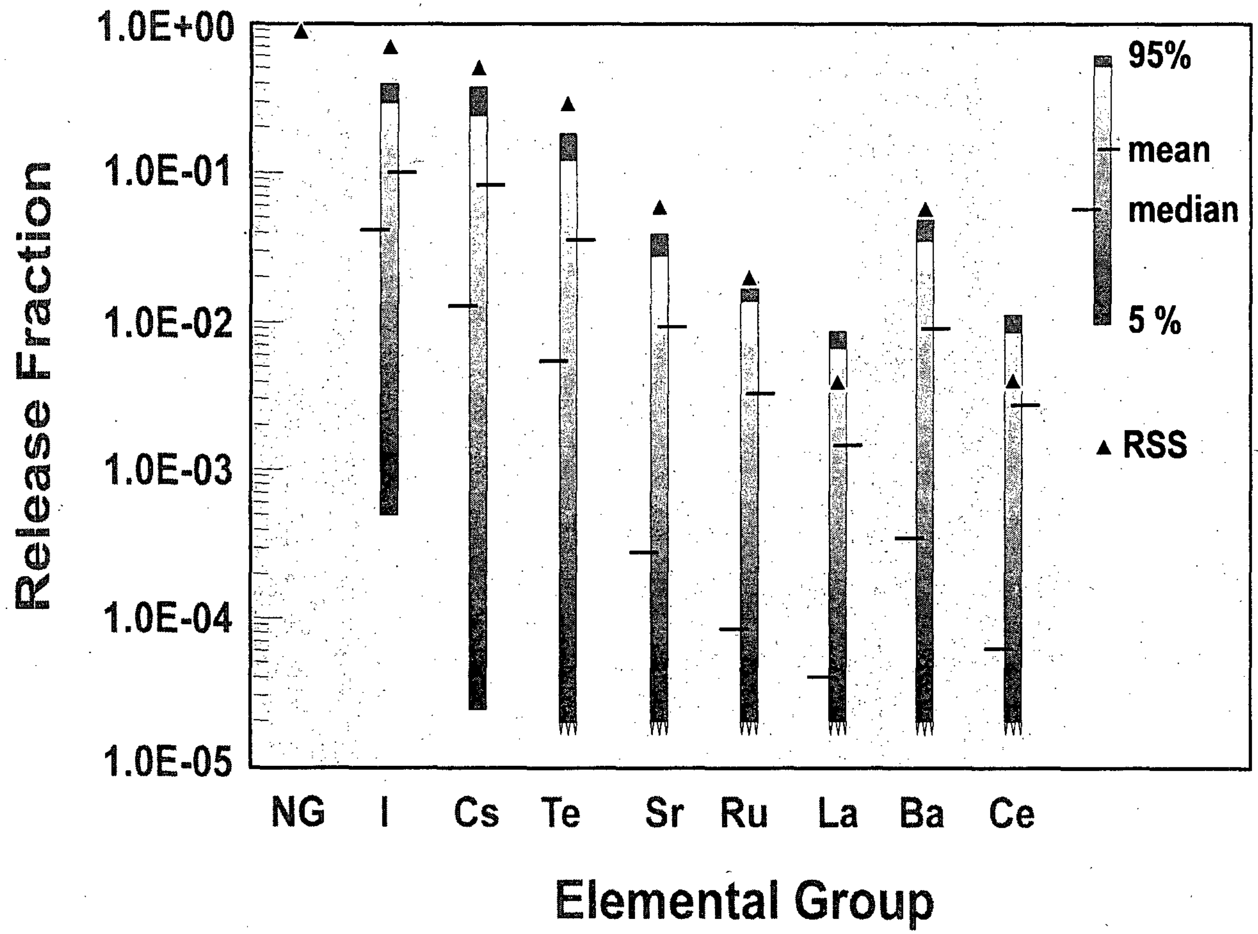
Aside

- The so-called "Sandia siting study" was done, in fact, to ascertain if an improved understanding of the release of radionuclides would result in better understanding of accident consequences despite the substantial uncertainties in accident consequence modeling
  - The study showed using a large and small source term at each site that better understanding of the source term would be useful for Level III risk assessments

The Effort Culminated In:

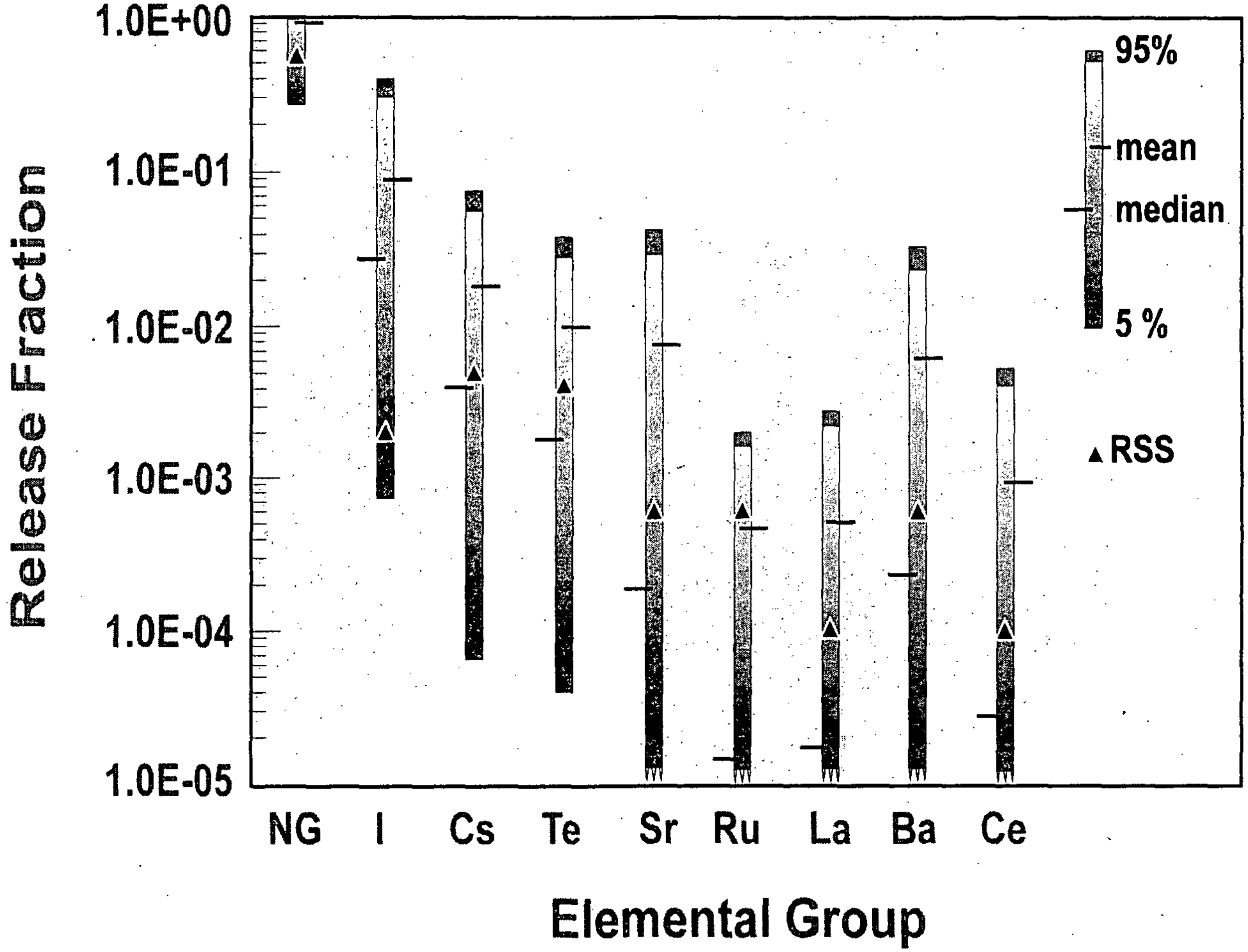
- Source Term Code Package
  - Models accident progression, fission product release and transport
- NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants"
  - Modernized version of the Reactor Safety Study(WASH-1400)
- NUREG-1465
  - Replacement for TID-14844 source term
- Recognition that understanding was adequate for regulatory needs at the time
  - Large uncertainties remained

NUREG-1150 Uncertainties in accident source term for a PWR



RSS = Source term estimate from WASH-1400

NUREG-1150 Uncertainties in accident source term for a BWR



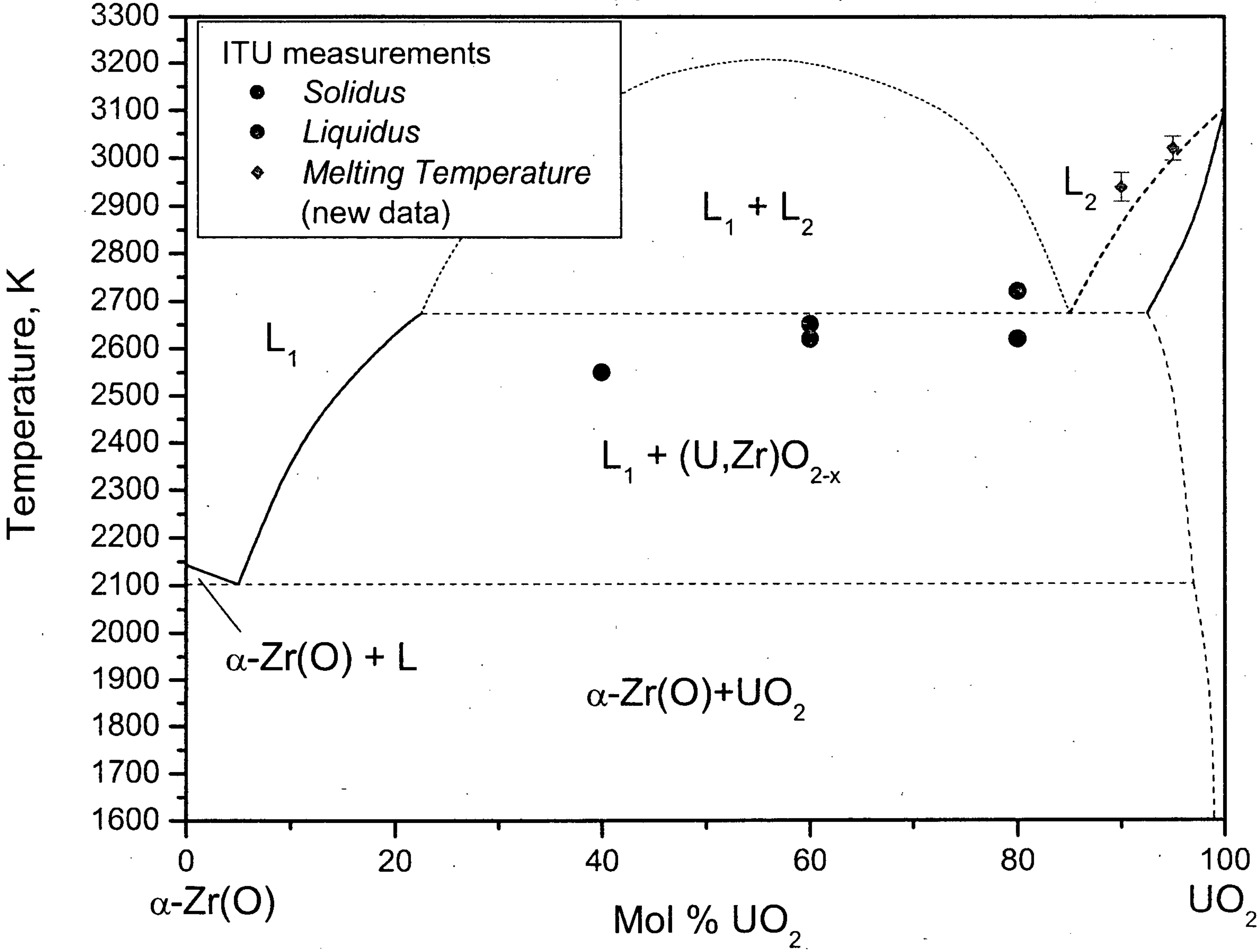
RSS = Source term estimate from WASH-1400

Status at the Conclusion of NUREG-1150

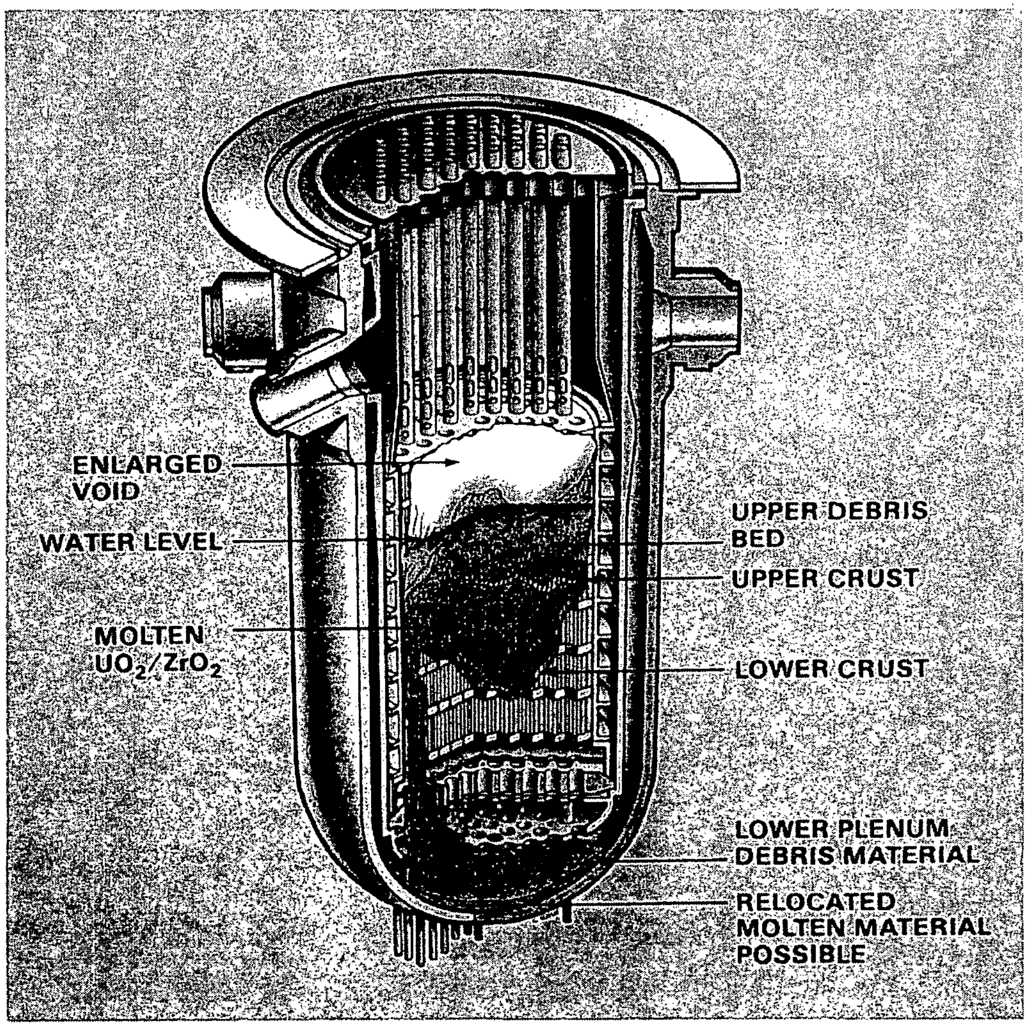
- **Major strides had been made in accident progression modeling**
  - Steam oxidation of cladding
  - Fuel melting
  - Core debris coolability
  - Core debris interactions with concrete
  - Hydrogen deflagration and detonation
  - Direct containment heating

THE QUASIBINARY α-Zr(O) - UO_2 SYSTEM

(by C. Politis, KFK)



Core Melting Begins Near Midline of Core and Progresses Slowly because of Heat Loss to Structures



Aerosol Production During Core Debris Interactions with Concrete

Status at the Conclusion of NUREG-1150, cont'd

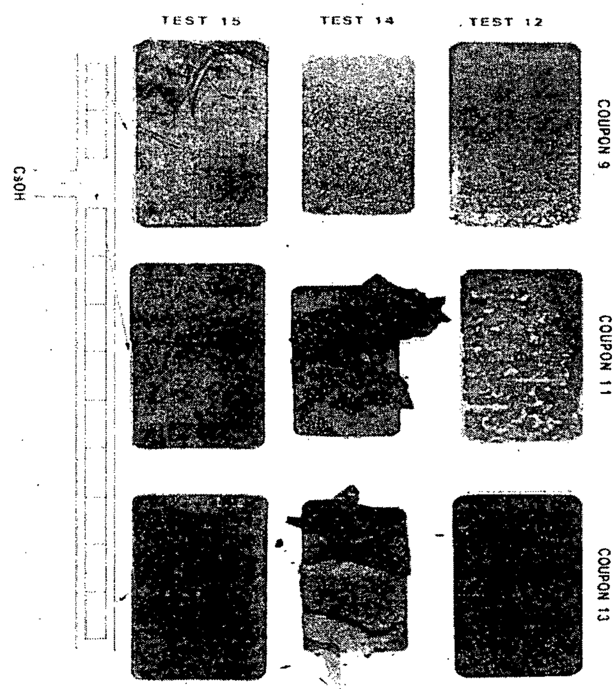
- Release from fuel up to fuel melting
  - Un-irradiated fuel differs from irradiated fuel
  - Strong molten clad interactions with fuel
- Retention in the reactor coolant system
  - Neglected in past studies; significant for risk important accidents; chemical interactions of fission products
- Aerosol physics
  - Revolutionized modeling aerosol behavior
  - Effects of engineered safety systems (sprays, suppression pools, ice condensers, filters, fans, etc.)
- Nature of iodine behavior
  - Neither all particulate nor all gas
- Issues of revaporization and resuspension
  - Prolonged release up to 100 hours

Cesium Hydroxide Vapors Affect Stainless Steel Oxidation in Steam

CsOH Steam 1123 K	CsOH Steam 1273 K	CsOH Argon 1273 K

Prior to CsOH Exposure

Exposed To CsOH



Interaction of CsOH with Stainless Steel at 1273 K

Outer Oxide (Fe_3O_4)

Inner Oxide ($FeCr_2O_4$)

Stainless Steel

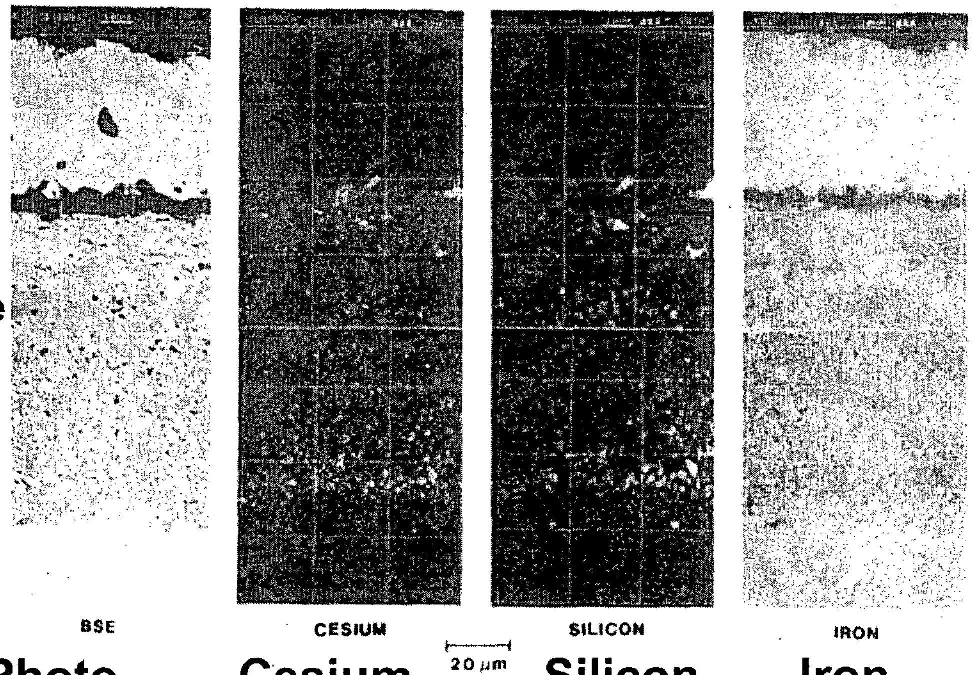


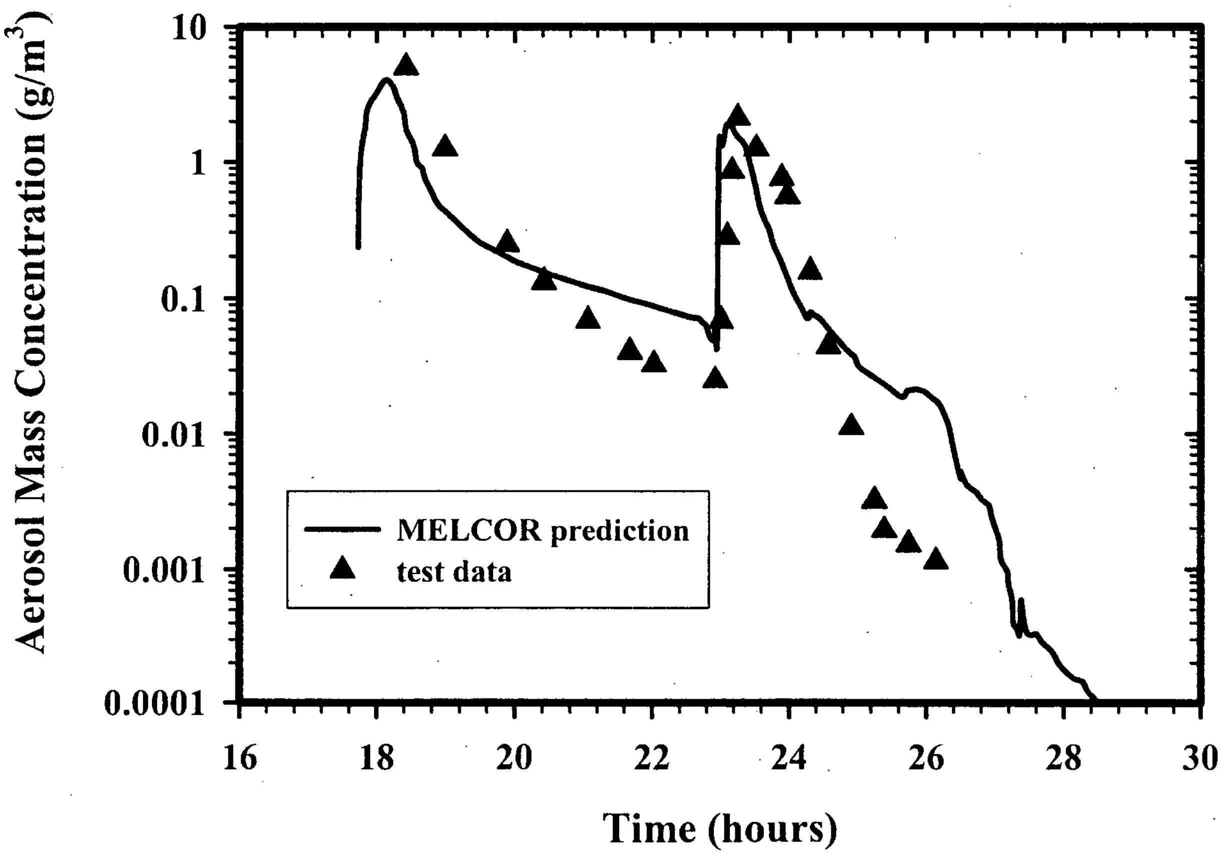
Photo (Back scattered Electrons) **Cesium** **Silicon** **Iron**

Mass ratios indicate the chemical form is $Cs_2Si_4O_9$.

Similar finding for Cs on TMI-2 Lead Screws above core.

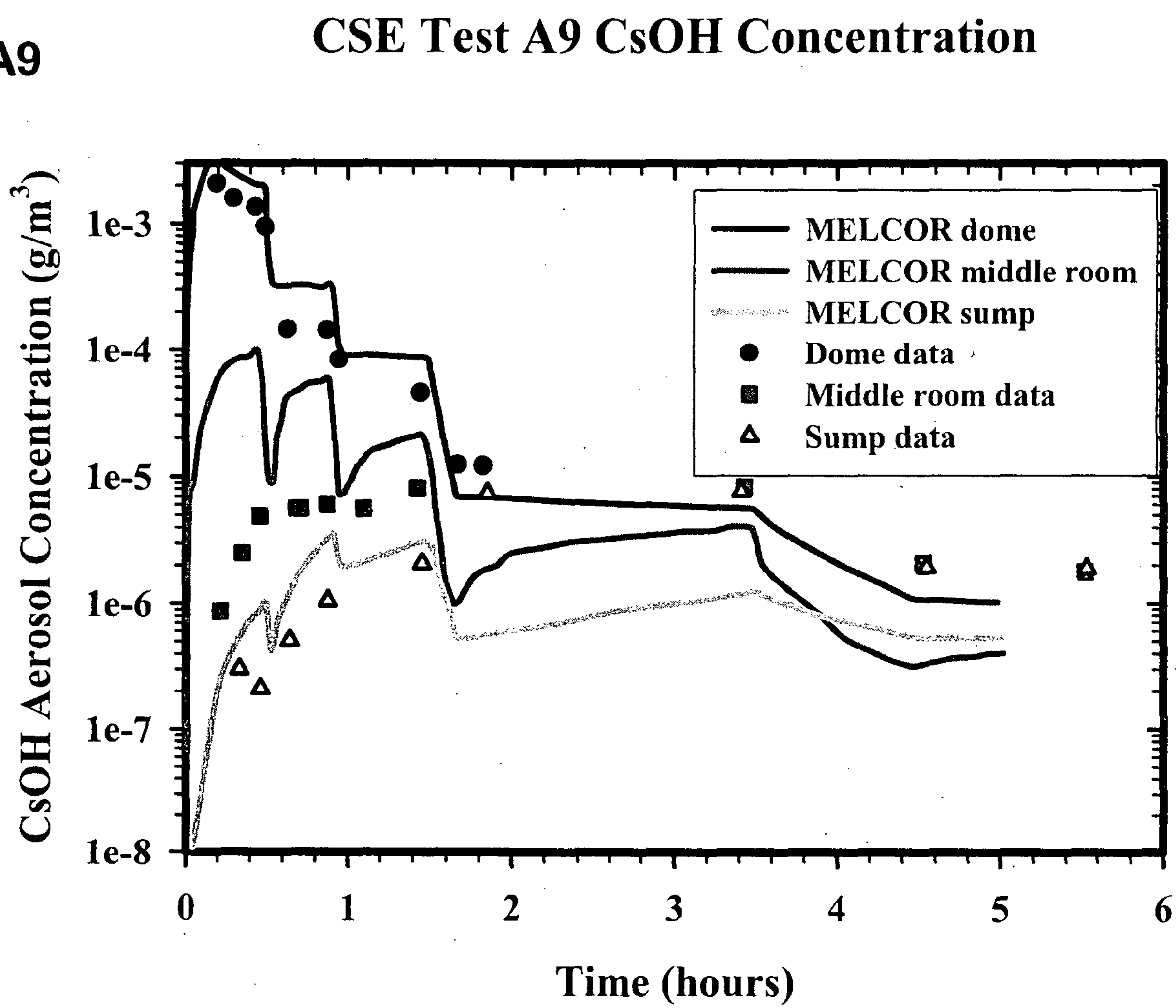
Comparison of Aerosol Test Data and Model Predictions

VANAM Test **Aerosol Depletion in Dome**



Comparison of Aerosol Test Data and Model Predictions

CSE Test A9



NUREG-1465 Alternate Source Term

- Replaced TID-14844 source term
  - 100% noble gas
  - 50% iodine as a gas
  - 1% of all else as aerosol
  - Instantly available in containment
- With a more realistic depiction of timing and radionuclide distribution
  - Gap release following clad rupture
  - Invessel release during core degradation
  - Exvessel release – core debris interactions with concrete
  - Late Invessel release – revaporization
  - 5% iodine gaseous; 0.15% organic iodide

NUREG-1465 BWR Releases Into the Containment*

	Gap**	Early in-Vessel	Ex-Vessel	Late In-Vessel
Duration (Hours)	0.5	1.5	3.0	10.0
Noble Gases: Xe, Kr	0.05	0.95	0	0
Halogens: I, Br	0.05	0.25	0.30	0.01
Alkali Metals: Cs, Rb	0.05	0.20	0.35	0.01
Tellurium group: Te. Sb. Se	0	0.05	0.25	0.005
Barium, Strontium: Ba, Sr	0	0.02	0.1	0
Noble Metals: Ru, Rh, Pd, Mo, Tc, Co	0	0.0025	0.0025	0
Lanthanides: La, Zr, Nd, Am Eu, Nb, Pm, Pr, Sm, Y, Cm.	0	0.0002	0.005	0
Cerium Group: Ce, Pu, Np	0	0.0005	0.005	0

* Values shown are fractions of core inventory.

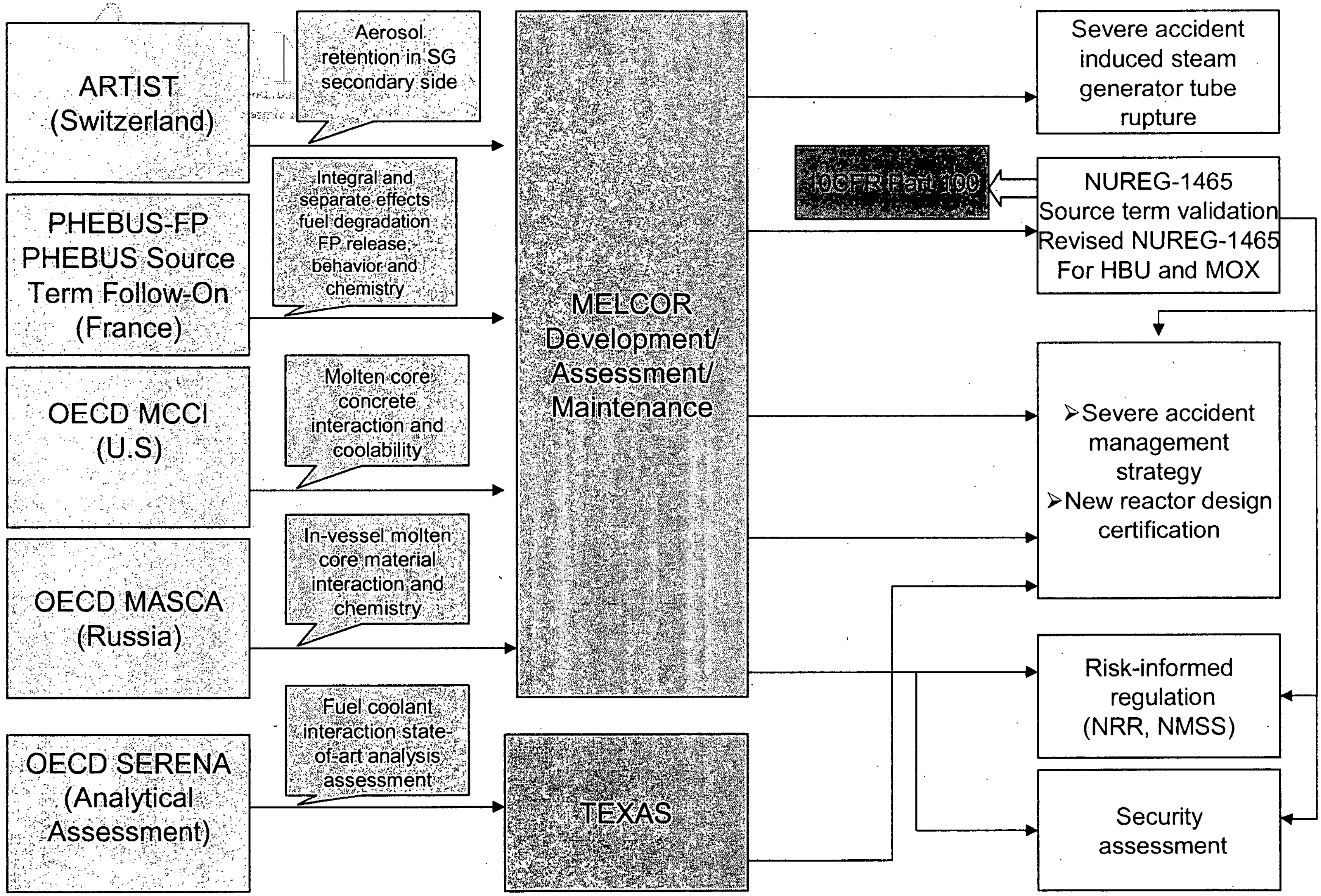
**Gap release is 3 percent if long-term fuel cooling is maintained.

Status at Completion of NUREG-1150

- Understanding of severe accidents adequate for regulatory needs at the time
  - May not be adequate in the future as Level III analyses become more important
- Further advances needed more realistic data
  - In-pile testing with irradiated fuel strains resources
  - Too many possible chemical alternative to include in models; experiments needed to refine options
- Integrated, systems level model needed as a repository for knowledge and understanding that developed in the future
  - MELCOR code selected to replace Source Term Code Package

CURRENT STRATEGY

- International collaboration on experimental studies
  - PSI ARTIST
  - OECD MASCA
  - OECD MCCI
  - PHÉBUS-FP and PHÉBUS-ST
- Develop MELCOR as the repository of knowledge
  - International standard problems to test code
- Maintain TEXAS for FCI analysis
- NRC Cooperative Severe Accident Research Program



Severe Accident Code Development/Assessment/Maintenance, Experiments and Applications

Phébus-FP

- Integral, phenomenological tests of fission product release and transport from irradiated reactor fuel organized by the Institut de Radioprotection et de Sûreté Nucléaire at the Cadarache facility in France:
  - Release from degrading fuel in steam
  - Transport through a model RCS including a steam generator tube
  - Behavior in a model containment

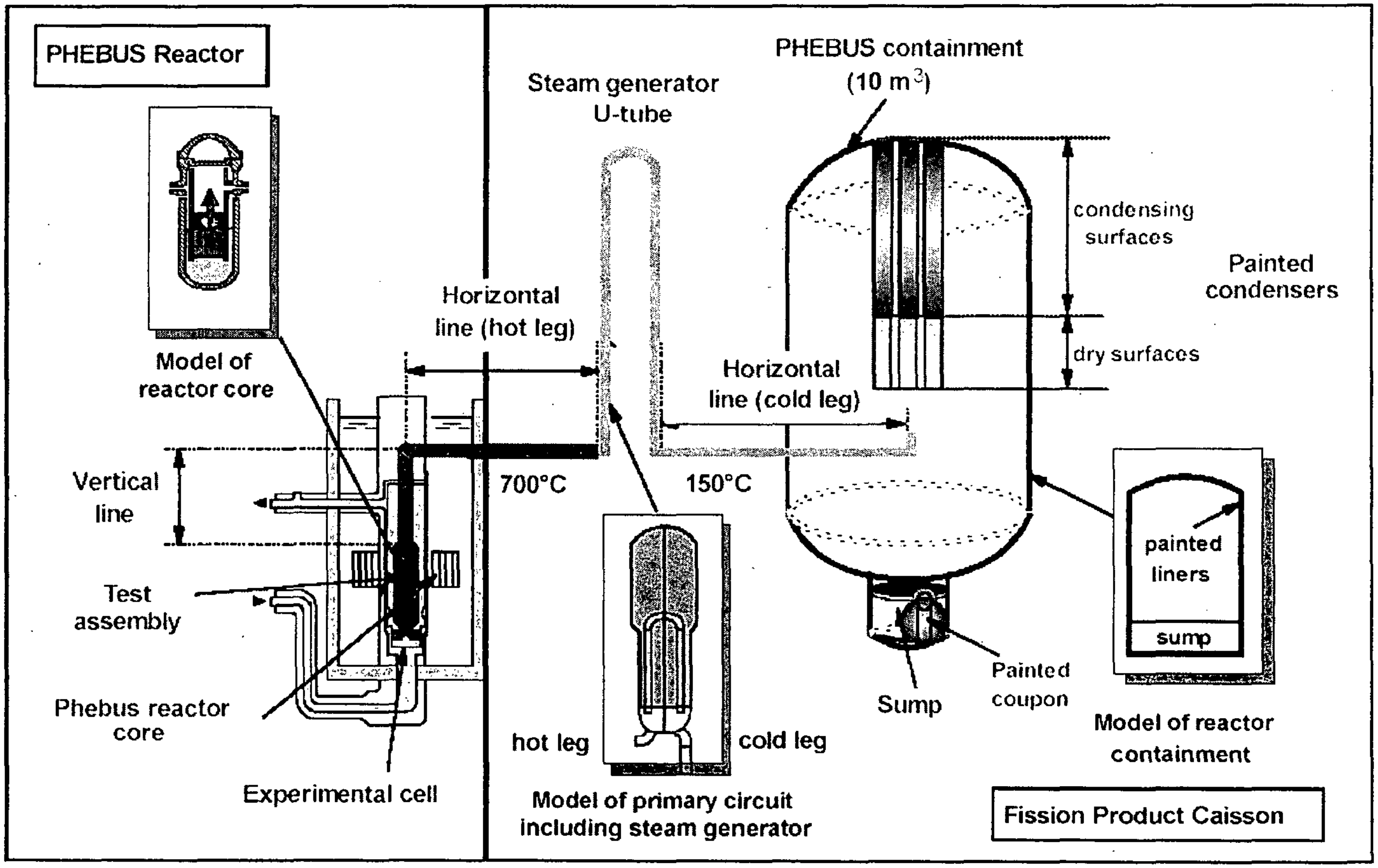
Organization of the Collaborative Effort

- Key feature of the Phébus-FP Effort
  - Should be emulated by other collaborative projects
  - Almost as important as tests themselves
- Steering Committee (Meet once a year)
- Scientific Analysis Working Group
  - Bundle interpretation Circle
  - Containment Chemistry Interpretation Circle
  - Circuit and Containment Aerosol Interpretation Circle

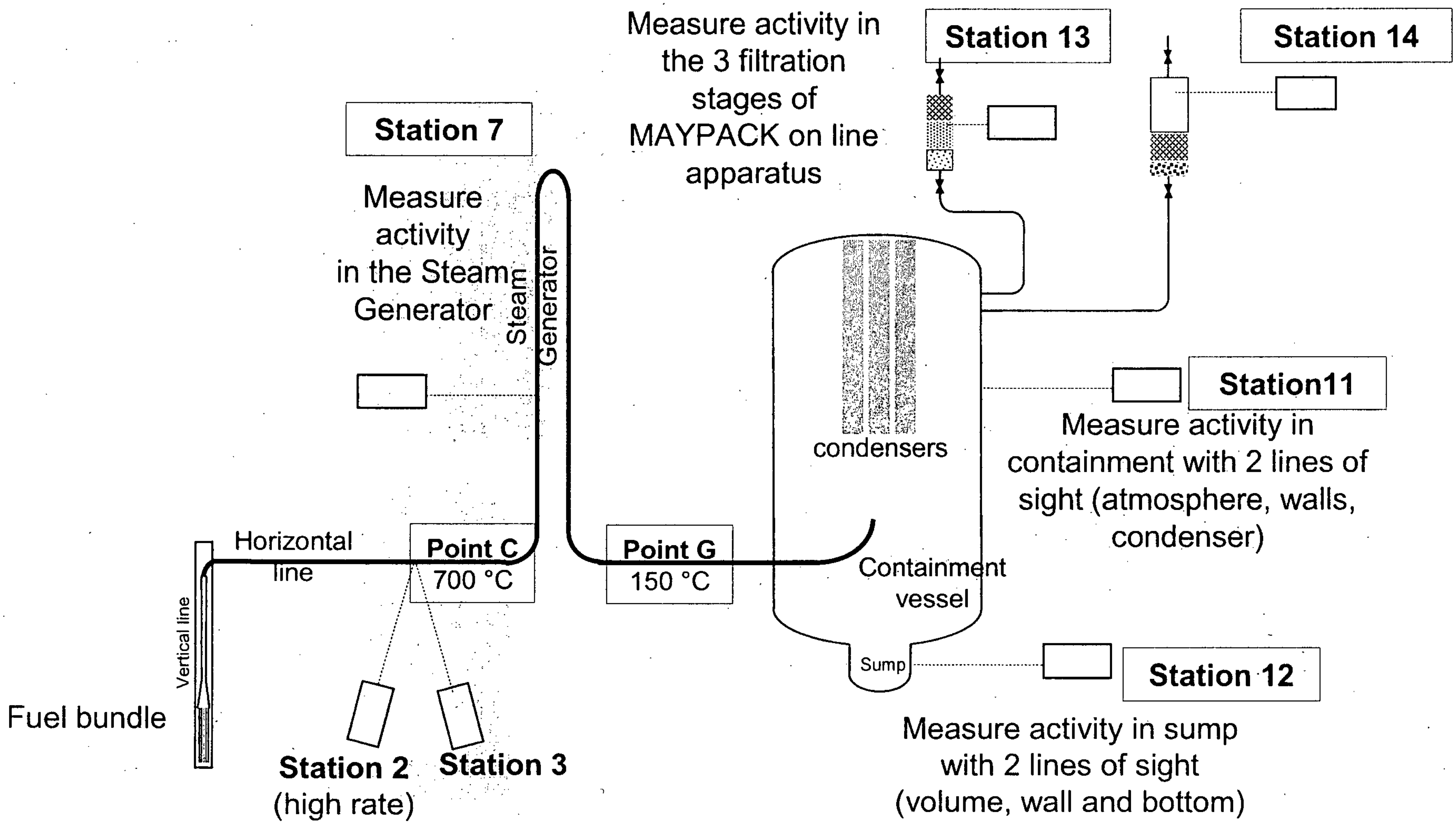
  Meet every 6 months to review progress and plan the next steps in the project

Facility Scaled 1:5000 from a French 900 MW_e PWR

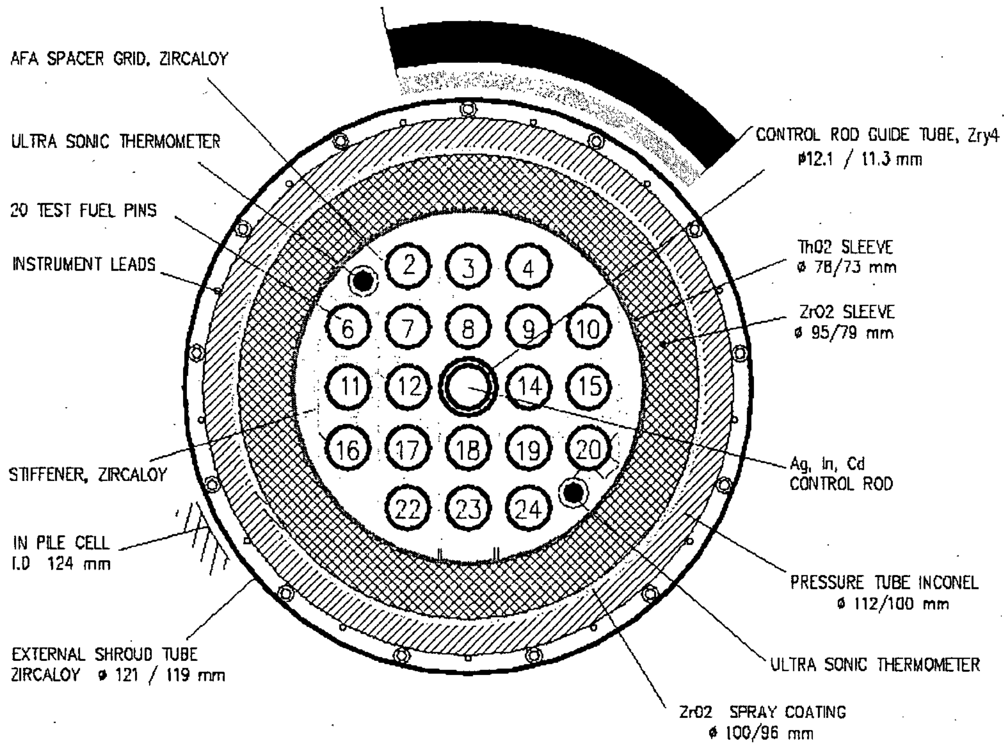
PHEBUS facility



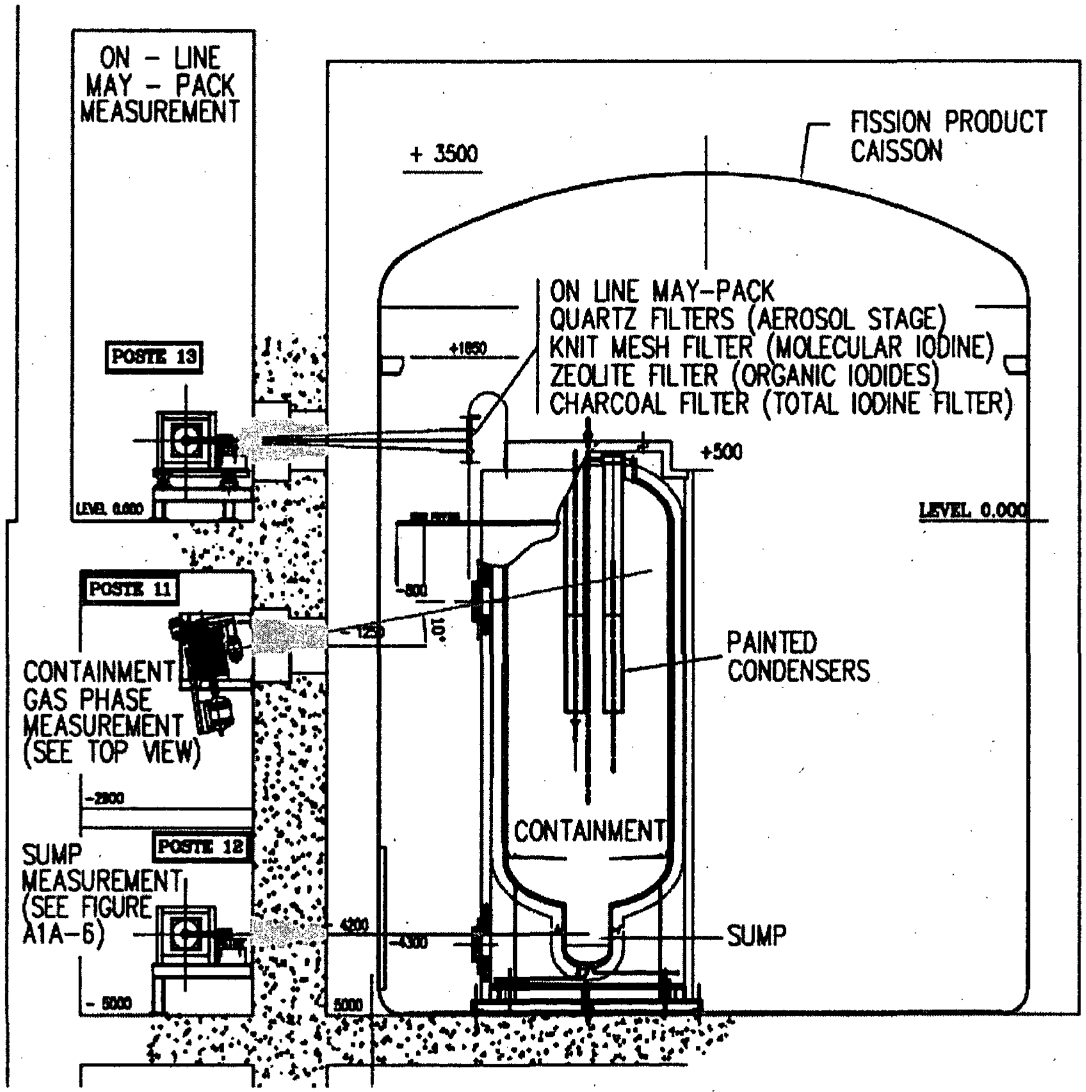
Major Elements of the Instrumentation of PHÉBUS-FP Tests



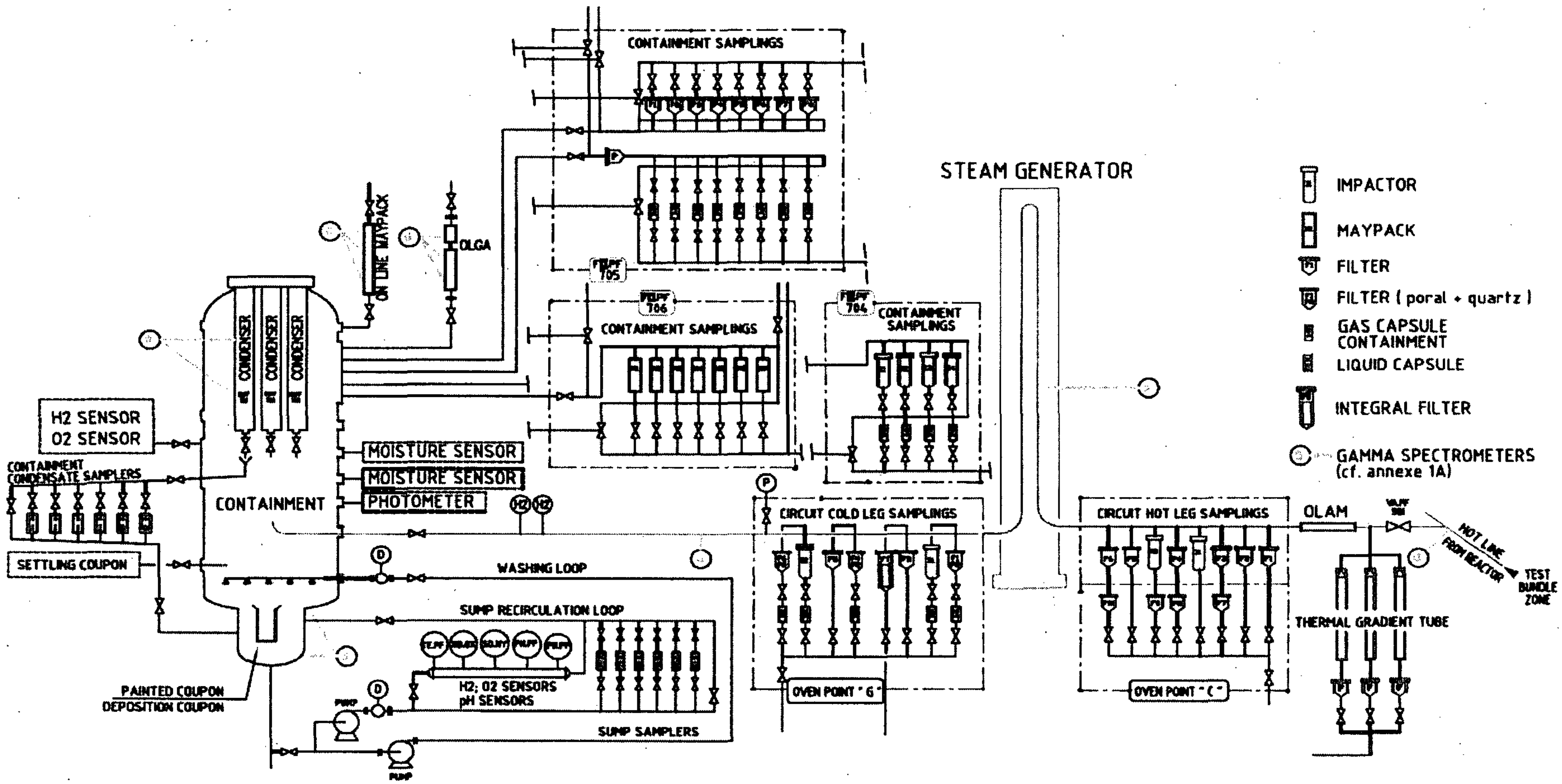
Cross-section of Fuel Bundle



Some Detail on the Containment Model and the Surrounding Fission Product Caisson Used in the PHÉBUS-FP Tests



Overview of the Instrumentation for the Circuit and Containment in the Tests



FPT1 INSTRUMENTATION PLAN

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Extensive Instrumentation

- Thermal Gradient sampler tubes
- Filters
- Cascade impactors
- Optical attenuation
- Maypack iodine samplers to separate particulate, molecular and organic iodine
- Gamma spectrometer stations

The PHÉBUS-FP Test Matrix

Test	Fuel	Flow	Control Rod	Other
FPT-0	Trace irradiated	1.5 g steam/s	Ag-In-Cd	Sump at pH = 5
FPT-1	23 GWd/t	1.5 g steam/s	Ag-In-Cd	Sump at pH = 5
FPT-2	32 GWd/t	0.5 g steam/s Includes boric acid	Ag-In-Cd	Sump at pH = 9; evaporating sump
FPT-3	24 GWd/t	0.5 g steam/s	B_4C	Sump at pH = 5; evaporating sump
FPT-4	38 GWd/t		None	Test of late stage release
FPT-5	Planned as a test of air ingression; deleted for technical and financial reasons			

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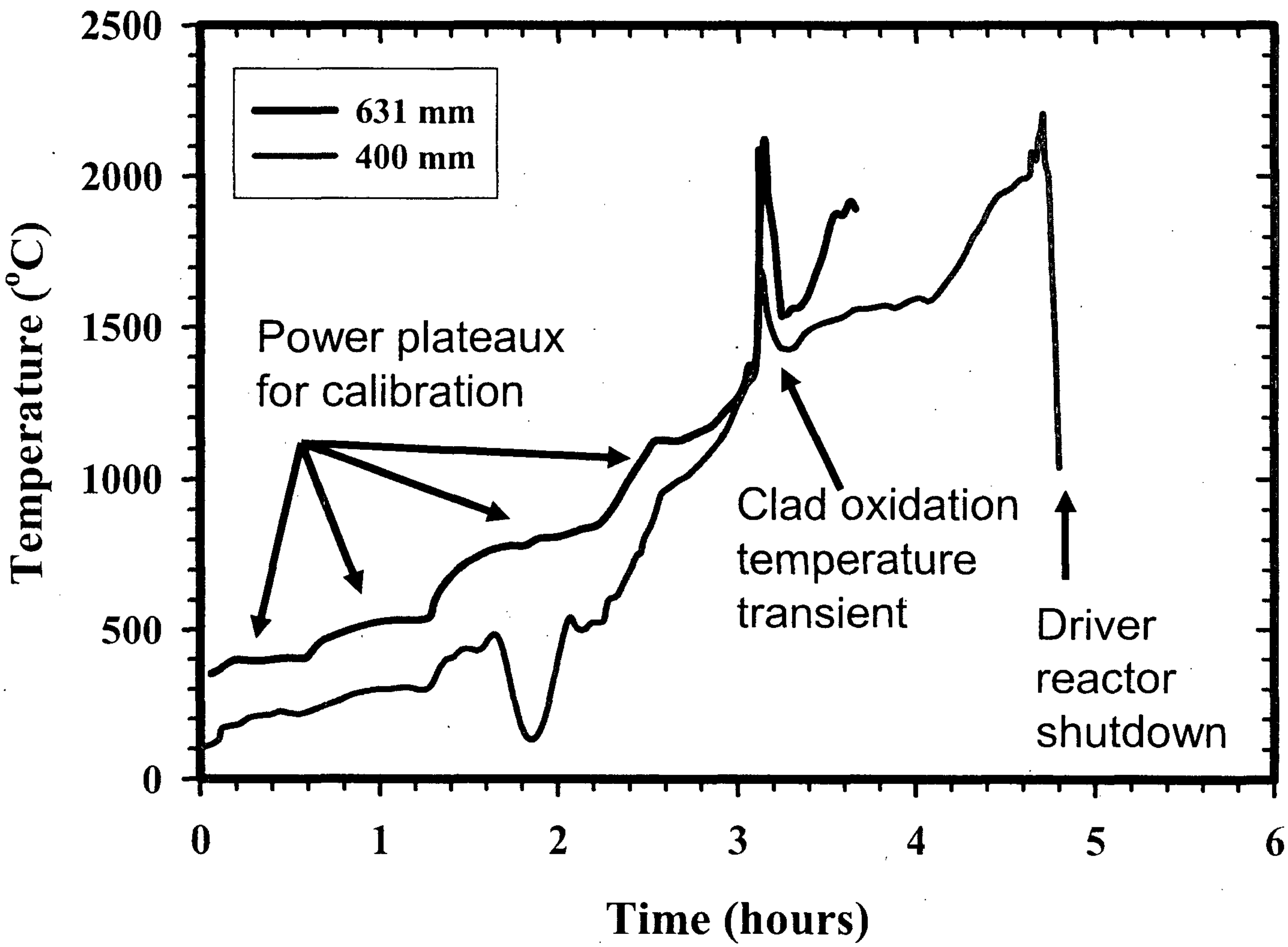
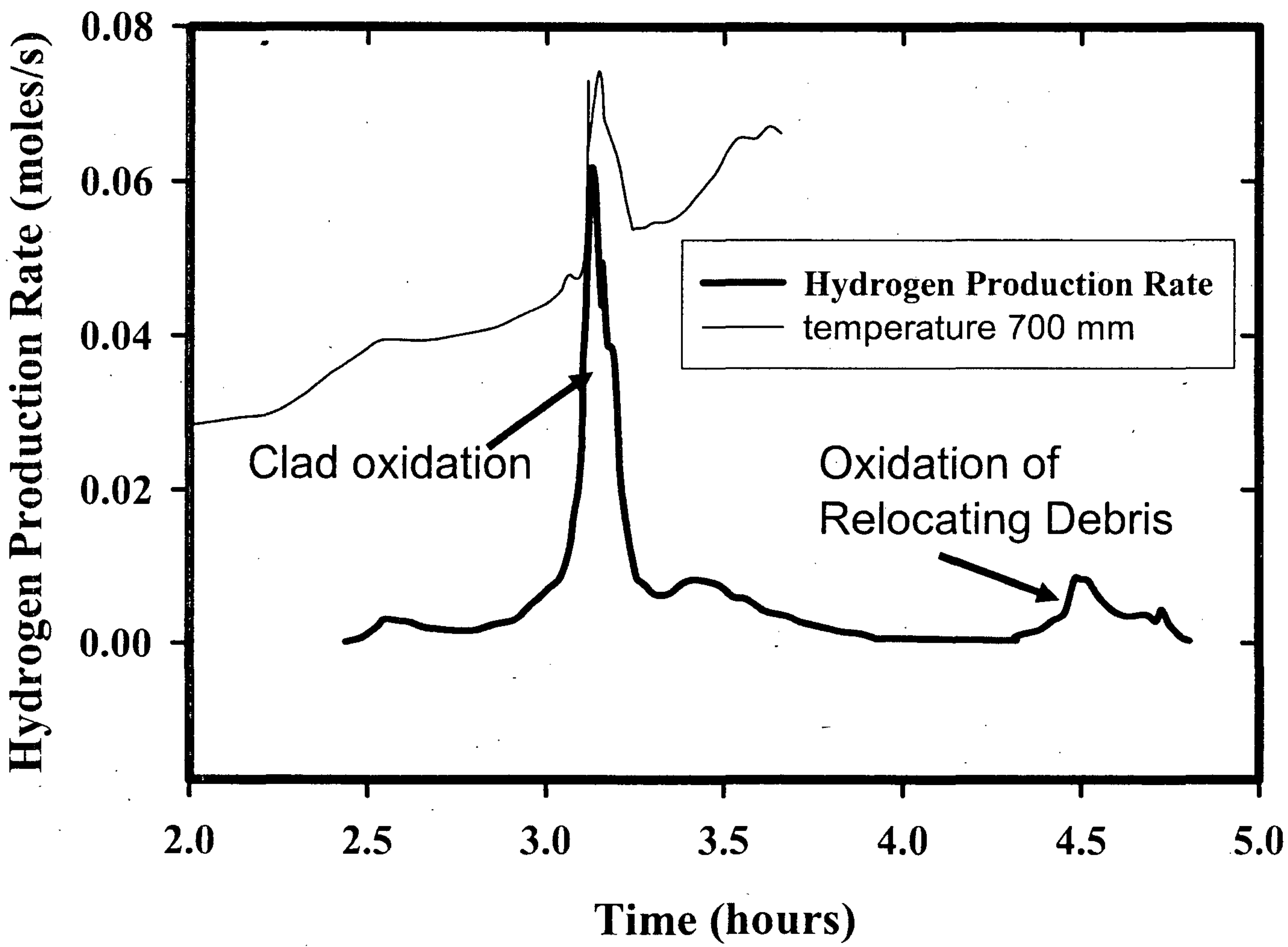
Typical Test Protocol

- Re-irradiate test bundle for ~ 8 days to build in shorter life fission products – especially iodine
- Temperature plateaux for calibration of instruments etc.
- Active degradation – 1 to 2 hours
- Aerosol phase ~ 1 day
- Washing phase to move radionuclides for containment lower head to the sump
- Chemistry phase to monitor the behavior of iodine in the containment model ~ 3 days

Temperatures at Two Elevations in the Fuel Bundle Used in Test FPT - 1



Hydrogen Production Test FPT-1



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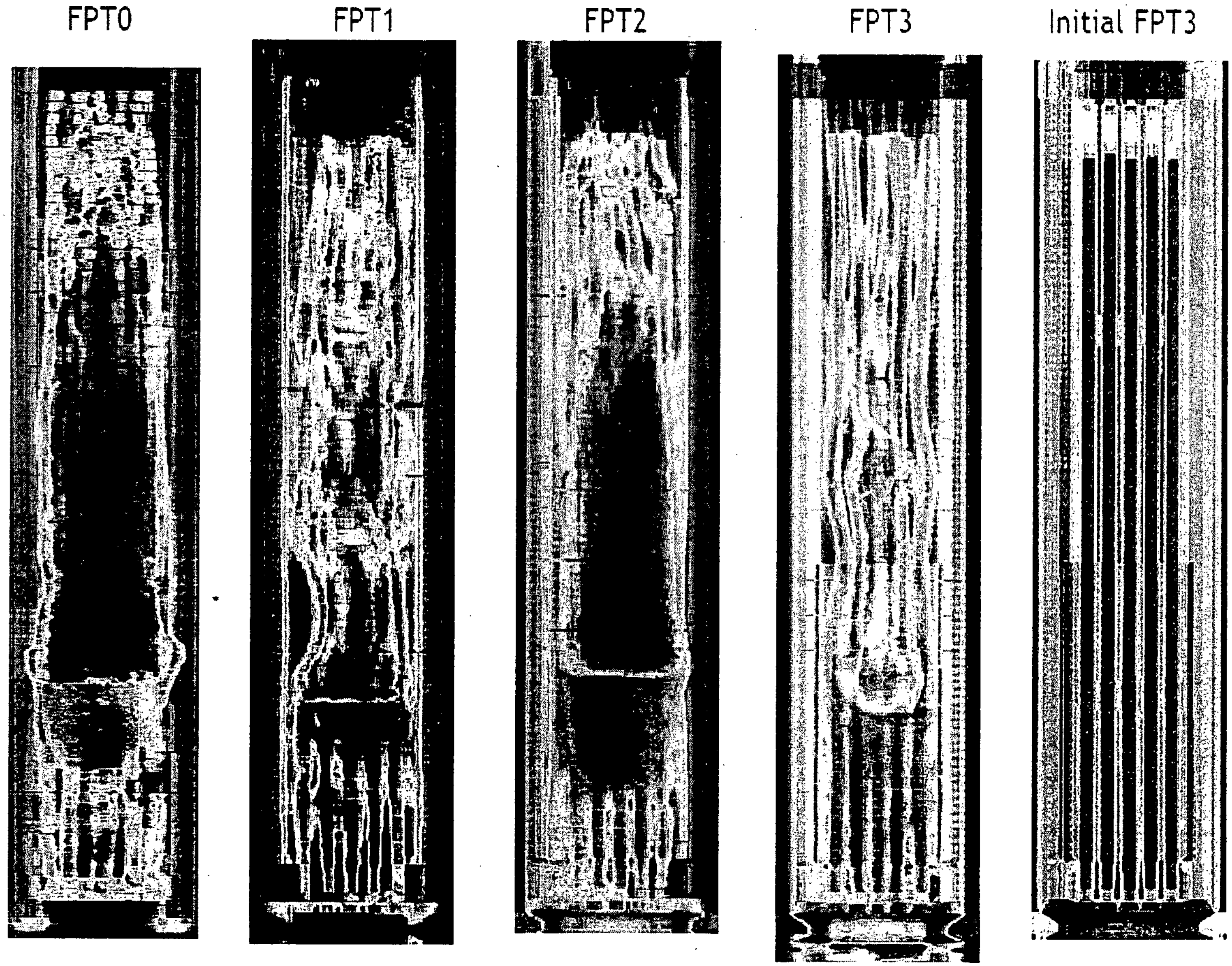
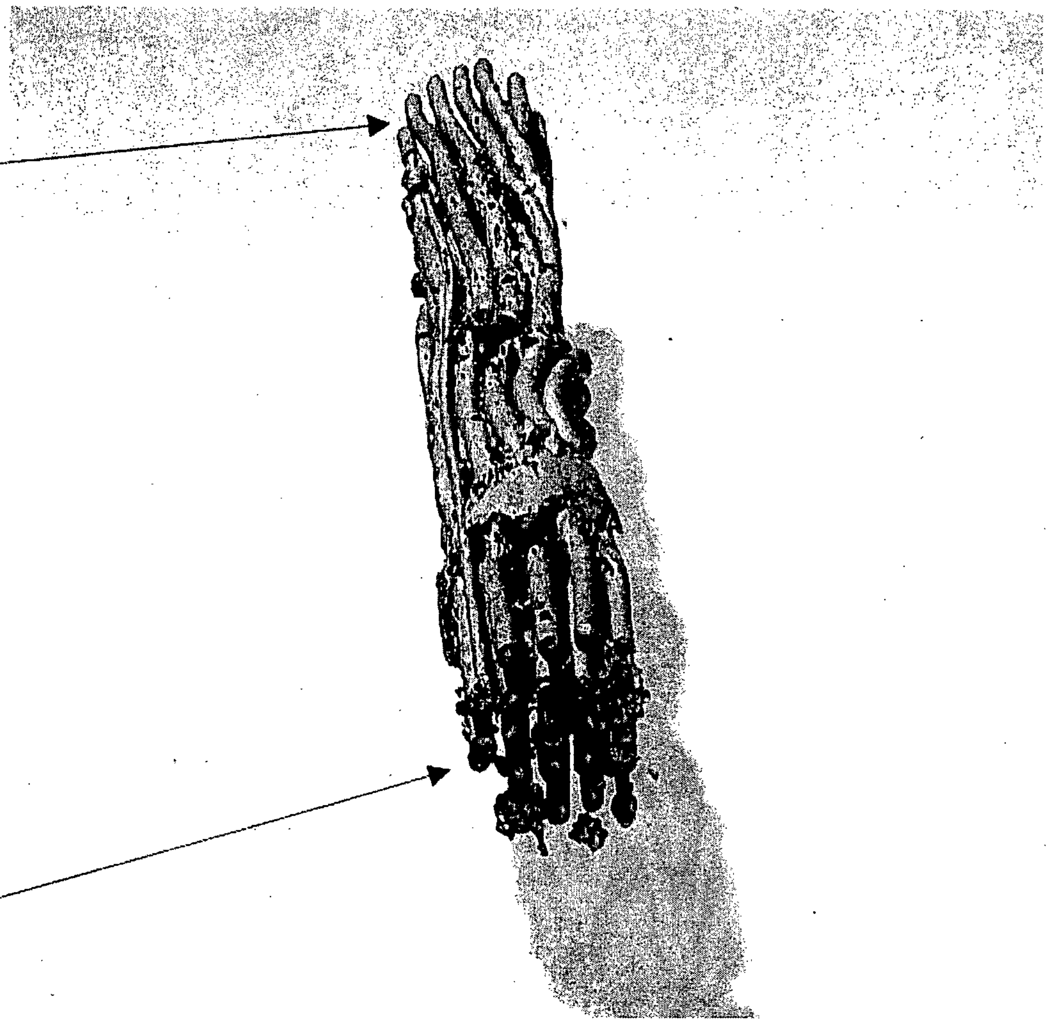
Examples of Fuel Degradation Observed in PHÉBUS-FP Tests



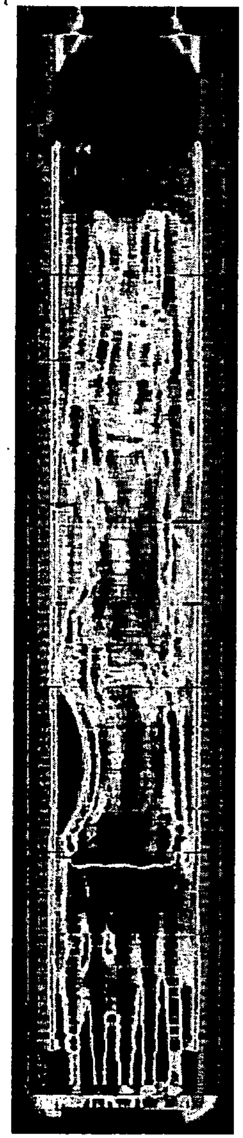
Computed Tomograph of FPT1 Fuel Bundle

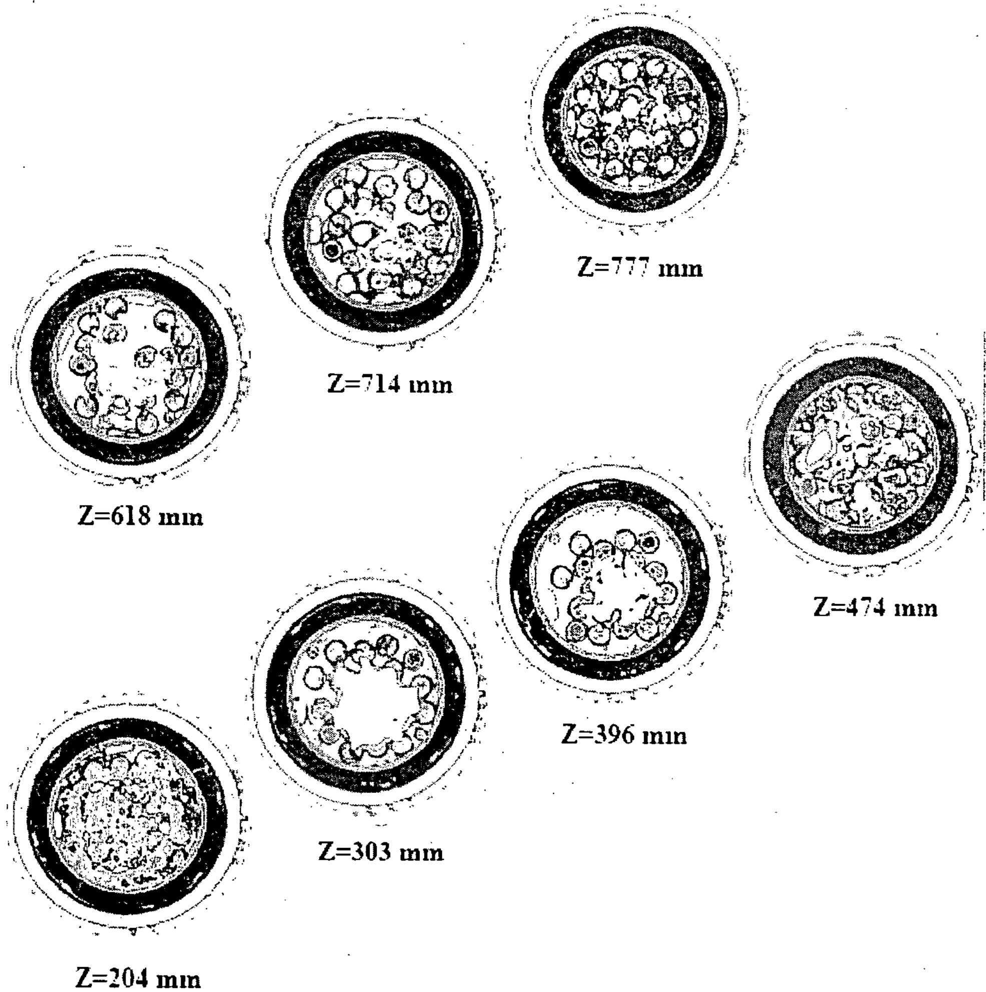
Upper part of the bundle
Figure 4.2-48b



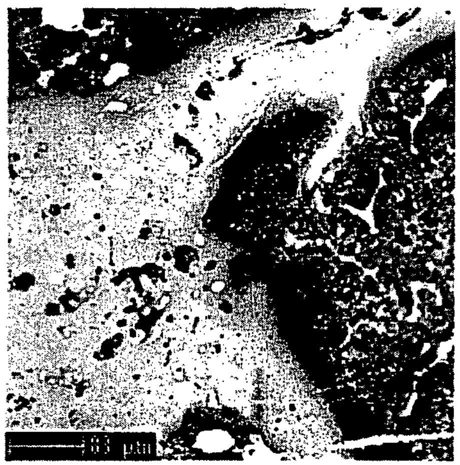
Lower part of the bundle
Figure 4.2-48c

Radiography and tomograms of the FPT1 bundle

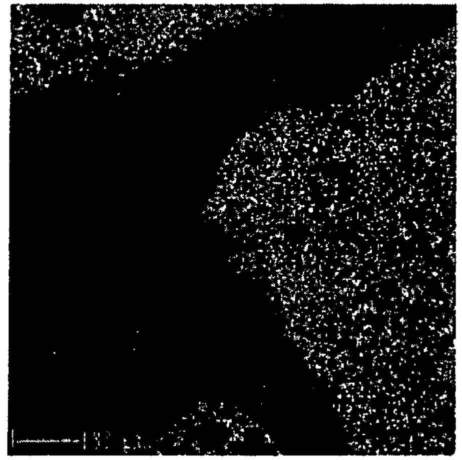




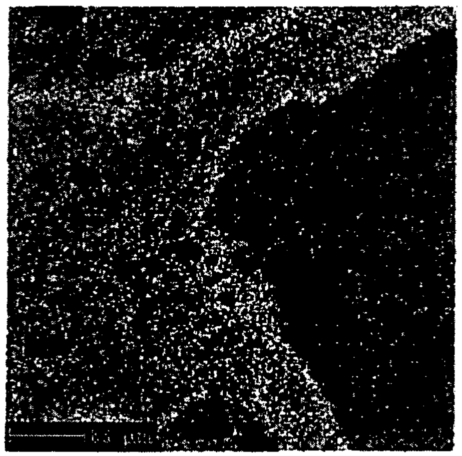
Post Irradiation Examination of Molten Clad Interactions with Fuel



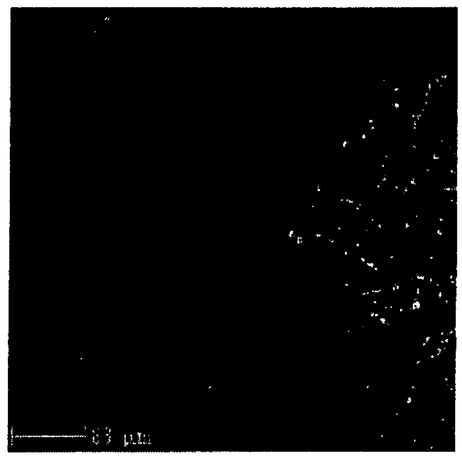
Absorbed Electron Image



U Image

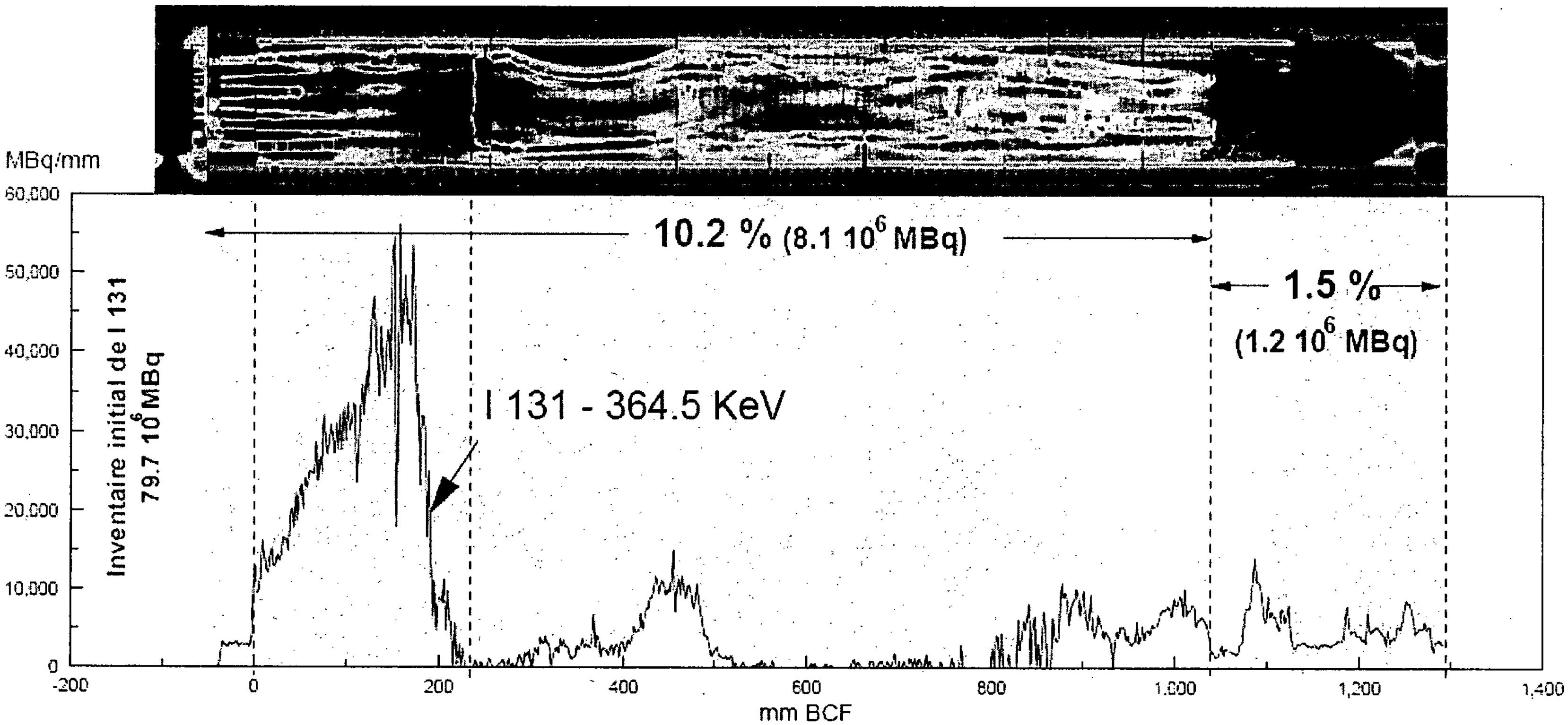


Zr Image

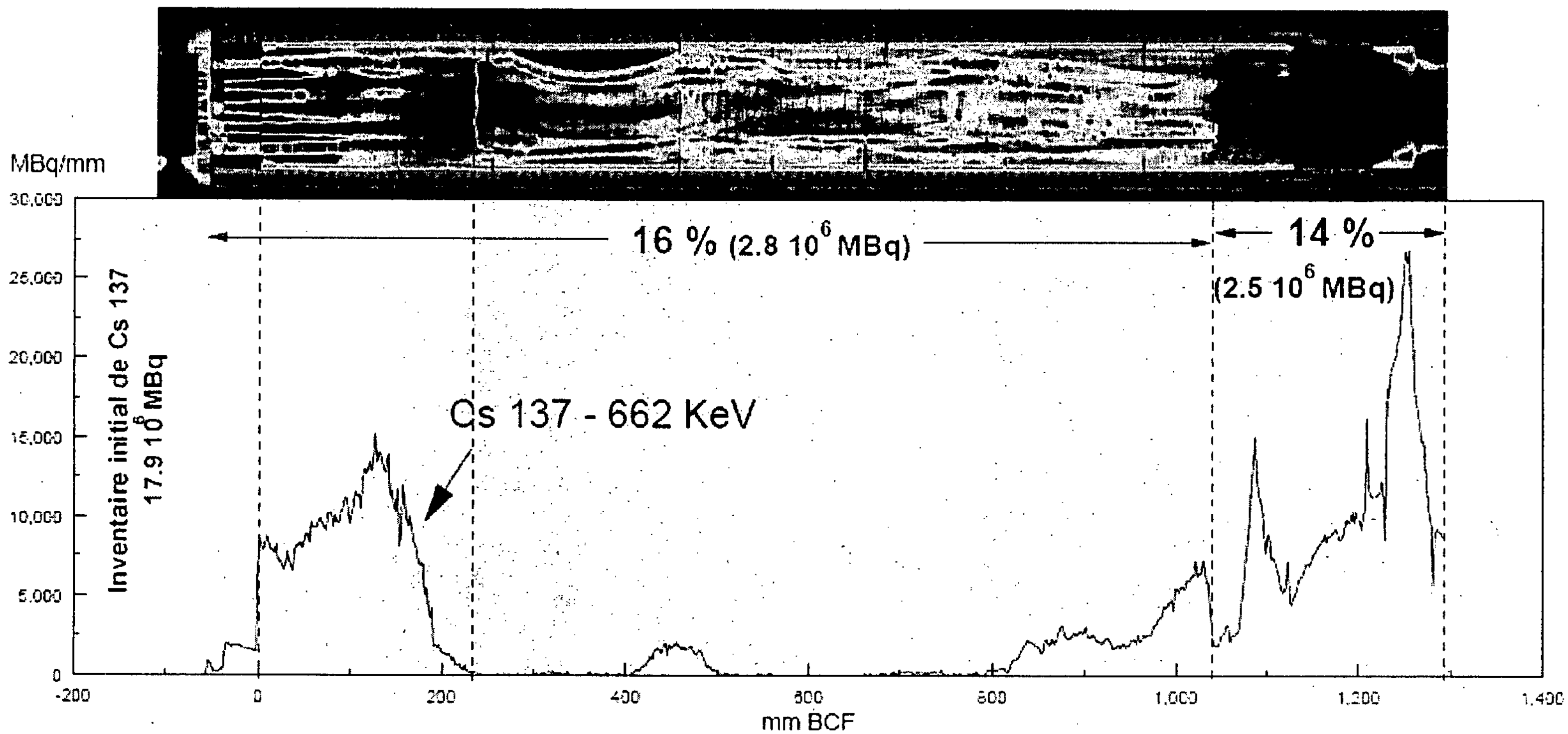


Fe Image

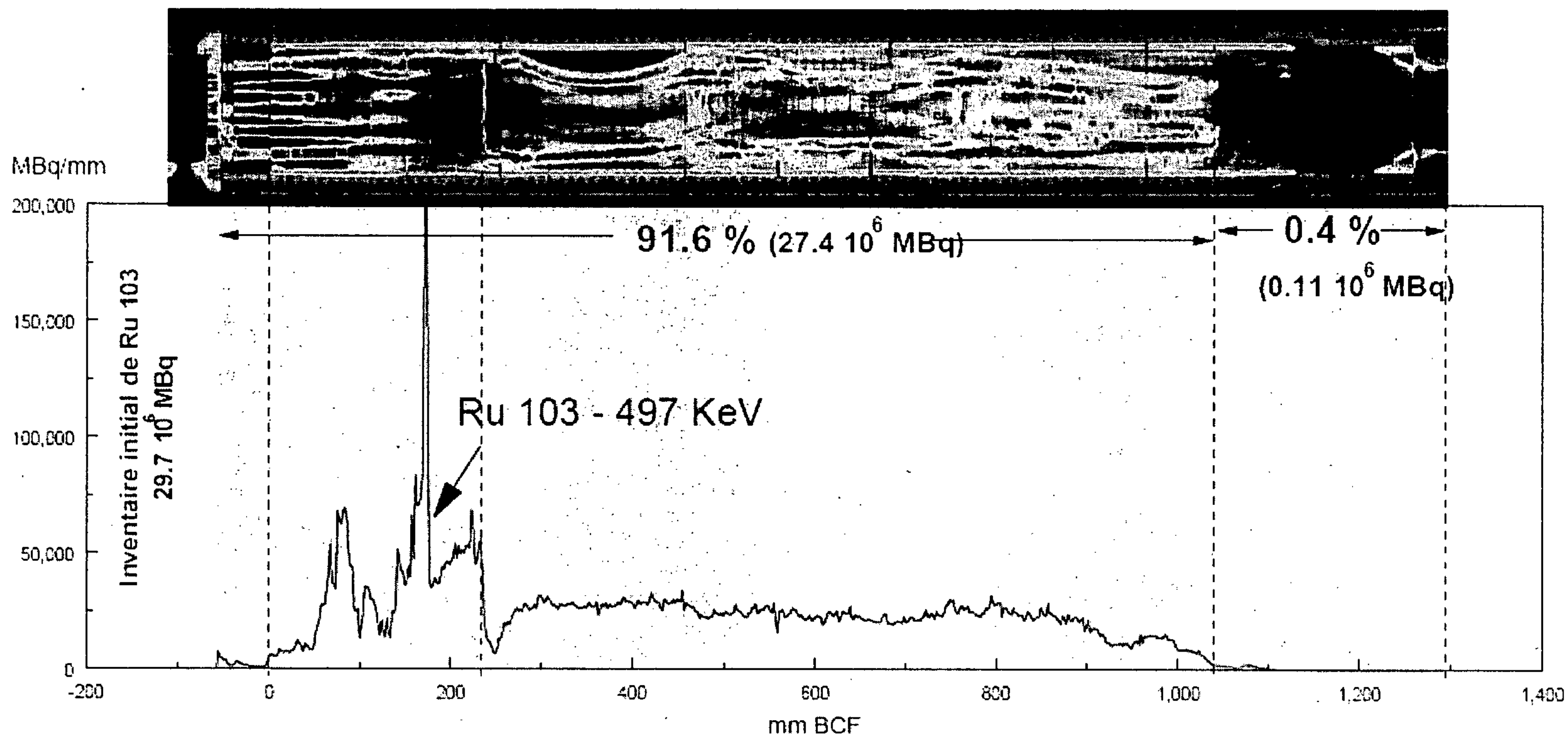
Iodine remaining in the fuel bundle FPT-1



Cesium remaining in Fuel Bundle FPT-1



Ruthenium remaining in the Fuel Bundle



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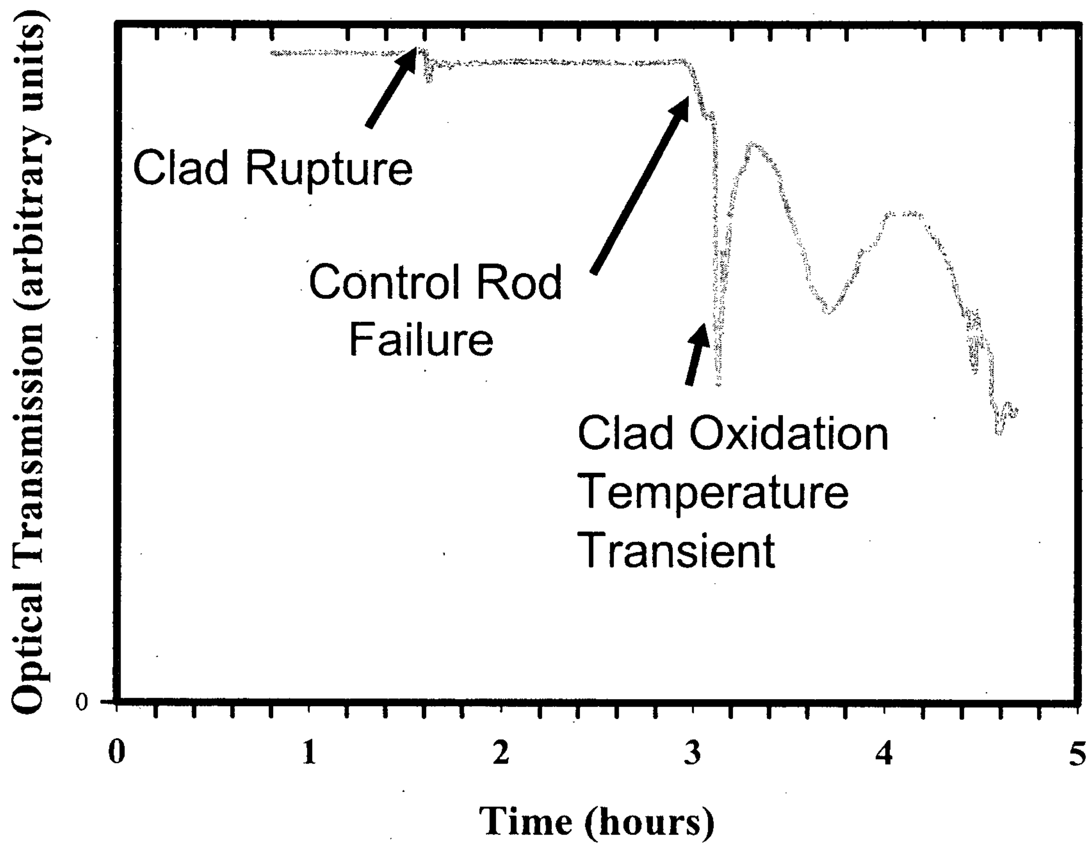
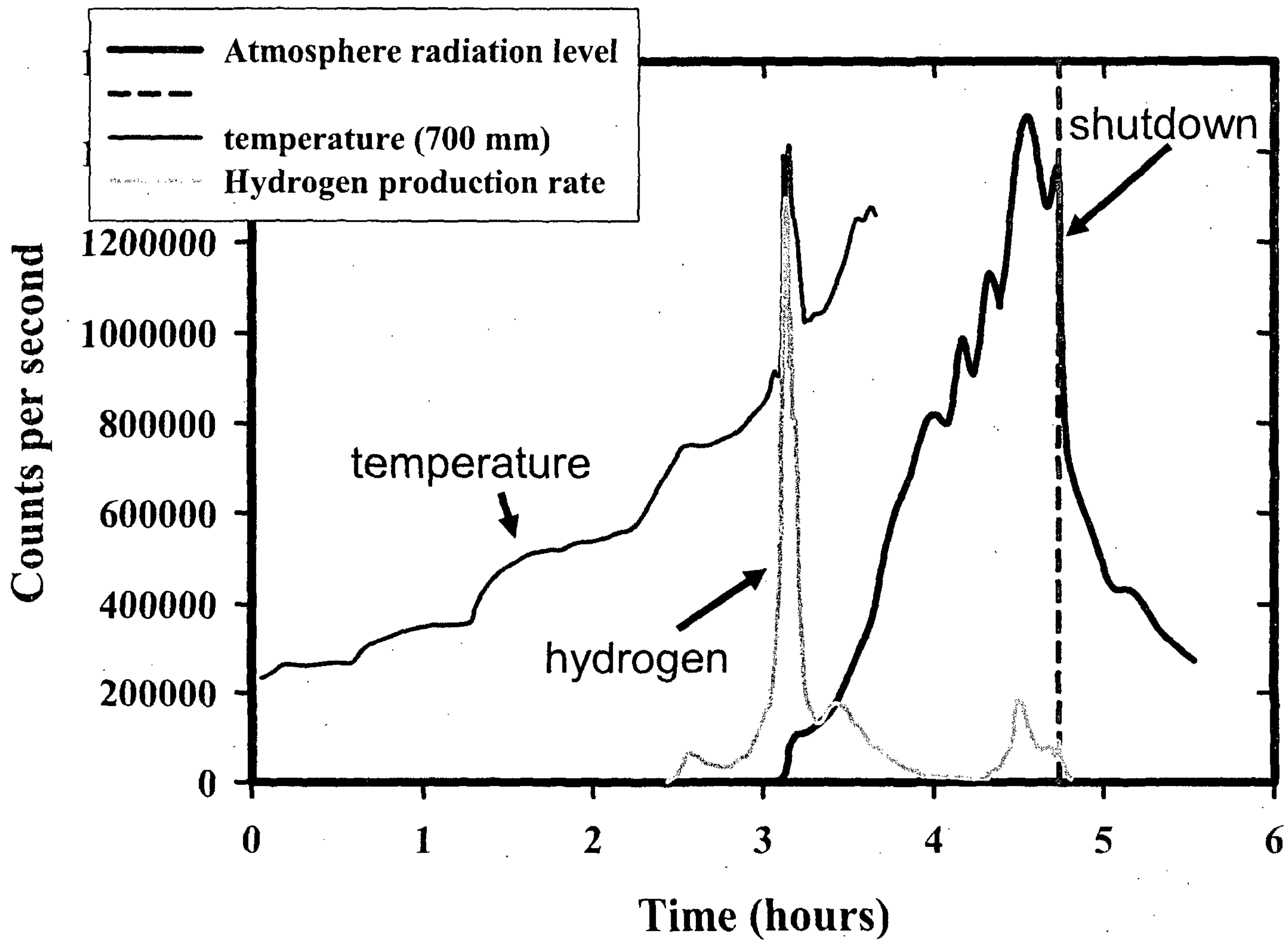
Release from Fuel

	% Released	
Element	Observed	Predicted (MELCOR)
Xe	77	86
I	83-91	77
Cs	83-85	79
Te	82-84	77
Mo	52-60	43
Sn	> 38	37
Ba	< 5	0.1
Ru	< 5	0.7

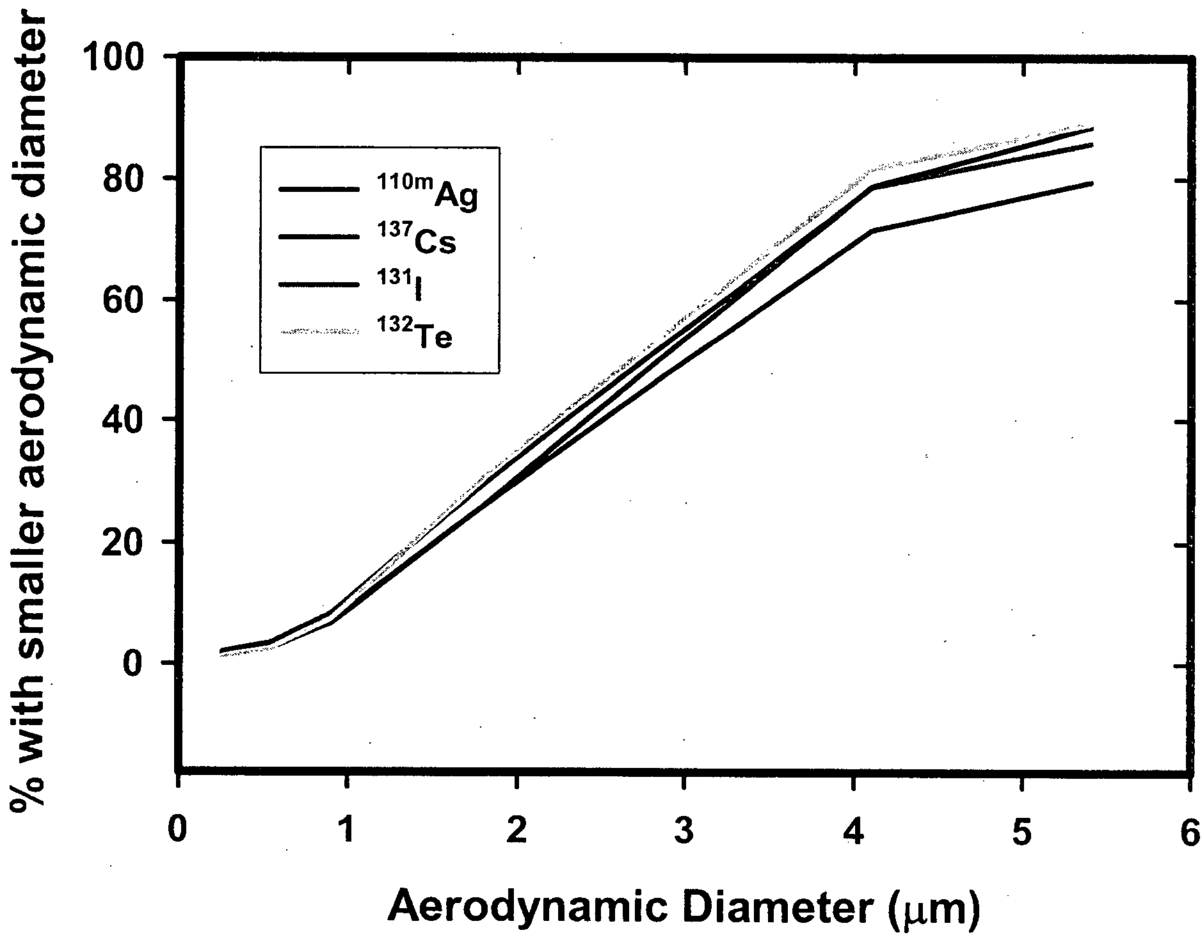
Optical Transmission in Circuit FPT-1



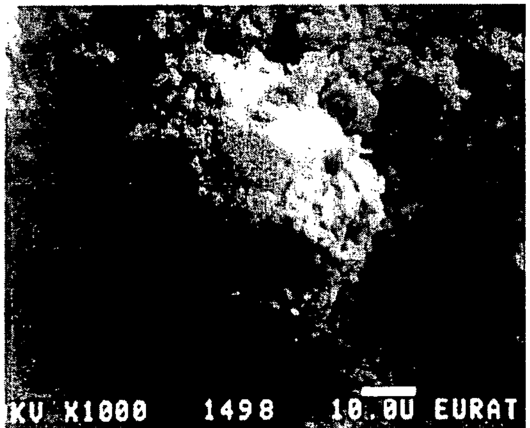
Radiation in Containment FPT-1



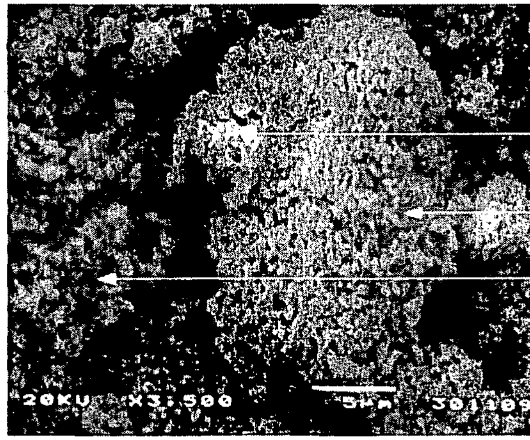
Aerosol Size Distribution FPT-1 after the steam generator tube



FPT1 - Scanning electron microscopy examination of circuit samples (specific particles)



10.00U=5μm



Particle A

Particle B

Particle C

Zr-rich particle on point C filter FIPF 701

element	weight %
Zr :	38.0%
U :	25.0%
Ag :	13.0%
Re :	13.0%
Ni :	3.0%
Fe :	3.0%
Si :	2.0%
Sn :	1.0%
In :	1.0%
Cr :	1.0%

Particles on point G impactor IMPF 703

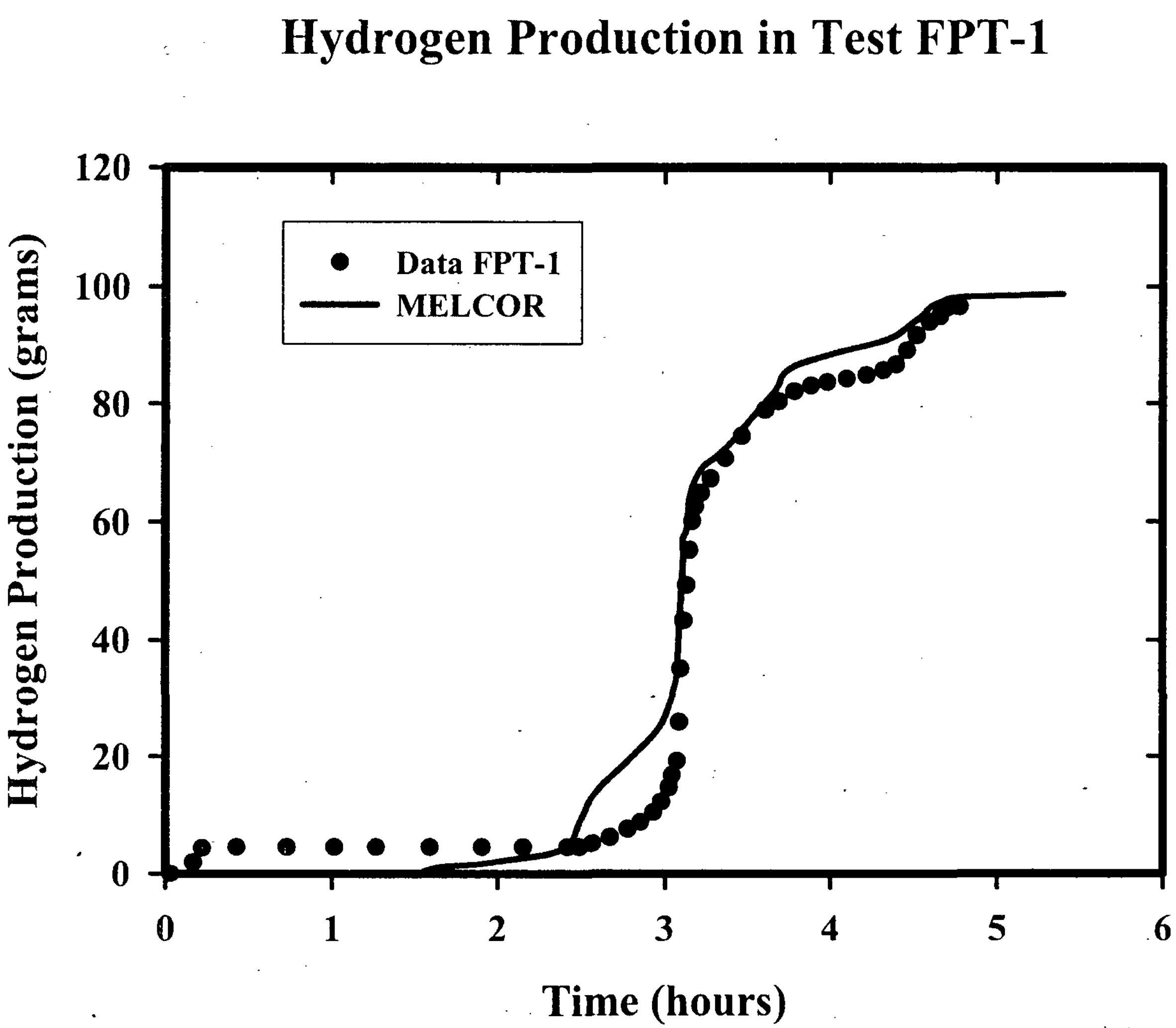
20kV analysis (weight %)

element	particle A	particle B	particle C
Re :	20.0%	46.0%	12.0%
Ag :	21.0%	7.0%	67.0%
Al :	2.0%	1.0%	1.0%
U :	23.0%	5.0%	11.0%
Sn :	5.0%	2.0%	3.0%
Si :	12.0%	3.0%	2.0%
Cs :	2.0%	28.0%	
W :	15.0%	3.0%	2.0%
Cl :		3.0%	
Tc :		2.0%	
Mo :			2.0%

PHEBUS-FP Data

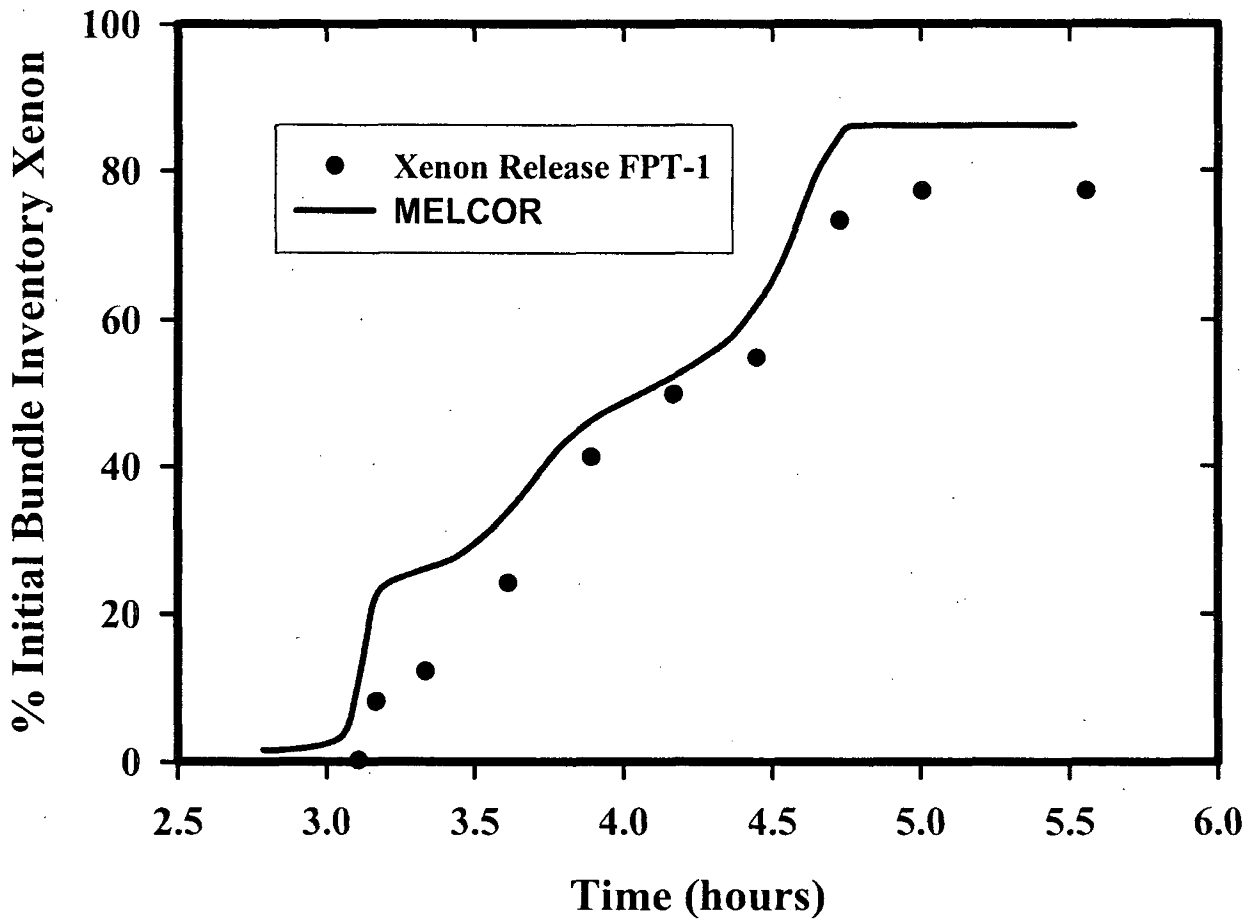
- Only a snapshot of a small fraction of the data can be shown.
- Years of analysis will be needed to assimilate it all.

MELCOR vs. test data

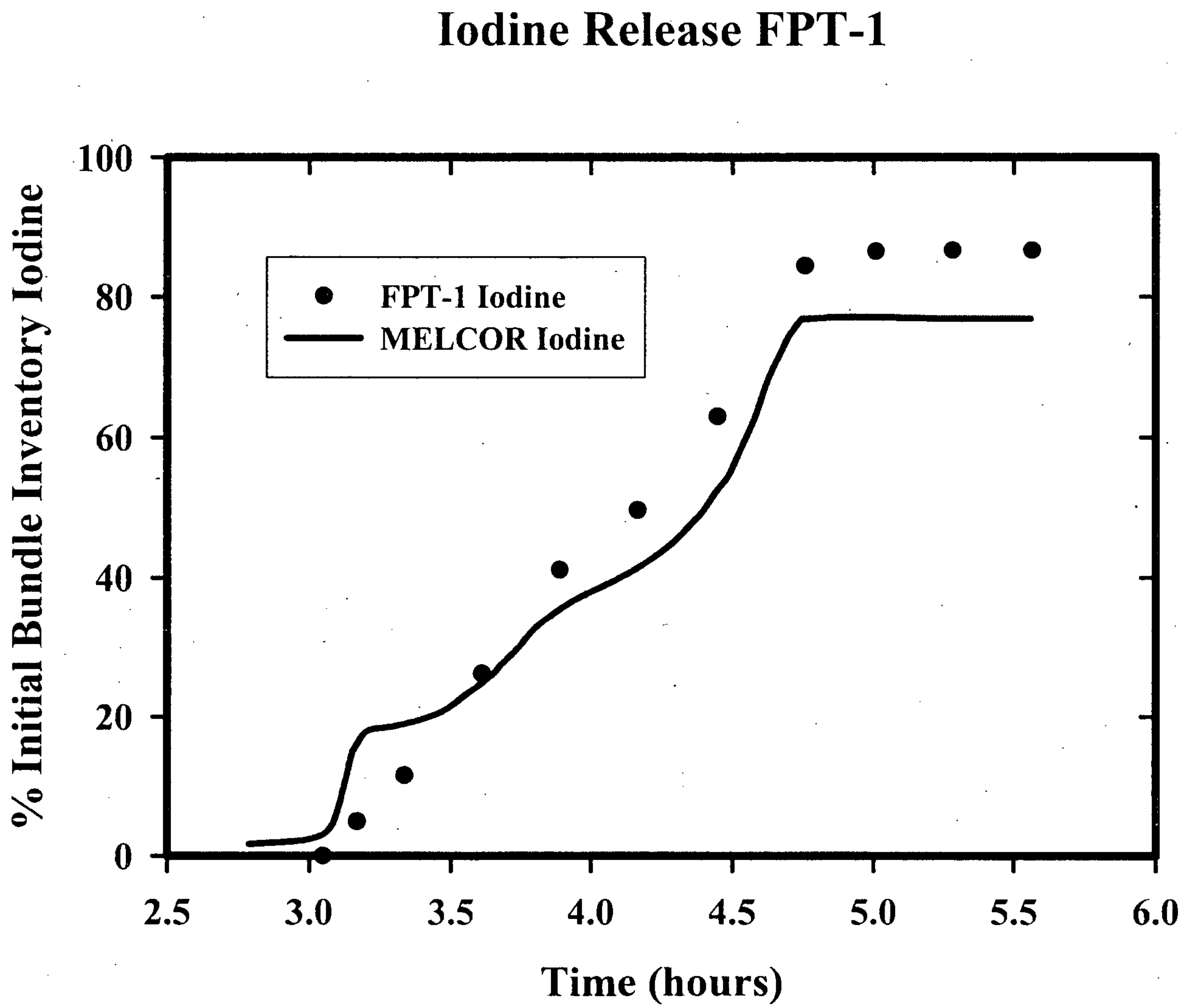


MELCOR vs. test data (continued)

Xenon Release FPT-1

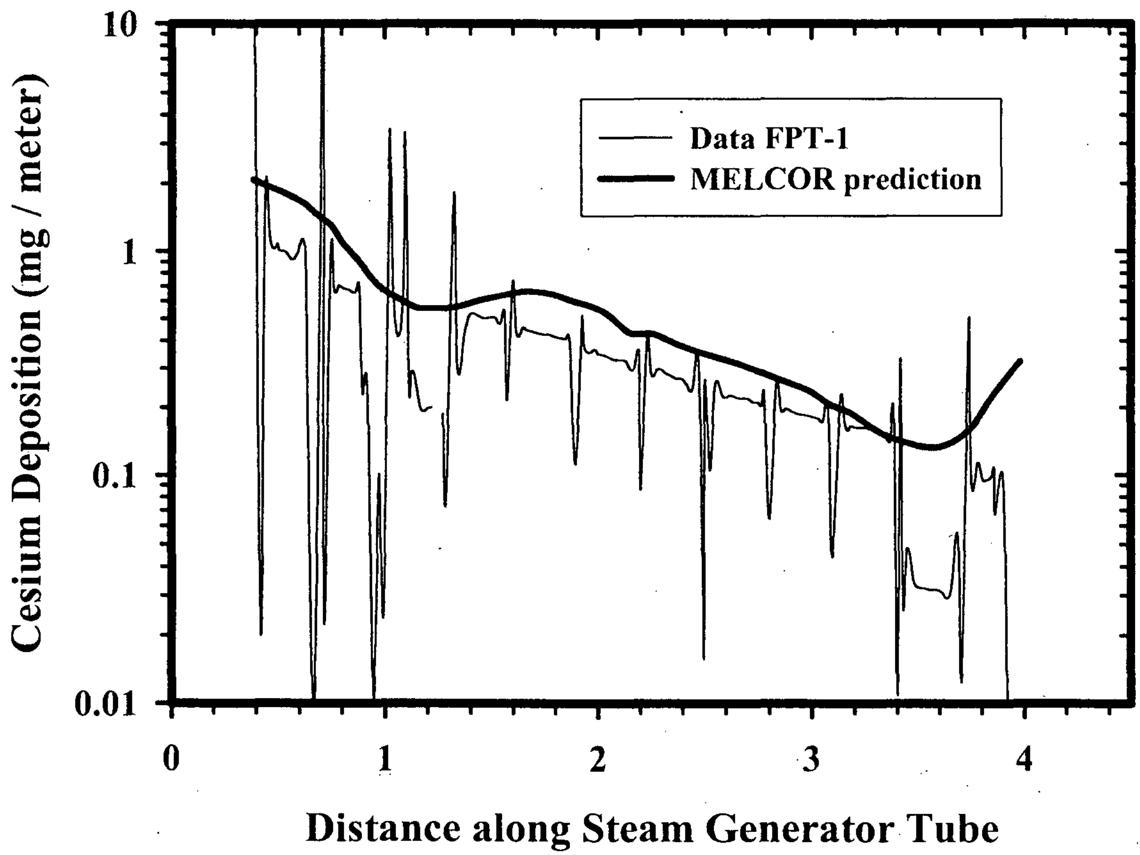


MELCOR vs. test data (continued)



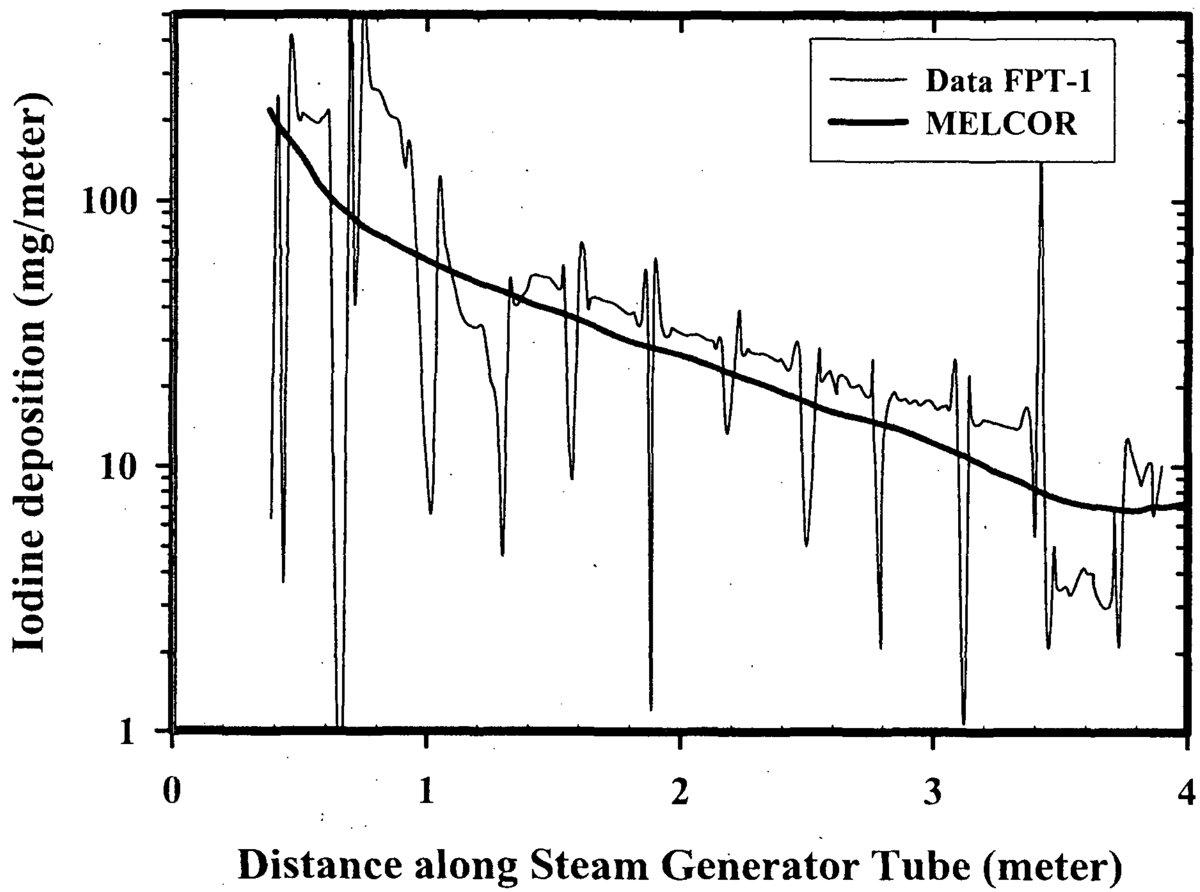
MELCOR vs. test data (continued)

Cesium Deposition in Steam Generator



MELCOR vs. test data (continued)

Iodine Deposition in Steam Generator Tube



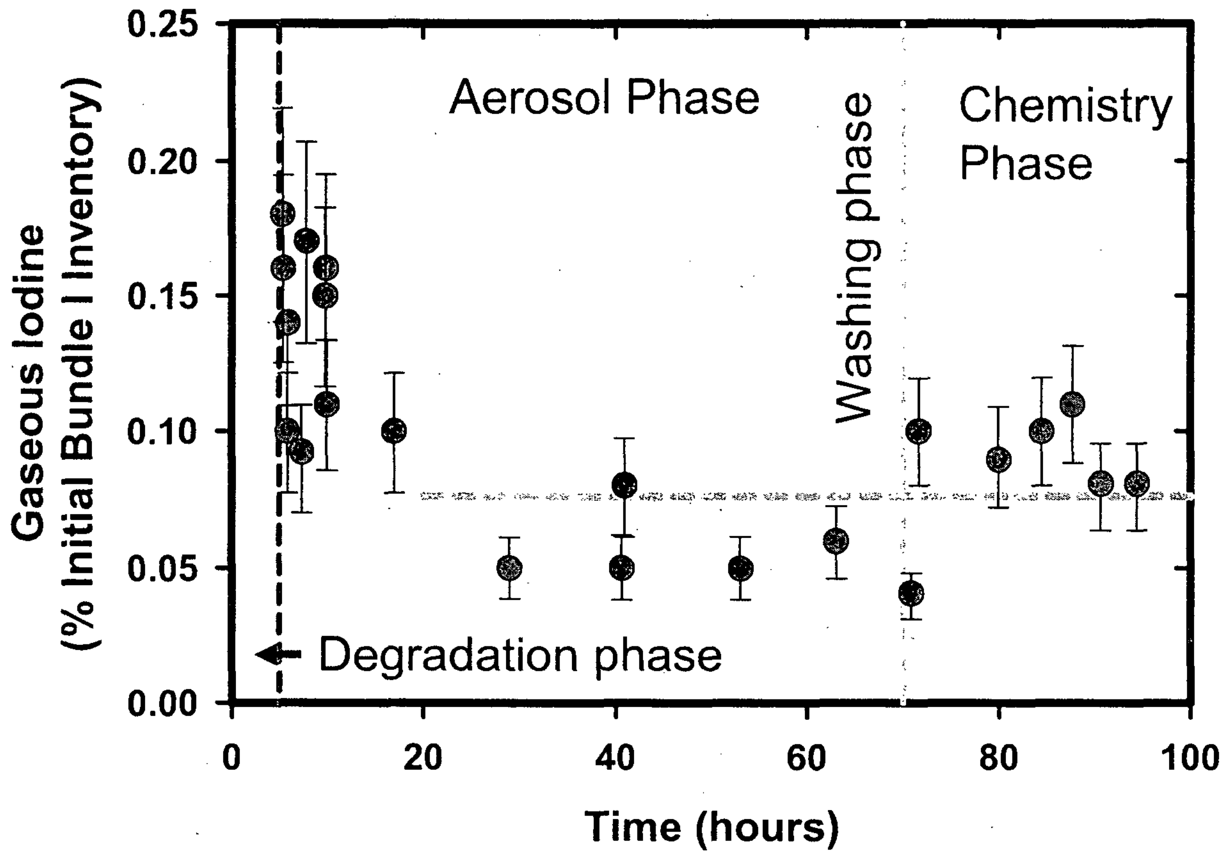
What we have learned

- Fuel relocation takes place at lower temperatures than previously anticipated
- Codes tend to overpredict deposition in the circuit
- Coagulation makes aerosol composition essentially size independent
- Large nodes adequate to predict temperature, pressure and relative humidity of containment
- Silver from control rods will precipitate iodine in sumps so the iodine cannot partition back into the atmosphere
- Cesium is probably not released from irradiated fuel as CsOH; Cs_2MoO_4(gas) is more likely.
- Evidence of revaporization of radionuclides deposited in the model RCS following the active degradation phase

What we have learned, cont'd

- A steady-state, gaseous iodine concentration develops in containment regardless of:
  - Whether the sump is acid or basic
  - Whether silver is present to precipitate iodine from the sump water
  - Whether the sump is evaporating or condensing
  - How much iodine initially enters the containment in gaseous form

FPT-1 Gaseous Iodine in Containment



Follow-on Program: Phébus-ST

- The Phébus-FP integral tests revealed new information that requires separate effects tests to better understand
  - EPICUR: iodine chemistry tests
  - CHIP: fission product chemistry in the reactor coolant system
  - BECARRE: oxidation of boron carbide-stainless steel mixtures
  - MOZART: tests of clad oxidation in air
  - VERDON: fission product release from MOX and high burnup fuel pellets in steam and air.

Summary

- Phébus-FP tests provide major opportunity to validate and improve MELCOR use for accident and risk analyses.
- Phébus-ST provides separate effects data to better understand findings from Phébus-FP
- Insights on NUREG-1465 Source Term used in the regulatory process.
- Steady state gaseous iodine in the containment atmosphere.

Further Reading on Phébus-FP

- M. Schwarz, G. Hache, and P. von der Hardt, "PHÉBUS-FP: a severe accident research programme for current and advanced light water reactors", **Nuclear Engineering and Design**, ***187*** (1999) 47-69.
- M. Schwarz, B. Clément, and A.V. Jones, "Applicability of PHÉBUS-FP results to severe accident safety evaluations and management measures", **Nuclear Engineering and Design**, ***209*** (2001) 173-181.
- J. Birchley, T. Haste, H. Bruchertseifer, R.Cripps, S. Güntay, and B. Jäckel, "PHÉBUS-FP: Results and significance for plant safety in Switzerland", **Nuclear Engineering and Design**, ***235*** (2005) 1607-1633.

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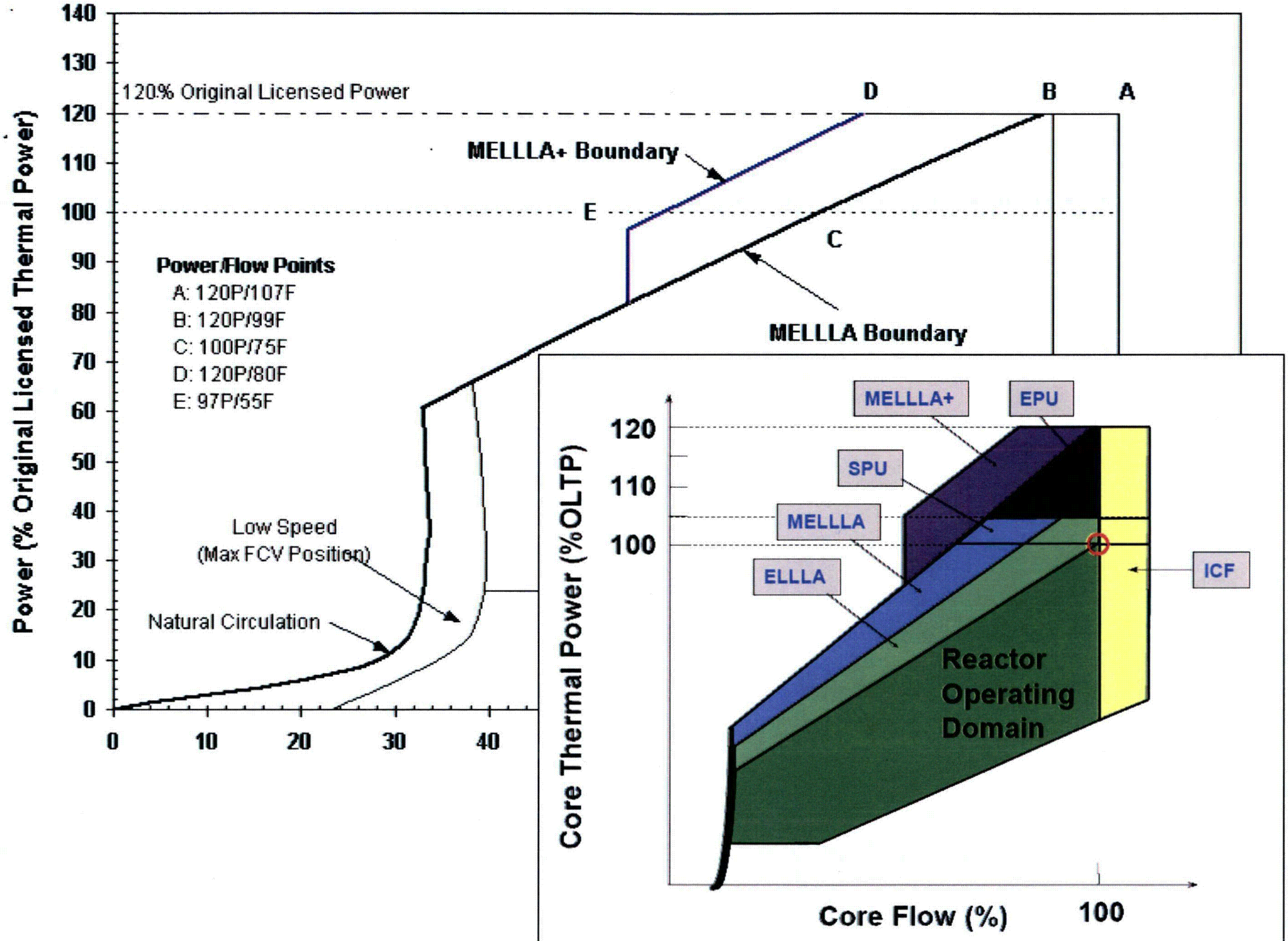
Review of Maximum Extended Load Limit Line Analysis Plus and Application of GE Methods to Expanded Operating Domains. (NEDC-33006P and NEDC-33173P)

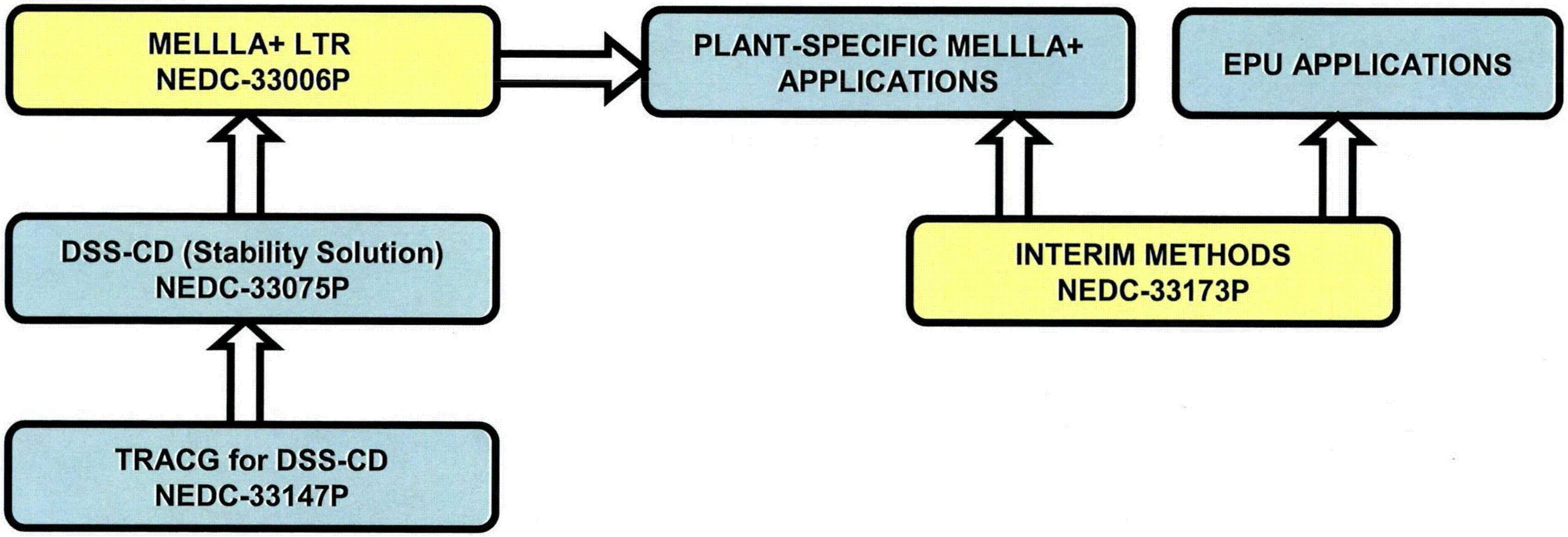
Zena Abdullahi (Lead Reviewer)
With NRC staff, ORNL, and PNNL Consultants

543rd ACRS Meeting
June 6, 2007



Power (% Original Licensed Thermal Power)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
120% Original Licensed Power
D
B
A
MELLLA+ Boundary
E
C
MELLLA Boundary
Power/Flow Points
A: 120P/107F
B: 120P/99F
C: 100P/75F
D: 120P/80F
E: 97P/55F
Low Speed
(Max FCV Position)
Natural Circulation
Core Thermal Power (%OLTP)
120
110
100
MELLLA+
EPU
SPU
MELLLA
ELLLA
ICF
Reactor
Operating
Domain
Core Flow (%)
100

Inter-Related Topical Reports



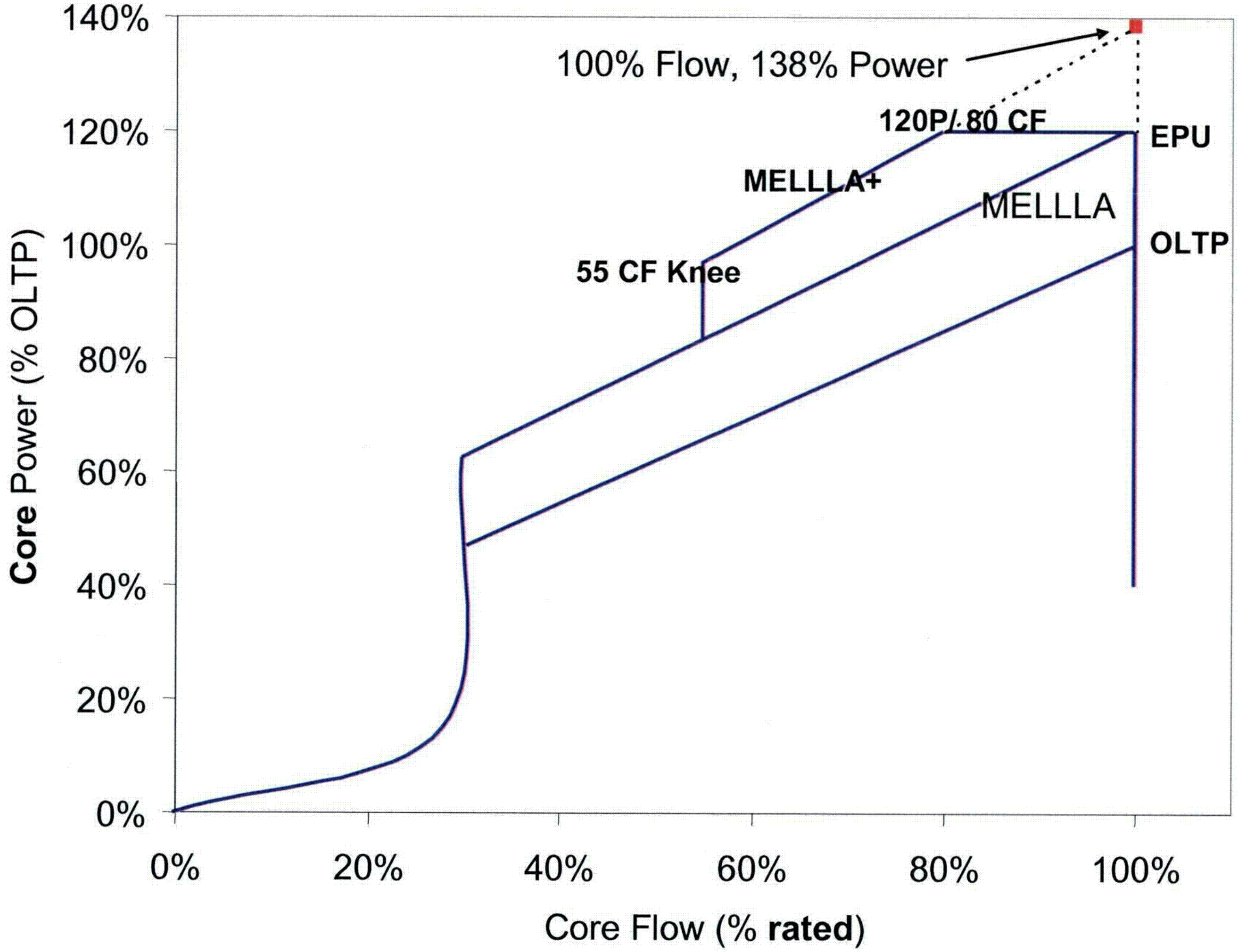
MELLLA+ Approval Contingent Upon Compliance with the Limitations Specified in the staff SE approving the Latest Versions of the three LTRs.

Overall Objective

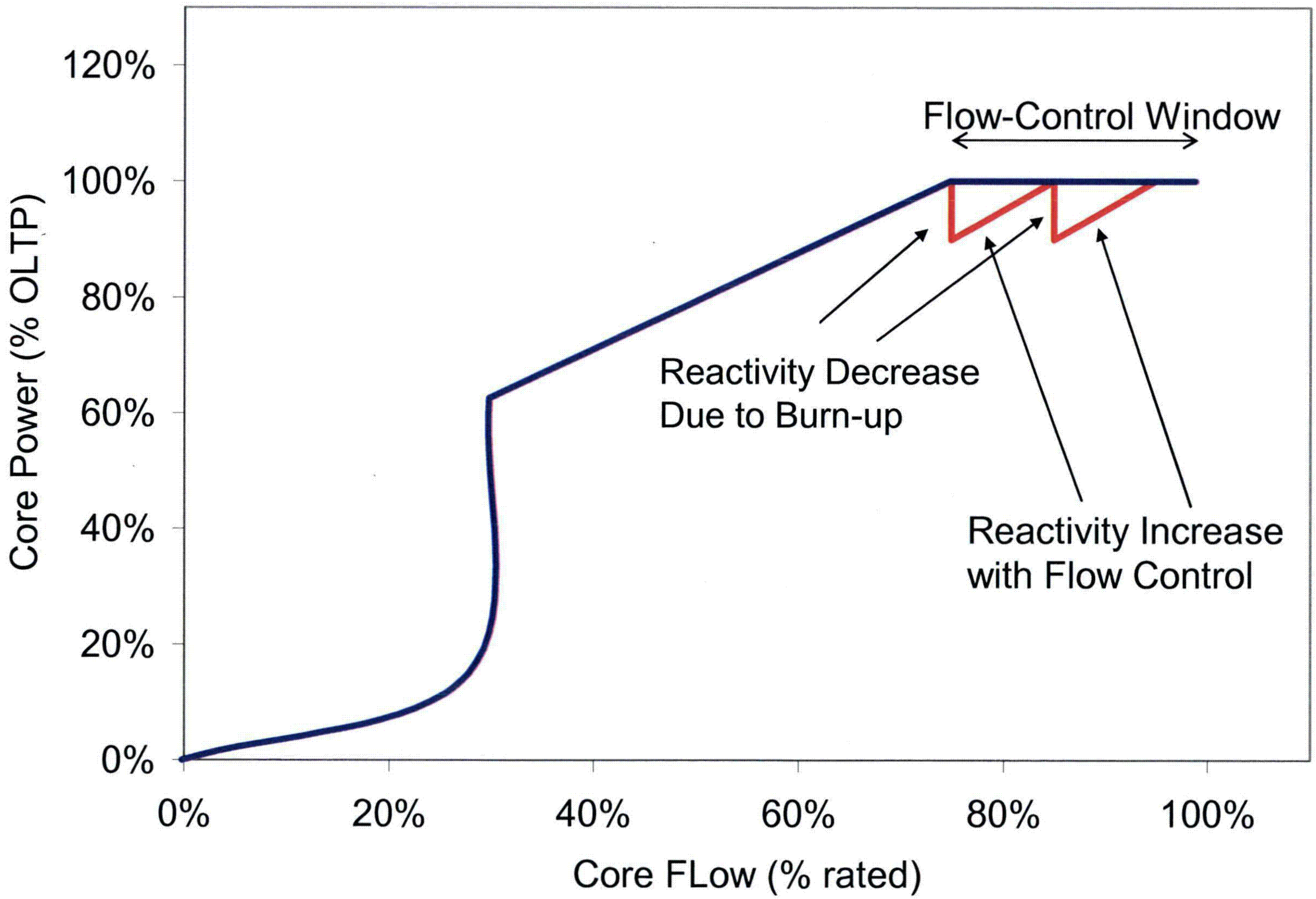
- MELLLA+ (NEDC-33006P)
  - Define what MELLLA+ operation entails
  - Present Fuel Dependent Analyses Significantly Affected by MELLLA+
  - Discuss ATWS Instability Impact
  - Conclusions

- Interim Methods (NEDC-33173P)
  - Supports EPU and MELLLA+ Applications
  - Discuss significant methodology topics reviewed
  - Conclusions

MELLLA+ Allows Operation Up to the ~138% OLTP Control Rod Line



Flow control of reactivity decrease due to burn-up



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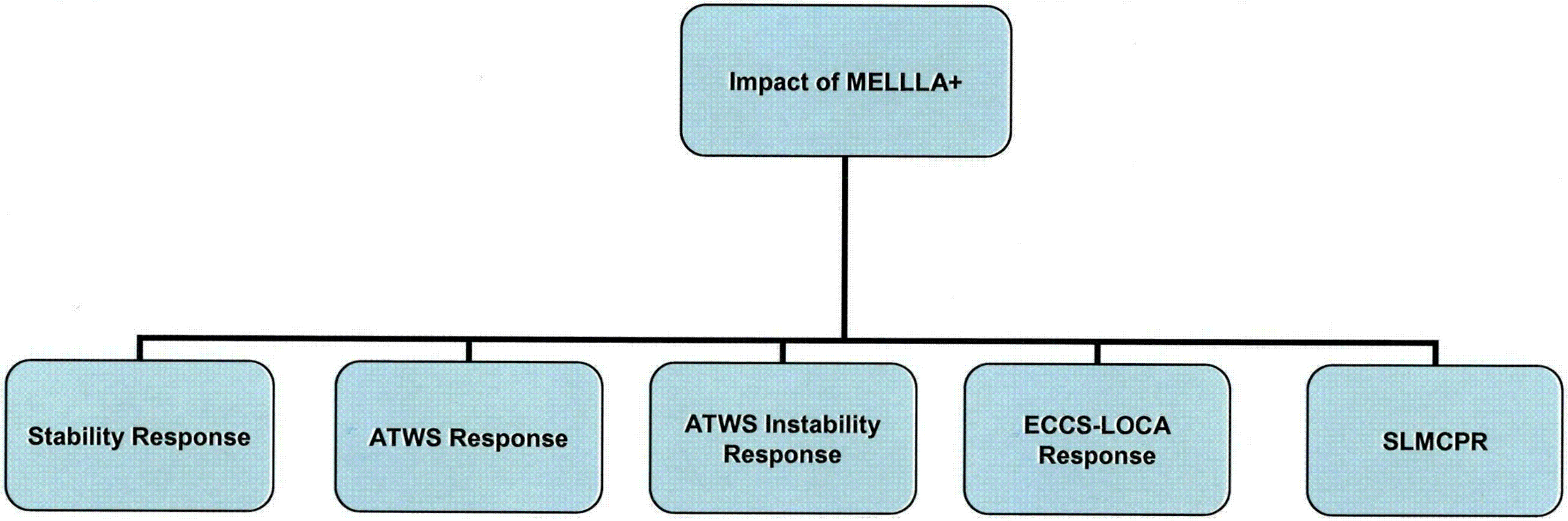
Protecting People and the Environment

MELLLA+ Impact



1. Selected Topic Presented at Subcommittee Meeting
2. Subcommittee Presentation Slides Provide Additional Proprietary Discussion
3. NEDC-33173P Presentations Cover the Applicability of GE Methods to EPU/M+ Core Thermal-hydraulic Conditions

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MELLLA+ CONCLUSION

- Staff performed comprehensive review because the reactor conditions and plant response will be outside the current experience base.

- Significant staff safety findings in the ATWS, SLCMPR, and ECCS-LOCA.

- Approving Revision 2 of the MELLLA+ LTR, which incorporated number of staff review and RAI conclusions.

- The staff performed confirmatory analyses where feasible and the necessary code modeling capability was available in order to obtain assurance that the BWRS can operate safely in the new operating domain.

- The staff also performed comprehensive analytical methods and benchmarking qualification data review in order to obtain reasonable confidence that the predicted plant responses were acceptable. This is covered in the staff SE of NEDC-33173P.

MELLLA+ CONCLUSION

- The staff concludes that the expanded operating domain defined by the MELLLA+ upper boundary does adversely impact the fuel dependent analyses.

- Without plant modification, some BWRs cannot implement M+ operation and meet the safety and regulatory requirements.

- The extent of the expanded operating domain BWRs can implement and meet the safety and regulatory requirements will be highly plant-specific.

- Plant-specific applications will provide the fuel dependent analyses and the SRLR, which will also include the fuel dependent analysis that are also cycle-dependent.

MELLLA+ operation is acceptable with the limitations specified in the staff SEs approving NEDC-33006P, NEDC-33173P, NEDC-33075P and NEDC-33147P.

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NEDC-33173P Applicability of GE Methods to Expanded operating Domain

Zena Abdullahi (Lead Reviewer)
With NRC staff and ORNL Consultants

543rd ACRS Meeting
June 6, 2007

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Methods Review Objectives (NEDC-33173P)

- Analytical methods and codes used to perform design-bases safety analyses are used within NRC-approved applicability & validation ranges.

- Uncertainties applied to thermal limit calculations will remain valid for the predicted neutronic and thermal-hydraulic core and fuel conditions during steady-state, transient, and accident conditions.

- The qualification database supporting analytical models remain valid and applicable to EPU/M+ conditions.

- If application of methods and codes are extended outside the NRC-approved ranges, the extension of the specific models must be demonstrated to be acceptable or additional margins are to be applied until such time the supporting qualification data is extended.

Approved Applicability Range

- Approval of analytical methods creates NRC-approved range

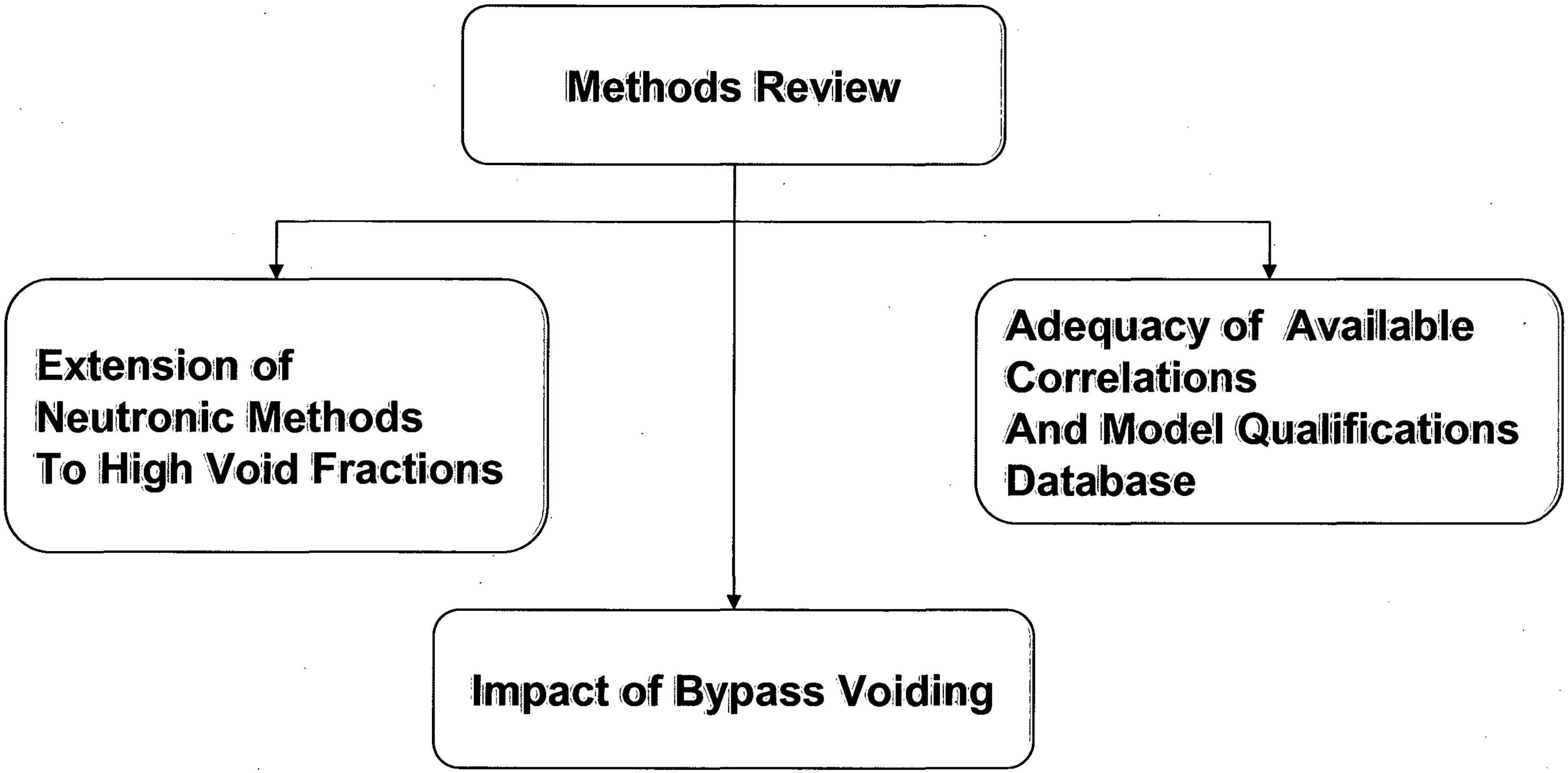
- Plant-specific applications review mostly limited to review of plant's response

- Any changes beyond the NRC-approved range require review and approval

- Any application of the NRC-approved methods outside the ranges will then be "Extension of the Methods" to beyond the conditions for which it was reviewed and approved. This will require NRC-review and approval

- The objective of the staff method review is to ensure that any "Extension of the NRC-approved," method beyond the conditions it was reviewed and approved is acceptable for operation at EPU and MELLLA+.

Methods Review Objectives



Methods Review Topics

- The following topics are covered in the subcommittee meeting slides on May 25th,2007:
  - Staff confirmatory code-to-code comparison
  - Void reactivity coefficient
  - SLMCPR
  - Bypass boiling
  - ATWS
  - Stability
  - Void quality correlation
    - Available benchmarking data
  - Fuel thermal-mechanical performance and benchmarking
    - Part 21

Neutronic Methods Conclusions

- Neutronic Methods Review
  - Performed confirmatory Code-to-code
  - Reviewed TIP data
  - Reviewed available Gamma scans
- Need additional Gamma Scans
- Additional gamma scans in progress
- 40% depletion assumption
  - Limitation for plant-specific demonstration of 10 % margin in thermal and mechanical overpower
- NEDC-33173P
  - Bundle and pin power distribution uncertainty increase
  - Interim Margin of on SLMCPR: 0.02 EPU and 0.03 MELLLA+

Void Quality Correlation

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- Evaluate the Findlay-Dix correlation for:
  - Applicability to the current fuel design features and operating strategies
  - Extension of the correlation to high void conditions
  - Adequacy of the experimental database supporting the correlation

- Determined additional benchmarking is required and additional margin is warranted in the interim
  - Under-prediction in magnitude of void fraction will result in under prediction of the void reactivity coefficient (Cv).
  - Need to quantify impact of errors in void fraction prediction on void reactivity coefficient propagated through the transient response

- Conclusion
  - an additional 0.01 will be added to the limiting OLMCPR as an interim

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Fuel Thermal-Mechanical Methods Assessment

- Performed confirmatory FRAPCON analysis for GE14 fuel design
  - Internal rod pressure
  - Thermal overpower
    - » Fuel centerline melt acceptance criteria
    - » GSTRM underpredicts fuel temperature by
  - Mechanical overpower
    - » 1 % diametric strain acceptance criteria

- Confirmatory analyses indicate GSTRM underpredicts
  – Fuel Temperature by 200 F
    - Underpredicted for burnups >10 GWd/MTU
    - 95% uncertainty treatment compensates for underprediction
  – Rod Pressures by >600 psi

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Part 21 Evaluation-Follow-up work

- GSTRM not adequately benchmarked or qualified
  - Small amount of data above 30 GWd/MTU
  - Data over 25 years old

- Staff requested
  - GE to perform Part 21 Evaluation
  - reviewed the adequacy of the GE's Part 21 report
  - Concluded rod internal pressure calculation is underpredicted at end of life and Part 21 assessment was not adequate

- GE committed to perform additional rod internal rod pressure calculations but not conclusive
- Staff will issue Part 21 report evaluation conclusion to GE.

Methods Review Conclusions

- Staff reviewed applicability of GE methods to EPU and MELLLA+ operating conditions
- The staff determined that some of the analytical methods used to predict the EPU/MELLLA+ conditions need additional validation data.
- Additional margins applied in the some of the methods as an Interim

The staff concludes that application of GE methods to EPU/MELLLA+ was acceptable as specified in the staff SER and based on the associated limitations

GE Energy, Nuclear

MELLLA+ and Supporting Topical Reports

Presentation to the
Advisory Committee on Reactor Safety
June 6, 2007
Open Session

imagination at work

GE Team

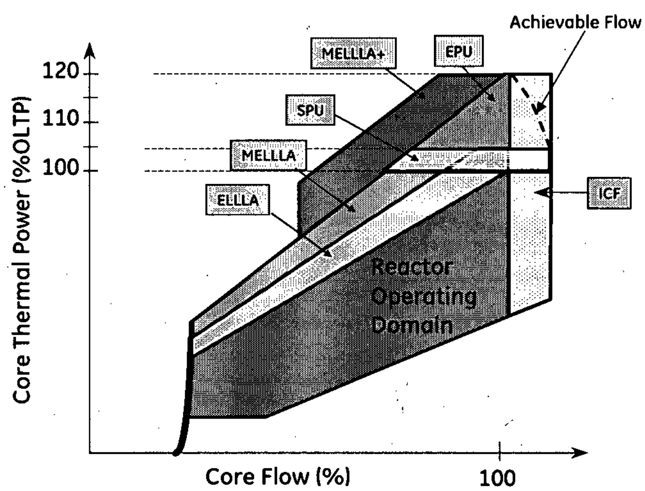
- Jens Andersen – Consulting Engineer – Thermal-Hydraulic Methods
- Scott Bowman – Manager – Methods and Software Development
- Patricia Campbell – Director – Washington Regulatory Affairs
- Jose Casillas – Consulting Engineer – BWR Plant Performance
- Randy Jacobs – Manager – Transient Analysis
- Rick Kingston – Project Manager – Methods Licensing
- Brian Moore – Manager – Methods and Software
- PT Tran – Project Manager – New Product Introduction/ MELLLA+

imagination at work

Purpose

- Seeking ACRS acceptance for use of the methodology in NEDC-33006 and supporting topical reports in conjunction with plant specific application for EPU and MELLLA+

BWR Operating Map Expansion



OLTP = Original Licensed Thermal Power

ELLLA = Extended Load Line Limit Analysis

ICF = Increased Core Flow

MELLLA = Maximum Extended Load Line Limit

SPU = Stretch Power Uprate (5% OLTP)

EPU = Extended Power Uprate (20% OLTP)

MELLLA+ = MELLLA Plus

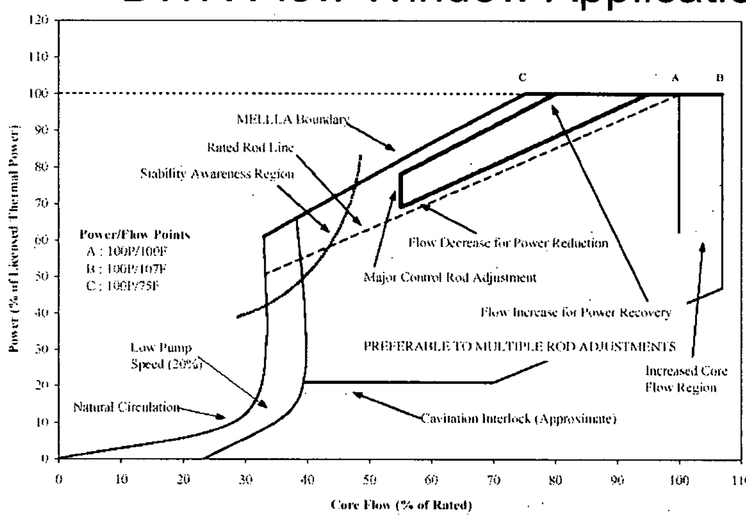
BWR Flow Window Benefits

- Significant reduction in control rod adjustments to compensate for reactivity changes with burnup
  - Increased reliability and human performance
- More efficient reactor startup
- Lower average core flow reduces duty on recirculation system
- Lower core flow reduces loads & vibration on reactor components

imagination at work

5
ACRS MELLLA+
June 6, 2007

BWR Flow Window Application



Map with Flow Window

Normal Startup

Xenon Built-in

Gadolinia Burnout

Fuel Depletion

Control rod Adjustment

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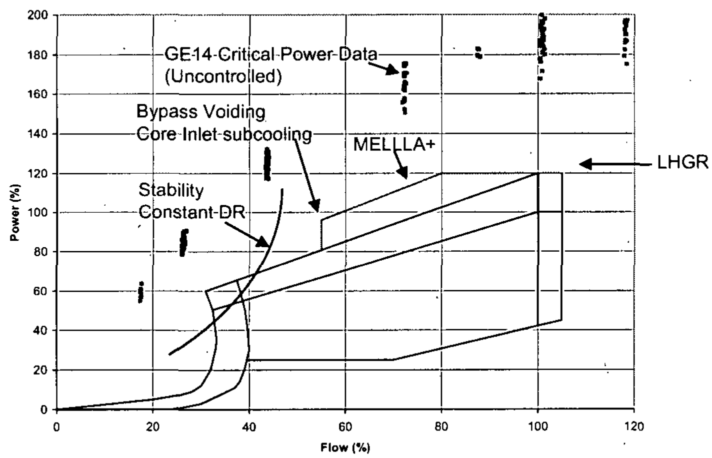
6
ACRS MELLLA+
June 6, 2007

MELLLA+
Design limitations for operating range



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Fuel Performance
What has changed to allow M+

- Increased Critical Power
  - Increased heated perimeter

Bundle Type	Heated perimeter
8X8 (60 rods)	2.31/2.31
9X9 (74 rods)	2.60/2.38
10X10 (92 rods)	2.97/2.51

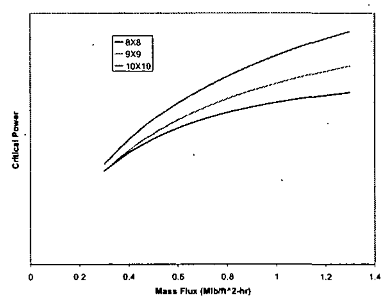
  - Improved spacer performance
  - Improved bundle design
    Enrichment and Gd distribution

- Increased Nodal Power
  - Typical LHGR limit: 13.4 kW/ft

Bundle type	Nodal Power
8X8 (60 rods)	0.75 MW/ft
9X9 (74 rods)	0.90 MW/ft
10X10 (92 rods)	1.12 MW/ft

(1.1 local peaking)

- Reduced stored energy and fuel centerline temperature (smaller rod diameter)



Typical Critical Power Comparison

Increased Power Capability for Modern Fuel

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Fuel Performance
What has changed to allow M+

- Bundle Pressure Drop
  - Total bundle pressure drop essentially unchanged
  - Assures compatibility between different fuel designs

- Two-phase to single-phase pressure drop ratio
  - Introduction of part length rods
  - Reduced two-phase pressure drop and improved stability

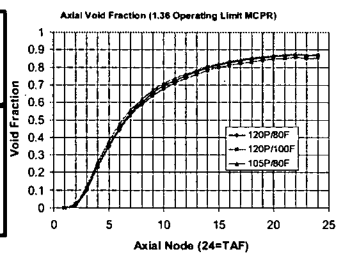
	Core			Channel[5]
	BOEC	MOEC	EOEC	
GE14	0.58	0.61	0.63	0.33
GE12	0.61	0.65	0.67	0.34
P8x8R	0.58	0.62	0.65	0.42

No Degradation of Stability Performance
for Modern Fuel

Core Conditions for EPU/MELLLA+
Hot Channel Constrained 1.36 MCPR

		Void Fraction				
% Power	% Flow	Core Avg	Avg. Exit	Pk. Exit	Avg. Bypass	Hot Bypass
105	80	0.504	0.761	0.875	0.000	0.000
120	100	0.499	0.754	0.854	0.000	0.000
120	80	0.536	0.795	0.869	0.000	0.021

% Power	% Flow	Core ΔP (psi)	Inlet Enthalpy (Btu/lbm)	Temp FW (F)
105	80	17.1	521.3	416.2
120	100	24.2	528.2	431.4
120	80	17.7	522.1	431.2



MELLLA vs MELLLA+ Key Safety Analyses

Topic	Safety Criteria	M+ Impact
Containment	Containment design limit	No impact on long term response. Short term analyzed – small impact (<1 psi)
Loads	Stress limits on reactor internals and equipment	M+ conditions similar to current license basis, small impact
LOCA	10 CFR 50.46	< 100F PCT change expected
Core and Fuel	Shutdown Margin, power dist., SLMCPR	Cycle specific shutdown margin, thermal limit margins & SLMCPR
Stability	SLMCPR (less than 0.1% rods reach transition boiling)	Faster growth rate in stability oscillation. New solution (DSS-CD) to scram with large margin to SLMCPR
AOO	SAFDL, RCPB	Change expected to be within normal cycle to cycle variation. Limiting AOOs analyzed every reload cycle per current process
ATWS	RCPB, Containment Design Limits, Fuel Integrity, 10 CFR 100	< 60 psi impact on peak vessel pressure and < 6F impact on peak pool temp expected
ATWS /Instability	RCPB, Containment Design Limits, Fuel Integrity, 10 CFR 100	Initial stability oscillation growth rate is higher. Oscillation magnitude at time of mitigation is comparable, requiring no change in operator *mitigation action/timing.*

GE NRC Approved Methods Applicability

Validation Range Assessment

- Void fraction
- Bypass voiding
- Data used for uncertainties
- LHGR and exposure

Hot Reactivity Data	Provided
Cold Critical Data	Provided
Operating Power Shape (TIP)	Provided
Bundle Gamma Scans	
Rod Gamma Scans	
Critical Power Data (GEXL)	Provided
Pressure Drop Data	Partial
Void Fraction Data	
Plenum Fission Gas	
Fuel Exposure	Partial

Final Assessment

EPU CPR Limitations

- 0.02 ΔSLMCPR for EPU
- 0.01 ΔOLMCPR additional margin

MELLLA+ CPR Limitations

- 0.03 ΔSLMCPR for MELLLA+
- 0.01 ΔOLMCPR additional margin

Limitations on process application

- Analytical check for bypass voiding
- Other GE specific process items

Summary

- MELLLA+ flow window is needed to efficiently operate plants to EPU power levels
- Seeking ACRS acceptance for use of the methodology in NEDC-33006 and supporting topical reports in conjunction with plant specific application for EPU and MELLLA+

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End of Presentation

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Acronyms

AOO – Anticipated Operational Occurrence

ATWS – Anticipated Transient Without Scram

BOEC – Beginning of Equilibrium Cycle

CPR – Critical Power Ratio

DR – Decay Ratio

DSS-CD – Detect and Suppress Solution – Confirmation Density

ELLLA – Extended Load Line Limit Analysis

EOEC – End of Equilibrium Cycle

EPU – Extended Power Uprate

GEXL – General Electric's critical power correlation

ICF – Increased Core Flow

LHGR – Linear Heat Generation Rate

LOCA – Loss of Coolant Accident

MELLLA – Maximum Extended Load Line Analysis

MELLLA+, "M+" – Maximum Extended Load Line Analysis Plus

MOEC – Middle of Equilibrium Cycle

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Acronyms - Continued

OLMCPR – Operating Limit Minimum Critical Power Ratio

OLTP – Original Licensed Thermal Power

PCT – Peak Cladding Temperature

RCPB – Reactor Coolant Pressure Boundary

SAFDL – Specified Acceptable Fuel Design Limit

SLMCPR – Safety Limit Minimum Critical Power Ratio

SPU – Stretch Power Uprate

TIP – Traversing In-core Probe

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PUBLIC COMMENTS AND NRC RESPONSES: HIGHLIGHTS

Raymond HV Gallucci, PhD, PE
Senior Fire PSA Engineer
Office of Nuclear Reactor Regulation

COMMENT-RESPONSE CATEGORIES

- 110 Total Comments
- *OMAs vs. Passive Features (4)*
- *Regulatory Footprint (12)*
- *Demonstration & Time Margin (31)*
- *OMAs & Terrorism (1)*
- *NUREG-1852 vs. Fire Safe-Shutdown (SSD) [13]*
- *Fire Design Basis (8)*
- *Staffing & Training (9)*
- *Defense-in-Depth (7)*
- Operator Manual Actions (OMAs) vs. Circuit Issues (5)
- Environmental Factors (2)
- Equipment Functionality (2)
- Available Indications (6)
- Inspection Guidance (4)
- Fire Modeling (6)

OMAs vs. PASSIVE FEATURES

- Theme of Comments
  - By allowing industry a compliance strategy through submission of a massive number of exemptions for a complicated array of dubious OMAs in lieu of qualified passive fire protection features as intended by law, NUREG-1852 diminishes the defense-in-depth for fire protection of SSD systems and increases the risks to the public's health, safety and security.
- Response
  - NRC has granted plant-specific OMA exemptions in the past where criteria, such as those in NUREG-1852, were met.
    - Plant-specific exemptions cannot be applied universally.
    - The appropriate regulatory vehicle remains the issuance of an exemption under 10 CFR Part 50.12.

REGULATORY FOOTPRINT

- Theme of Comments
  - Will suppression and detection be required when applying for an exemption?
  - The NUREG should reflect that NRC accepts use of certain types of OMAs.
- Response
  - RIS 2006-10, "Regulatory Expectations with Appendix R, III.G.2, OMAs," describes the corrective actions for failures to have a required fire barrier and the use of OMAs as an interim compensatory measure.
    - RIS 2006-10, not NUREG-1852, addresses regulatory requirements, including the need for fire detection and automatic suppression.

DEMONSTRATION & TIME MARGIN

- Theme of Comments
  - The NRC has previously accepted use of "nominal" values and "best estimate" codes for plant response to fire events.
    - Sufficient margin exists in these analyses, which assume that all fire damage occurs and consequently evaluate all OMAs in the timing.
- Response
  - The NUREG guidance is flexible on treating uncertainties.
    - A tradeoff exists between the realism of the demonstration and uncertainties to address in the time margin, which are inter-related.
    - *The NUREG has been enhanced to address consideration of uncertainties in the demonstration to justify adequate OMA time.*

DEMONSTRATION & TIME MARGIN (cont.)

- Theme of Comments
  - Due to a lack of clear quantitative guidance, both utility analysts and regulators will default to the factor of 2 inferred in Appendix B, "Summary of Expert Opinion Elicitation to Determine Time Margins."
    - The expert panel consisted entirely of NRC and their contractor staff, mostly PRA practitioners, thereby not providing the necessary diversity for practical assessment and implementation of nuclear plant OMAs.
- Response
  - NUREG Appendix B provides an example of how one expert panel developed a time margin.
    - The six-person panel consisted of a former Senior Reactor Operator, two NRC regional fire inspectors, one human factors specialist, and two PRA practitioners, with sufficient expertise considered to provide one reasonable method to address time margin.
    - NRC reviewers will not default to the factor-of-2 time margin -- the appendix is not binding. Nonetheless, the licensee still needs to consider time margin.

OMAs & TERRORISM

- Theme of Comments
  - The NUREG fails to account adequately for mitigating responses to aircraft impacts and other forms of terrorism. Broad industry non-compliance with physical fire protection does not lend public confidence to the Commission's assertions that plant operators can and will control and contain the consequences of terrorism causing significant fires.
    - In NUREG/CR-2859, Argonne experts state that "the claim that these fire/explosion effects do not represent a threat to nuclear power plant facilities has not been clearly demonstrated."

OMAs & TERRORISM (cont.)

- Response
  - A February 2002 NRC Order required licensees to examine the effects from extensive losses due to fires/explosions and identify "mitigative strategies" using resources already existing or "reliably available."
    - NRC inspections, 2002-2005, and additional studies examined implementation of the mitigative strategies. Additional site-specific studies will determine any need for more mitigating capability.
  - The NRC re-evaluated the aircraft crash issue after NUREG/CR-2859 was published (prior to 9/11/2001). The likelihood of both damaging the reactor core and releasing radioactivity that could affect public health and safety is low, with adequate time to implement mitigating actions and off-site emergency plans.
    - The NRC's emergency planning basis remains valid.

NUREG-1852 vs. FIRE SSD

- Theme of Comments
  - Feasibility criteria require SSD analysis when they should only support such analysis. Verifying that equipment be available requires SSD analysis specifically for OMAs.
- Response
  - To the extent SSD analysis already addresses equipment needed to conduct the OMAs, that analysis suffices. *The NUREG now emphasizes the functionality of equipment and cables needed to implement OMAs.*

FIRE DESIGN BASIS

- Theme of Comments
  - NUREG-1852 reclassifies post-fire SSD as an "Abnormal Operating Occurrence" (AOO), thereby imposing the radiation dose requirements of 10CFR20.1201.
    - Fire with post-fire SSD and manual operation occurs at a frequency << 1/yr. ANSI/ANS 58.6 and ANSI/ANS 58.14 classify post-fire SSD as a "Special Event."
- Response
  - ANSI 51.1/52.1 classifies fire as an AOO within normal radiation exposure limits.
    - An "initiating event" is the single abnormal occurrence/condition that can trigger an accident scenario, and excludes subsequent failures that comprise the scenario frequency, not that of the initiating event.

FIRE DESIGN BASIS (cont.)

- Theme of Comments
  - The NUREG requirements exceed those for other design basis events and Emergency Operating Procedures (EOPs).
- Response
  - Unlike EOPs, which (1) generally assume no plant damage, (2) involve mostly control room actions and (3) are integral aspects of regulations and design basis analysis, OMAs in III.G.2 areas constitute a deviation from regulatory requirements.
    - OMAs are postulated in lieu of redundant train separation or alternative SSD.
  - *The NUREG has been revised to recognize that specific OMAs may need to meet the guidance to varying degrees, i.e., some of the factors within the criteria may not always be relevant.*

STAFFING & TRAINING

- Theme of Comments
  - The NUREG is too prescriptive when requiring that operators who perform manual actions be on-site at all times.
    - Acknowledge plant staff augmentation available under the Emergency Plan.
  - The NUREG implies that an operator can no longer be on the fire brigade as a "collateral duty during a fire."
- Response
  - *The NUREG now allows plant staff credited with performing OMAs to be "available" rather than "on-site," with proper justification. Also, "...in all cases their duties should not interfere or be concurrent with the credited OMA(s)."*
    - An operator cannot serve on the Fire Brigade and be responsible to perform an OMA <u>at the same time</u>. He/she could serve as a Brigade member provided another operator had his/her OMA responsibility during the same shift.

STAFFING & TRAINING (cont.)

- Theme of Comments
  - The NUREG requires that each crew perform an integrated demonstration on fire scenarios, a significant new burden on Operations Training.
    - Initial, not continuous, verification and validation of OMA feasibility should suffice when combined with periodic task-based training and Job Performance Measures.
- Response
  - Relative to other training activities, the OMA feasibility and reliability demonstration must be sufficiently rigorous because it is used in lieu of physical separation to maintain a comparable level of defense-in-depth (DID).
    - *The NUREG reiterates the acceptability of using bounding techniques to cover similar OMAs demonstrated under similar circumstances.*

DEFENSE-IN-DEPTH

- Theme of Comments
  - The DID considerations exceed the minimum requirements from the boundary conditions in a post-fire SSD analysis.
    - Many are theoretical in nature and very difficult to apply.
- Response
  - RIS 2006-10, not this NUREG, addresses DID for post-fire response, including passive fire protection through highly reliable, operable fire barriers.
    - Reliance on typically less reliable OMAs still requires that adequate fire safety be maintained.

DEFENSE-IN-DEPTH (cont.)

- Theme of Comments
  - Reference to RG 1.33, Appendix A, requiring post-fire SSD procedures is a new staff position, inconsistent with Generic Letter 86-10, Staff Position 5.2.3.
    - NUREG-1852 re-interprets the Administrative and Detection/Suppression echelons of DID.
- Response
  - GL 86-10, Position 5.2.3, addresses the use of procedures for areas requiring Alternate Shutdown Capability (III.G.3), not Fire Brigade activities.
    - NRC expected licensees to comply with III.G.2. The NUREG-1852 criteria are consistent with NRC guidance and requirements.
    - NRC requires post-fire SSD procedures. RG 1.33's QA Program Requirements and ANSI/ANS 3.2-1982's reiteration of the need for SSD procedures give guidance on OMA feasibility and reliability.

REGULATORY REQUIREMENTS WITH RESPECT TO III.G.2

- Three-hour fire barrier

- One-hour fire barrier with fire detection & automatic suppression

- 20-foot separation (no intervening combustibles) with fire detection & automatic suppression

** NO PROVISIONS FOR OPERATOR MANUAL ACTIONS (OMAs) **

INTENDED ROLE OF NUREG-1852

- If a licensee chooses to rely on an OMA, as opposed to the passive features required by the regulations, and seeks NRR approval via an exemption from the rule (pre-79 plants), or an amendment to the license (post-79 plants), the NRR staff will use NUREG-1852 to ensure consistent reviews of those requests …….. i.e., the NUREG is an extension to our SRP

NATURE OF COMMENTS

- Even though we requested comments on the content of the NUREG, most comments were directed towards the regulatory use of the NUREG as opposed to the NUREG itself.

- Staff is seeking ACRS endorsement to issue the NUREG.

NUREG-1852
Demonstrating the Feasibility and Reliability of Operator Manual Actions In Response to Fire

Erasmia Lois, PhD
Senior Risk and Reliability Engineer
Division of Risk Assessment and Special Projects
Office of Nuclear Regulatory Research

Presentation to
Advisory Committee on Reactor Safeguards
June 6, 2007

Purpose of the Briefing

- Summarize the content of NUREG-1852 and how it was revised to address public comments
- Request ACRS endorsement to publish the NUREG

NUREG-1852--Background

- Draft RG DG-1136, "*Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire*," July 2005, was developed to support the fire manual action rulemaking
- Rulemaking activity was stopped (SRM-January 2005). However:
  - Manual actions are being and will continue to be used by licensees
  - NRC staff makes decisions on the feasibility and reliability of proposed actions to achieve and maintain safe shutdown
  - Technical bases and guidance for the "acceptability" of such actions were developed for DG-1136
  - NRC staff needs guidance to review licensee requests to implement manual actions (exemptions)
- NUREG-1852 was developed to retain the technical work and guidance developed as part of DG-1136 to support NRC staff reviews of manual actions
- NUREG-1852 is referenced in Regulatory Guide 1.189, providing the details on how the NRC staff plans to review manual actions
- ACRS Fire Subcommittee has been briefed on DG-1136 (November 2004) and on draft NUREG-1852 (September 2006)

NUREG-1852 Objective/Scope/Status

- Objective
  - Provide technical bases and deterministic guidance for justifying that manual actions are both feasible and reliable
  - To be used as reference guide by the staff reviewing licensee submittals
- Scope
  - Feasibility and reliability criteria for manual actions that licensees may choose to use in lieu of meeting the separation criteria in Paragraph III.G.2 of Appendix R for the protection of redundant trains located in the same fire area.
  - Does not address control room evacuation
  - Does not establish defense-in-depth criteria to show that manual actions can substitute for regulatory requirements for fire protection (III.G.2)
- Status
  - Briefed the ACRS Fire Subcommittee, September 2006
  - Released for public comment, October 2006
  - Revised after public comment, April 2007
  - Brief the ACRS, June 2007
  - Submit to publication, September 2007

NUREG-1852-- Approach

- Deterministic criteria developed on the basis of
  - Existing inspection guidance, insights and experience developed through the years of inspecting manual actions currently used by licensees in response to fire
  - Human factors guidance documents and standards addressing human actions in general and in response to fire in particular, e.g.:
    - SRP Chapter 18.0, "Human Factors Engineering"
    - Information Notice 97-78, "Crediting of Operator Actions In Place of Automatic Actions and Modifications of Operator Actions, Including Response Times"
    - ANS/ANSI 58.8, "American National Standard Time Response Design Criteria for Safety-Related Operator Actions"
  - Review of findings/insights from plant updated PRAs, IPEEE reports, Fire Re-Quantification project, and HRA development and applications
  - In many respects, the NUREG-1852 criteria are/were implicitly used by the staff in review and inspection activities—now they are explicitly documented
- Risk–informed approach to support review of risk-informed submittals (NFPA 805) will be developed in collaboration with EPRI—to be initiated in June 2007

NUREG-1852 -- Overview

- Contains both feasibility and reliability criteria
- Two parts:
  - Documentation of the criteria along with the technical bases
  - Guidance for implementing the criteria
- Criteria essentially the same as those contained in DG-1136
- Differences
  - No specific time margin is recommended in NUREG-1852
    - A factor of 2 was recommended in DG-1136
  - Demonstrating that "extra" time needs to be available to cover variability/uncertainty in fire conditions and manual action time is still emphasized and discussed
  - Licensees can justify their approach for addressing variability and uncertainties
- These changes was done as result of public comments and Commission direction (SRM on SECY-04-0233, 1/18/05)
  - The Commission agreed with the time-margin concept but recommended not to use a specific factor

Criteria in NUREG-1852

The NUREG provides criteria for

- Time needed to ensure feasibility and reliability ("Time Margin")
- Environmental factors
- Equipment functionality and accessibility
- Availability of indications
- Communications
- Portable equipment
- Personnel protection equipment
- Procedures, training and staffing
- Demonstrations of the credited human actions

Overview of Comments/Changes

- Most comments dealt with the use of the NUREG in the regulatory process, or the regulatory process itself
  - No changes were made in the NUREG; the staff will document its staff position to these comments
    - RIS 2006-10, "Regulatory Expectations with Appendix R, Paragraph III.G.2, Operator Manual Actions"
- Some comments dealt with clarifications or text changes
  - Pertinent sections were revised as appropriate
- Some comments dealt with the technical content of the NUREG
  - Pertinent sections were revised to address as appropriate
- From an overall perspective, no significant changes were made
- A summary of the comments, staff responses and changes made in NUREG-1852 will be discussed by Dr. Gallucci

NUREG-1852, Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fires

Jose Ibarra, Chief, Human Factors and Reliability Branch, Office of Nuclear Regulatory Research

Request for ACRS endorsement so staff can publish NUREG-1852, Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire.

Sunil Weerakkody, Chief, Fire Protection Branch, Office of Nuclear Regulatory Regulation
Discuss the regulatory use of the NUREG

Erasmia Lois, Senior Risk and Reliability Engineer, RES
Summarize content of NUREG and revisions due to public comment

Ray Gallucci, Senior Fire Probabilistic Safey Assessment Engineer, NRR
Discuss the public comments and the staff response

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Protecting People and the Environment

ATWS Instability

Zena Abdullahi (Lead Reviewer)
With NRC staff, ORNL, and PNNL Consultants

543rd ACRS Meeting
June 6, 2007

[redacted]

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ATWS INSTABILITY

- Thermal-Hydraulic Subcommittee Meeting (Open Items)
    - Potential use of PARCS/TRACE to confirm TRACG ATWS Instability Conclusions
    - Acceptability of Generic ATWS Instability Analyses
    - Reliance on findings of single bounding ATWS instability analysis
    - Potential plant-specific ATWS/Instability analysis

- Staff will discuss
    - ATWS Instability
        - Event description
        - MELLLA+ impact
        - TRACG Sensitivity analysis performed
        - Use of PARCS/TRACE for confirmatory
        - Conclusions

[redacted]

ATWS Instability

- Low Frequency Event

- Original ATWS Instability Work
  - NEDO-32047-A, "ATWS Rule Issues Relative to BWR Core Thermal Hydraulic Stability", dated June 1995.
  - NEDO-32164, Rev. 0, "Mitigation of BWR Core Thermal Hydraulic Instabilities in ATWS", dated December 1992.

- ATWS Instability Acceptance Criteria
  - Radiological consequences to be maintained within the 10CFR100 guidelines;
  - Primary system integrity to be maintained;
  - Fuel damage limited so as not to significantly distort the core, impede core cooling, or prevent safe shutdown;
  - Containment integrity to be maintained; and
  - Long-term shutdown and cooling capability maintained.

[redacted] [redacted]

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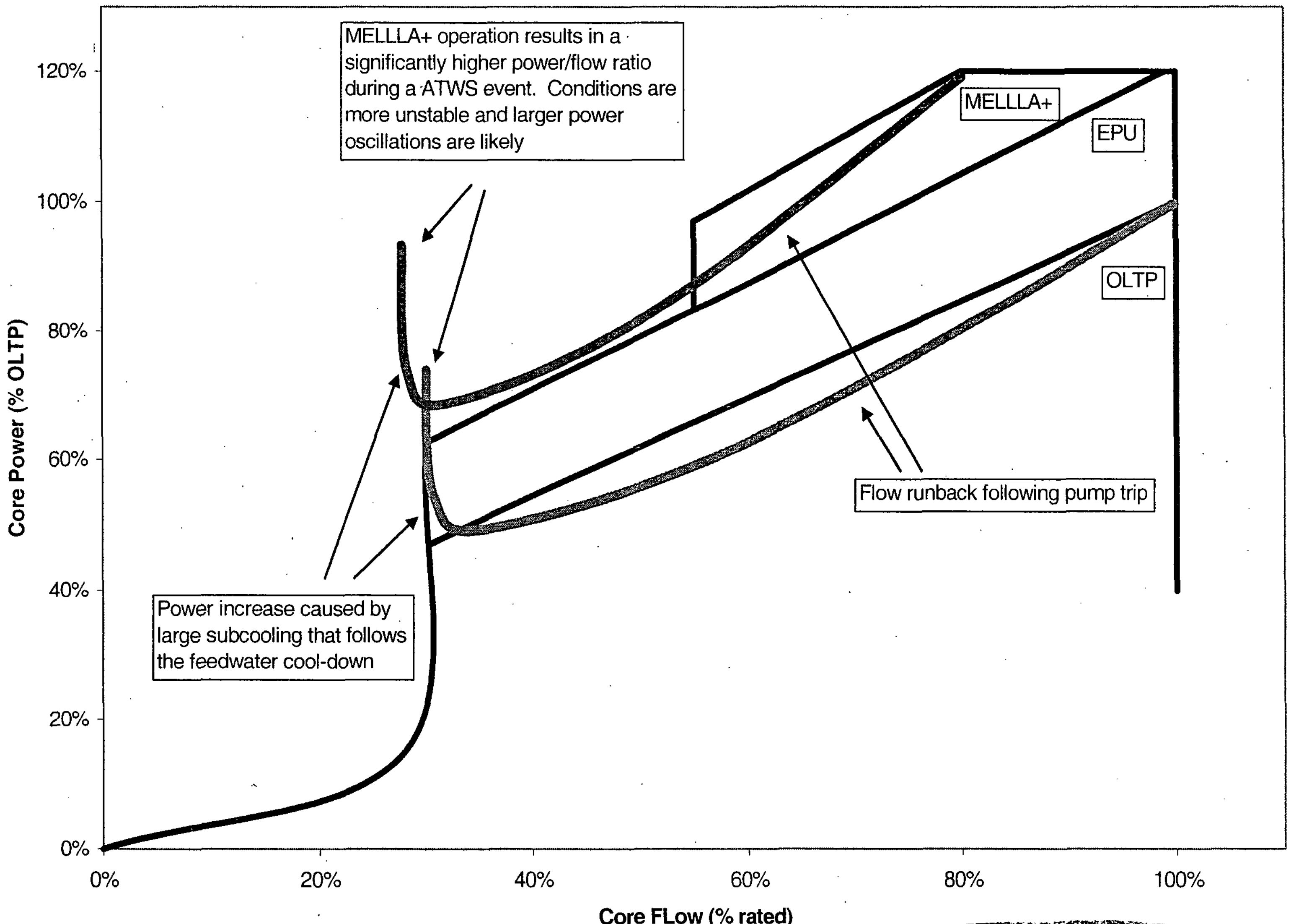
MELLLA+ IMPACT ON ATWS INSTABILITY



[redacted] [redacted]

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MELLLA+ Adversely Impacts ATWS Instability

EPU/MELLLA+ ATWS INSTABILITY IMPACT

- GENERIC ANALYSIS
  - GE14 Core
  - Core/Power/flow Ratio 52 MW/Mlm/hr
  - Limitation

- CORE AND FUEL DESIGN
  - Higher Bundle/Power Flow & Power Density
  - More Max Powered Bundles &Core Reactivity

- REDUCED CORE FLOW STATEPPOINT
  - Reduces Runback Effectiveness
    - Higher initial Power after RPT
    - Results in Earlier Instability Onset

CONCLUSIONS
- Higher Power Oscillation and More Fuel Experience Dryout
- Mitigation Action Shown to Continue to be Effective

[redacted]

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ATWS Instability Event

ATWS INSTABILITY EVENTS

↓

- **NON-ISOLATION TRANSIENT**
  - **Turbine trip**
  - **No scram**
  - **ATWS RPT**
  - **Cold Water Injected into Core: > (Sub-cooling)**

↓

- **OSCILLATION GROWTH AFFECTED BY**
  - **Subcooling**
  - **Fuel and Core Design**
  - **Core Power/Flow Ratio**
  - **Power Density**

↓

- **CONSEQUENCE CONTROLLED BY**
  - **Mitigation Actions: (EPG/EOP Actions)**
  - **Reduced FW to 2 ft Below FW Sparger (pre-heating reduces subcooling)**
  - **Early Boron Injection**
  - **ATWS RPT**

ATWS Instability Sensitivity Analysis

- Unmitigated cases used
  - Establish gravity of event with MELLLA+ relative to baseline
  - Determine key parameters affecting instability response
  - Establish impact of operation at different flow conditions on the ATWS Instability response

- Baseline ATWS Instability case (unmitigated)
  - Compare impact of MELLLA+ operation to original generic ATWS analysis
    - 100% OLTP/75% core flow
    - TTWBP and RPT
    - GE14 fuel

- MELLLA+ ATWS Instability Sensitivity Analyses (Unmitigated)
  - 120% (EPU)
  - 8 Sensivity cases

[redacted] [redacted]

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Mitigated MELLLA+ ATWS Instability Case

- Mitigated ATWS case
  - MELLLA+ Condition
  - Water level reduced to 2 ft below FW sparger (pre-heat incoming flow)
  - Boron injection
- Consequence
  - PCT below 2200F
  - Fuel duty effect
  - Instability suppressed
  - Reactor shutdown
  - Heat load mostly condenser not suppression pool for limiting event (TTWBP)

[redacted] [redacted]

Mitigated MELLLA+ ATWS Instability Conclusion

- Low Probability Event
- Impact of MELLLA+ Operation Evaluated
- MELLLA+ does Impacts by ATWS Instability
- Fuel performance changes compensate
- Conservatisims in Calculations
  - EPU reduces percentage of turbine bypass
  - Calculation continue to use 100% TT bypass
  - Assumed initial conditions conservative
  - EPU/MELLLA+ includes option for increase of boron concentration
    - Effects long term shutdown

Mitigation Actions Continue to be Effective

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Mitigated MELLLA+ ATWS Instability Conclusion

- Radiological consequences to be maintained within the 10CFR100 guidelines;
  - Mitigated case shows PCT less than 2200F
- Primary system integrity to be maintained;
  - Nonisolation transient limiting for ATWS instability and does not challenge vessel integrity
- Fuel damage limited so as not to significantly distort the core, impede core cooling, or prevent safe shutdown;
  - Regional mitigated case shows PCT<2200F
  - Calculated energy deposition not very high (Unmitigated Regional)
  - Cannot exclude additional thermal overpower effects
- Containment integrity to be maintained;
  - Heat load mostly in condenser for the limiting TTWBP ATWS instability event
- Long-term shutdown and cooling capability maintained.
  - Suppression pool heatup less than isolation ATWS for TTWBP event
  - Mitigated RPT event less severe