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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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SUBCOMMITTEE ON THERMAL HYDRAULIC PHENOMENA:

UPDATE ON GS-191, "ASSESSMENT OF DEBRIS ACCUMULATION

ON PWR SUMP PERFORMANCE" -

STATUS AND FUTURE ACTIVITIES

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TUESDAY

SEPTEMBER 23, 2008

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

COMMITTEE MEMBERS PRESENT:

SANJOY BANERJEE, Chairman

SAID ABDEL-KHALIK, Member

MICHAEL CORRADINI, Member

OTTO L. MAYNARD, Member

MICHAEL T. RYAN, Member

WILLIAM J. SHACK, Member

ACRS STAFF:

DAVID BESSETTE, Designated Federal

OFFICIAL CONSULTANTS:

THOMAS S. KRESS

GRAHAM B. WALLIS

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

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Adjourn	

P R O C E E D I N G S

(8:31 a.m.)

OPENING REMARKS

CHAIRMAN BANERJEE: The meeting will now come to order.

This is a meeting of the advisory committee on reactor safeguards, thermal hydraulic phenomena subcommittee.

I am Sanjay Banerjee, chairman of the subcommittee. Members in attendance are Said Abdel-Khalik; Michael Corradini; Otto Maynard; Michael Ryan; and William Shack, just in time.

I would also like to welcome ACRS consultants, and actually former ACRS chairs, Tom Kress and Graham Wallis.

David Bessette is the designated federal official for this meeting. The purpose of today's meeting is to review the status of resolution of generic safety issue 191, assessment of debris accumulation on pressurized water reactor sump performance.

We will hear presentations from the staff and from the PWR owners' group.

The subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full committee.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register.

We have received a request for time to make a statement from the Union of Concerned Scientists.

A transcript of the meeting is being kept, and will be made available as stated in the Federal Register notice.

We request that participants in this meeting use one of the available microphones when addressing the subcommittee. The speakers should first identify themselves, and speak with sufficient clarify and volume so that they can be readily heard.

And with that, I think we can start.

MEMBER SHACK: Mr. Chairman, I just want to note that I have a conflict of interest on the portion of the work dealing with the chemical affects, since Argonne National Laboratory has been involved in that work.

CHAIRMAN BANERJEE: Sure. And I request

that we try to proceed in a fairly orderly fashion, because I'd really like to get this meeting finished more or less on time.

So with that, I'll turn this over to NRR. Is Bill Ruland going to address us?

MR. RULAND: Yes, thank you, Mr. Chairman.

NRR OPENING REMARKS

MR. RULAND: Good morning. I'm Bill Ruland. I'm the division director for the Division of Safety Systems in NRR.

Thank you for the opportunity today to present our current status of the staff's efforts on GSI-191, and our strategy on coming to ultimate closure for this issue.

We believe the topics we are going to present today are responsive to the subcommittee's wishes.

The staff and industry have come a long way toward closure, and it's taken some time of course, although there is still considerable work to be done. And just a partial list of kind of what our status is: All PWRs have now installed significantly larger strainers, and we know that some of the ACRS members have seen these new strainers firsthand.

Many have done, or will do, additional

modifications such as removing insulation, replacing sump buffers, et cetera.

Generally the staff has found most vendor testing protocols as either conservative or prototypical of post-LOCA conditions.

Many have completed or will complete in the near future their strainer testing, and also some people will have to retest.

The staff review of submittals is ongoing, and some of our requests for additional information have been issued, with more under development.

As you will hear today progress has also been made on the in-vessel downstream effects topical report.

The staff asks the ACRS to consider a letter that supports the staff's strategy and process to closure for Generic Letter 2004-02 that will be described to you today.

And I'd like to introduce the staff that will be starting the presentation. To your ultimate right is Donnie Harrison, who is acting for Mike Scott. As you recall Mike has been the branch chief in charge of the GSI-191 branch for some time. He was a former staff member on the ACRS. He's on rotation up to Region 1 right now. And Donnie, who works for me in the balance of plant section, in the balance of plant branch, is now filling in for Mike.

Donnie has over 25 years of nuclear experience, and he has mostly in the PRA area, and Donnie was the PRA member of the GSI-191 team early on. So he has some familiarity with the issue, and he is coming up to speed.

By and large the rest of the staff that is dealing with GSI-191 has been stable. And we hope to provide you the information today that you are interested in hearing.

Donnie, and could you introduce the rest of the staff, the NRC staff, please?

UPDATE ON GS-191 - STATUS AND FUTURE ACTIVITIES

MR. HARRISON: Again, I'm Donnie Harrison. To my right is Steve Smith. He is going to be speaking today on the sump strainer head loss testing.

Paul Klein will be speaking on chemical effects, and then John Burke will be speaking on the chemical effects phenomenon and the identification ranking table, the PIRT. So and then after the Westinghouse presentation, we will come back. And Bill, I'm going to mispronounce your name, Krotiuk, will be presenting on the staff's work on in vessel downstream effects.

To get us going, we put together this picture just so we can see kind of how the flow is of where we are in the process. All the licensees have provided supplemental submittals in the February-March timeframe on Generic Letter 2004-02. The staff is looking at that information, and 14 different technical areas, and as part of that review the staff, in their performing of the detailed review, are developing requests for additional information.

As they put together an entire package for a plant, they then feed all those - that information to an integration review team that consists primarily of three senior staff members and a senior level scientist and a senior GG-15 staff member that are familiar with the GSI-191 to evaluate all the requests for additional information, the information from the licensee and they, the commission directed us to perform what's referred to as a holistic review. They kind of stepped back from the issue, look at it in total, and kind of weigh the uncertainties in one area with maybe the conservatisms in another area to make a final recommendation or determination by the team.

DR. WALLIS: In this team the same for all licensee submittals?

MR. HARRISON: Many of the members are the same, but the team is not necessarily the same. They have like four or five members with three at a time -

DR. WALLIS: I was just wondering how you are going to assure consistency across the board.

MR. HARRISON: There has been at least one member that has been on every one of the teams. Another member has been on every one except for one. And then there is another member that has been on almost all of them. It's been a fairly stable group. There is only - the early ones I think had four people that rotated among the three. The latter ones are different four people, the same three plus a different four. So there is fairly good consistency of that review team, because it's review from one application to another.

They make their determination. They write up and document their results. They interact back with the staff that actually did the detailed technical review, especially if they are determining that certain RAIs are not necessary to be able to make a finding that the sumps will have adequate reasonable assurance of performance.

And there is a loop that goes back and forth with the technical staff and the IRT members. They document their results, including minority opinions, if there is a minority opinion. That comes to the management for an ultimate decision on either pursuing additional information from the licensee or documenting why the generic letter is adequately closed.

So this loops back around if there are additional questions back to the licensee to provide additional information; we'll come back to the process again.

With that loop, then at what point does the licensee reach an endpoint? And the simple part is, basically when they have responded to all the RAIs and provided all the information that is considered sufficient ultimately by the IRT and the management that they provide reasonable assurance that the sump will actually perform.

DR. WALLIS: Now could you clarify, all of this is accessible to the public?

MR. HARRISON: All the documentation goes into a closure package, and I believe, I'm not sure, maybe the staff could help me on this, is all that information made publicly available, the IRT documentation?

MR. RULAND: To my knowledge it is not public at the moment. At this juncture, it's pre-decisional.

DR. WALLIS: But eventually it will be?

MR. RULAND: We are going to take a look at the packages and decide what parts of it can be released to the public, and what should be pre-decisional. Individual staff questions that staff has decided that staff has asked kind of the - basically the interrogatories may or may not be public. But the final IRT package where they document their decision about their bases, that will be public.

DR. WALLIS: So a student in a university could get hold of a package and see what you did?

MR. RULAND: They would not necessarily get all the questions that the technical staff asked themselves.

DR. WALLIS: But they would get the submittal and the decision?

MR. RULAND: That's correct.

DR. WALLIS: And the rationale for the decision?

MR. RULAND: That's correct.

DR. WALLIS: Thank you.

CHAIRMAN BANERJEE: would they get any proprietary information

MR. RULAND: No.

CHAIRMAN BANERJEE: Like some licensees obviously will do their own testing, right? So I don't think that will be public.

MR. HARRISON: Right, we will still follow all the normal rules on, if it's proprietary information, you'd have to have a non-proprietary version.

CHAIRMAN BANERJEE: So there would be data?

MR. HARRISON: There will be data. There will be information.

DR. WALLIS: It won't just be words. It'll be sort of hard core stuff that really proves something.

MR. LEHNING: This is John Lehning of the staff from NRC. There will be data. Most of the numbers, like the final head loss values, that all is nonproprietary. That is part of their licensing basis, and stuff we review. So there would be a substantial amount of data in those submittals.

And the licensee submittals are typically already publicly available and on our website, so those already are going to be reviewable.

MR. RULAND: And of course the RAIs are publicly available.

MR. HARRISON: Right, when we issue RAIs

those become publicly available. There's also - the licensees would need a response to any open items that we identify during staff audits of specific plant testing. There would need to be a final supplemental response after all the testings and evaluations are completed by the licensee to indicate that they believe they've completed all that is necessary to show that the sump performance is adequate.

And then there is this in-vessel downstream effect that we are going to hear about from Westinghouse. That W-CAP is still under review, or under revision. It'll be coming to the staff in the near future. All the licensees that rely on that W-CAP will need to respond once that has been reviewed and issued by the staff.

DR. WALLIS: Are we going to review that again?

MR. HARRISON: That would be the prerogative.

MR. KLEIN: Dr. Wallis, Paul Klein from NRI. I think there is still a number of tests to be performed, and I guess the expectation would be to provide that data in the future along with the staff assessment.

So at this point the topical report will be revised, and the staff will review that revision, issue a safety evaluation. So there is more information to be gained in the future in that area.

CHAIRMAN BANERJEE: I guess he's asking, will it come back to the ACRS? I guess it will.

MR. RULAND: That's your call.

MR. KLEIN: If you would like, I'm sure we can come back.

MR. HARRISON: That would be your prerogative, your decision.

Following the licensee's activity, the closure activities for the staff includes reviewing the supplemental information, RAI responses, in accordance, following that closure process, a diagram. The regions have conducted and will continue to conduct inspections of the implementation of any modifications that a licensee proposes; any other commitments such as procedure changes or water management or whatever the licensee proposes the regional inspectors will follow that.

After we have gone through the process the staff will issue a closure letter for each licensee when we believe there is sufficient information to close the issue for that plant. After we've closed all the issues for all the plants, we will then come back and issue a closure letter formally for the generic letter.

I recognize that some of these closure letters will be written for licensees that may have proposed modifications in the future for their plant. And so in some cases a plant may say, I'm going to take fiber out of my plant, and remove insulation, in a future cycle. That modification may not have been performed when we actually close out that plant's generic letter of response. However we will continue to track the commitments for that plant to achieve completion of their activities.

And the expectation is that we will complete the generic letter activities next year, 2009.

Just a current status of where we are again: all licensees have installed significantly larger sump strainers. Many licensees have removed insulation or replaced their sump buffer, some licensees will be doing that in the near future.

And strainer testing activities have been completed for many licensees. Some licensees will continue to need to do some additional testing.

CHAIRMAN BANERJEE: So about how many licensees, or roughly what percentage have completed their strainer testing?

MR. HARRISON: Do you want to answer that, Steve?

MR. SMITH: I could probably give you a rough -

CHAIRMAN BANERJEE: Very rough.

MR. SMITH: Probably about - well, some are going to have opportunities to answer RAIs, but I'd say probably half are done.

CHAIRMAN BANERJEE: But the staff has sort of satisfied themselves that these were roughly typical and represent -

MR. SMITH: Well, I think that a lot more than half are going to get RAIs, and will have to satisfactorily respond to those before we would say yes.

CHAIRMAN BANERJEE: So half have completed testing but not necessarily got closure?

MR. SMITH: I think a lot more than half have completed testing. I mean everyone, just about every licensee has done testing, right? But my feeling is that about half might be done; maybe less; maybe more. We have to see the responses that come back after we ask the questions.

MEMBER CORRADINI: So beyond testing, the other things in the second bullet, how many have modified their insulation or changed their buffering, which are more upstream things that would potentially preclude -

MR. KLEIN: I can speak to the buffer changes. There has been probably at least half a dozen and probably less than 10 plants that have changed buffer to try and reduce chemical effects.

MEMBER CORRADINI: And the insulation? What buffer do they use now? Or do they just not use it?

MR. KLEIN: The most common change has been to switch to sodium tetraboride. Nobody has come in and said that they are not using a buffer.

DR. KRESS: Okay, that's good. Because you are trading one problem for another. Have there been any studies of the sodium tetraboride, the chemical effect?

MR. KLEIN: We have done a number of tests at ANL that suggest sodium tetraboride may be one of the best buffers. It really depends on the -

DR. KRESS: I'm sure it's a good buffer, but does it - from the standpoint of not having chemical effects on the sump.

MR. KLEIN: Yes, that's what I meant.

DR. KRESS: Thank you.

(Comments off the record.)

CHAIRMAN BANERJEE: Carry on, Donnie.

MR. HARRISON: Most licensees requested extensions beyond - the generic letter had an original date to complete by December, 2007. Nearly all the licensees requested extensions beyond that to either perform integrated head loss testing including the chemical effects to provide some downstream effects analysis or to perform plant modifications.

MEMBER CORRADINI: I ask the second part of this just to - the insulation part, did anybody have some background there?

MR. SMITH: I don't have - John was going to jump up here. He may have a number; I don't know.

MR. LEHNING: This is John Lehning from NRC staff. A significant number of plants have done some type of insulation modifications. Most plants haven't like a wholesale replaced 100 percent of the insulation in containment. But I'd say over half of plants have done some sort of fiber removal, miscellaneous material, or calcium silicate, have taken that out in selected locations to mitigate certain breaks.

CHAIRMAN BANERJEE: So the numbers as of

last year that I have, now these might be out of date, six plants were going to be engaged in software changes; 15 insulation change outs; 20 major ECCS mods; and 19 were looking at containment sprays.

These might be 2007 numbers. But they probably change in 2008. And these were sort of planned. Whether they were actually done, I don't know.

MEMBER CORRADINI: Thank you very much.

MR. HARRISON: All plants submitted supplemental responses to the generic letter in February-March timeframe, and the staff is currently in the process of reviewing those supplements and providing RAIs or going to the RIT list to see if there can be a determination to close out the generic letter.

Currently the staff has informed a number of licensees that are typically low fiber plants that the staff has a few additional questions for them. They could be looked at as essentially they have gone through the process. We are not looping back around with very many questions.

Those other plants we expect to receive more RAIs, more questions on their testing and their different technical issues in the 14 areas. In addition most licensees are getting a place order RAI dealing with the in-vessel downstream effects, since most plants relied on the W-CAP to resolve that aspect.

CHAIRMAN BANERJEE: Have any plants actually resolved the downstream effects at the moment with their own testing in lieu of W-CAP?

MR. HARRISON: I believe there was one licensee's plant where we informed them that we would not be asking them any questions. And that was because they did not have a sufficient fiber loading to create a problem downstream, as well as at the sump spring. So --

CHAIRMAN BANERJEE: I guess what I'm asking is, are all plants relying on this W-CAP to close out this issue, or proceeding on their own?

MR. HARRISON: If not all nearly all.

MR. SMITH: There was one plant that did significant testing on their own. Other than that most plants are going to rely on the W-CAP.

CHAIRMAN BANERJEE: Just one plant?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: And was this sort of typical or any other plants, or was it just very unique, this plant?

MR. SMITH: They are all kind of unique as far as the debris loading is concerned. But it's a typical bottom nozzle type of protective grid. They will get into this a lot later on, the Westinghouse presentation, and we have a later presentation that will talk about this in-vessel in a lot more detail, we'll have pictures on it.

MR. HARRISON: So to come to closure on my part of the presentation, the staff established a process for closing the Generic Letter 2004-02. We believe that if we follow that process we will come to closure.

DR. WALLIS: When you refer to this process, this process is this diagram?

MR. HARRISON: Essentially the diagram, yes.

DR. WALLIS: But that doesn't tell us anything about what technical questions are going to be asked, and have to be answered. Presumably you have a much more detailed process which says, you've got to show us ABCDEFG and all that sort of thing?

MR. HARRISON: The process - yes, when you look at the box that deals with the detailed review area, there are 14 different technical areas that are being reviewed in detail.

DR. WALLIS: Okay, so that is the interesting part of the real process to me.

MR. HARRISON: Right, that part, and then the feeding into the IRT are -

DR. WALLIS: And are you going to tell us about that?

MR. HARRISON: We will hit on pieces of it, but we are really focused here on the strainer testing, which is going to be -

DR. WALLIS: But how do you relate the testing to the reality in the plant?

CHAIRMAN BANERJEE: Do you have a list of those 14 areas of review?

MR. RULAND: Not only do we have those 14 areas, we have some topical reports that have been reviewed and approved for those areas. We have review guidance for the individual reviewers.

So we provided substantial guidance to the technical staff in doing this review.

MR. HARRISON: I'll give you a complete list, but some of the items are - it ranges from the break selection, debris generation, latent debris, debris transport, head loss, coatings, structural analysis.

DR. WALLIS: And then there is guidance on all of these issues?

MR. HARRISON: There is a content guide.

CHAIRMAN BANERJEE: So can we do this? If you would give Professor Wallis a list of these, and if he needs any more information on any of these you can ask for it. And get back on this.

DR. WALLIS: Is it just for me?

CHAIRMAN BANERJEE: Well, if there are any other people on the committee who wants to see it. Maybe the thing to do is to give it to David Bessette, and then that is available to anybody who wants to see it.

But let's make sure at least that whatever Professor Wallis wants gets to David Bessette.

DR. WALLIS: That is a big open-ended -

CHAIRMAN BANERJEE: We have to bring it to closure at some point.

MR. RULAND: David, when we provide this - this is a substantial amount of information you are asking for. So we will work with the committee to try to provide this.

MR

. BANARJEE: Let's start with the 14 areas, just the list. And then if much more is needed we will ask for it.

MR. HARRISON: We'll do that. And just to conclude again, there have been significant modifications to prevent strainer blockage, and as you will hear in a little bit there has been considerable work on establishing conservative test protocols -

DR. WALLIS: I have another question, I'm sorry. I'm going to get these areas. Do I get them this morning, so I can ask questions about them? Or do I have to wait?

MR. HARRISON: I can give you a list at the break. And then we will come back with a content guide later.

Again, I think we've established conservative test protocols that can be used to show satisfactory strainer performance, as I've said before, and we are going to talk about today. The investment downstream effects will be resolved as part of the W-CAP review.

And with that I'll turn it over to Steve Smith to talk about the head loss testing.

CHAIRMAN BANERJEE: Now before we go on, you've got until 10:45 to finish. How many slides do you have for your part of the presentation that you need to get through by 10:45?

MR. HARRISON: We have 20 slides in the

chemical effects area.

MR. SMITH: Approximately 45.

CHAIRMAN BANERJEE: Forty-five? Okay. It should be possible, as long as the committee lets them get through it, subcommittee.

DR. WALLIS: You're suggesting we don't ask questions.

CHAIRMAN BANERJEE: You can ask questions, not on every slide though.

MR. SMITH: If you could limit them to two questions each that would be perfect.

MR. HARRISON: And easy questions we can answer faster.

CHAIRMAN BANERJEE: Okay, let's go, Steve.

UPDATE ON GS-191 - STATUS AND FUTURE ACTIVITIES

MR. SMITH: Okay, Steve Smith. We are going to talk about strainer testing.

Just an overview of what we are going to be talking about. Strainer testing is being conducted by almost all licensees to ensure that they have adequate NPSH margin. They are using plant-specific debris loads, and they are in sections of their plant-specific strainer to do the testing, scaled down sections.

We will go over the list, we will go over the current state of head loss testing. I will show you a list of the strainer vendors and testers who are doing strainer testing.

We will summarize the results of our generic letter 2004-02 head loss reviews, and how we see the process going forward. And we will talk about the biggest areas of concerns that we identified as we were going through the head loss testing process and trying to get the vendors and the staff to see eye to eye on good test procedures. And then we'll share some information on review guidance that we put out for head loss testing, and we'll go over the path forward.

CHAIRMAN BANERJEE: Is this a fairly large thing, or is it something that we close which is - we could transmit - the review guidance that you have given us?

MR. SMITH: The review guidance, it's about 60 pages. And we have review guidance for head loss testing, chemical effects, and we also have review guidance in the coatings area. So those are three specific areas that we've put review guidance out to help the industry with the testing, and how they do the evaluations.

CHAIRMAN BANERJEE: Okay, let's move on.

If we want to see some of this we can.

MR. SMITH: Okay.

The current status of head loss testing, we believe that most of the strainer testers and vendors have developed protocols that will give either prototypical or conservative head loss results when they test a strainer.

Because there are a lot of significant unknowns in how the bed will form in the plant, and other factors that affect the head loss, the staff has pushed the vendors into what we believe are relatively conservative test protocols.

DR. WALLIS: Question?

MR. SMITH: Yes.

DR. WALLIS: What is conservative for head loss may not be conservative for bypass.

MR. SMITH: That's true.

DR. WALLIS: How do you cover this sort of two-dimensional space?

MR. SMITH: In general the bypass testing and the head loss testing are separate tests, okay? And we'll talk about bypass testing later today in the other presentation, okay?

There are some vendors -

DR. KRESS: But you think the head loss is the critical issue compared to that?

MR. SMITH: Well, both issues are critical and important. The bypass is important for the downstream in-vessel effects.

DR. KRESS: But you think you could optimize the head loss and still live with the bypass problem? Is that the approach?

MR. SMITH: I think what we try to do is, we try to make the bypass testing be conservative, and the head loss testing be conservative. And they are done separately. So does that make sense?

CHAIRMAN BANERJEE: The screen area is quite a bit larger than the core flow area, so you've got to have a screen to take something out.

MR. SMITH: And one thing that we've seen, the tests that we've recently observed have been a lot better than earlier tests that were conducted.

Some vendors haven't provided adequate assurance that their current protocols will provide conservative and prototypical results, and those - the people who are using - or the licensees that are using these protocols are going to get some probably relatively difficult RAIs from us.

DR. WALLIS: I can see how you can perhaps get assurance of conservatism. I don't understand how you make sure it's prototypical, because you have all kinds of flow patterns and distributions within the sump region.

MR. SMITH: I agree.

DR. WALLIS: Which really cannot all be duplicated in a test, can they?

MR. SMITH: And that's why we would say it would range anywhere from conservative to prototypical.

DR. WALLIS: Well, maybe the word, prototypical, shouldn't be there, because I'm not sure you could do it. Conservative I understand, I think.

MR. SMITH: I would say if you ask these guys back here they probably think we are really conservative. But it probably tends more towards conservatism.

DR. WALLIS: I would think so. Are there any that are truly prototypical?

MR. SMITH: Well, some of the testing I think is actually quite prototypical. However there are a lot of other conservative assumptions that go into the entire analysis, and that is how much debris is generated; what the debris looks like. I mean there are a lot of unknowns there, so we are pretty conservative with a lot of those inputs.

CHAIRMAN BANERJEE: I guess prototypical might mean prototypical conditions in terms of approach philosophies or whatever.

DR. WALLIS: Yes, some things will be prototypical, but not everything perhaps.

CHAIRMAN BANERJEE: But the debris loading and all might be very conservative.

MR. SMITH: The third item there is that some plants are relying on testing that was conducted prior to the development of the more conservative protocols. And these licensees are also going to get some RAIs if they don't upgrade their testing with the newer protocols.

CHAIRMAN BANERJEE: But roughly you were saying about half of them have done things which even though they'll get some RAIs back they've done it under conservative prototypical conditions, and about half of them are still doing it?

MR. SMITH: That's probably about right. We'll have to see how the responses come back.

CHAIRMAN BANERJEE: I'm just trying to get a feel for the magnitude of the problem right now.

MR. SMITH: Right. A lot of the testing - most of the testing that has been done this year by licensees has been conservative. Testing that was done before 2007, or 2007 and before, may not have been done under a conservative procedure.

CHAIRMAN BANERJEE: And these take chemical effects and all these exhaust things into account?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: Using surrogates if necessary?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: Okay.

MR. SMITH: And we have witnessed a number of head loss tests at each vendor or tester, and we've incorporated the lessons that we've learned from these into our review guidance and into our reviews of the generic letter submittals.

Okay, this is a list of the people who are doing the trainer testing. Five of them, the first five are also vendors, or associated with vendors, and the second, the bottom two are just test vendors that have done tests for a relatively small number of clients.

MR. RULAND: Mr. Chairman, just as a piece of information, we have a detailed matrix that basically contains the status of every plant, RAIs, et cetera. So we'll give you a copy, and we'll make sure that we distribute that to the committee.

CHAIRMAN BANERJEE: Thank you.

MR. SMITH: We have reviewed most of the supplemental responses that have come in from the plants, probably two-thirds to three-fourths of the supplemental responses; the other ones are still under review. But most of the licensees are getting RAIs in the head loss area.

CHAIRMAN BANERJEE: The test vendors are the actual people who make screens? Or are they separate?

MR. SMITH: The testers, the top five there, the five main test vendors, are associated, some, like Alion tests the Enercon screeners, right, but these other ones here test their own screeners, the next four.

DR. WALLIS: So the people testing are the same people as the people who sell?

MR. SMITH: Yes.

DR. KRESS: Sounds like a conflict of interest.

CHAIRMAN BANERJEE: That's the first five, right?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: Wylie and Fauske are independent; they don't make it?

MR. SMITH: Wylie and Fauske are independent; that's correct. And that's why we're going out to watch these guys, because you don't want to have any conflict of interest there.

Okay, for the licensees that tested with the more recent and conservative procedures, they are not getting a lot of RAIs. They are probably getting some RAIs to document some things that maybe they left out, or just to ensure that they actually used a conservative procedure when they did the test.

And then for the plants that did testing with older protocols that weren't as conservative, they are going to get significant RAIs, and some of these plants are going to need to do some additional testing probably to adequately address the RAIs; at least that's our feeling. We have to wait until the information comes in from the plants, but that's the way we feel about that right now.

DR. KRESS: Have we heard what the current protocol is? Are we going to hear that?

MR. SMITH: It's probably, it's kind of complicated. There are a lot of things that go into it, and there's - every plant has a different debris load, and each strainer type may have some different ways that it would be tested. Some vendors use -

allow settling of debris during the testing, so they have different things they have to deal with. Each -

DR. KRESS: Is this protocol documented in some sort of document?

MR. SMITH: Each vendor has their own protocol, and they tailor that protocol to each plant that they test. So there is a lot of variability to how the plants are tested, depending on their plant-specific -

DR. KRESS: You guys have reviewed all these protocols?

MR. SMITH: We have not reviewed every plant's protocol. We have reviewed at least one of every test vendor's protocol, and usually more than one, and how that related to a specific plant. And we assume that if they are testing Plant X properly, that they probably are going to do okay on Plant Y.

CHAIRMAN BANERJEE: I guess one of the things that the subcommittee had concerns on was to allow the settling to occur, because it's very hard to estimate in plant conditions, or turbulence conditions. So one bounding thing would be to say that you estimate a certain amount of debris, which of course is an estimate, allow it all to be suspended and brought to the - so that would be sort of extremely conservative, of course. But it would be a bounding case.

MR. SMITH: Yes.

CHAIRMAN BANERJEE: And in some cases we sort of suggested you might want to do that rather than allow for settling. Now clearly what you are saying is that some of the vendors are taking account of this settling.

MR. SMITH: Yes.

CHAIRMAN BANERJEE: In their flumes, they are allowing it. That is very hard to guarantee for a prototypical -

MR. SMITH: I have a slide that will talk about that a little bit. There is one vendor in particular that uses settling for all their tests, and in general, most of the other vendors do the stir test, although not in all cases.

CHAIRMAN BANERJEE: I mean in reality of course there will be settling. It's very hard to estimate.

MR. SMITH: Right, that's why we've been kind of hard on the vendors that use settling. We look at that a little bit more closely. Although there are issues that can occur when you are stirring something and you have too much current near the strainer it could wash the strainer clean and cause the head loss to be lower. So there are pluses and minutes to the ways tests are done. There are a lot of different -

CHAIRMAN BANERJEE: Okay, well, let's move on, but I think we understand that you are taking cognizance of this.

MR. RULAND: Just for clarification, the staff is not - there were no topical reports submitted for these protocols, and the staff did not review and approve them. What the staff did was observe the testing and made comments to the vendors until we were satisfied that our issues were addressed. And it's because of the nature of how this issue has played out, right. The strainers were first installed, and then the engineering was done subsequent, and we've been trying our best to get this done. So it's a little unusual; it's not the typical staff approach.

CHAIRMAN BANERJEE: Right, but we agreed to that.

MEMBER MAYNARD: And I believe you said earlier, you have detailed guidance for your review of these?

MR. SMITH: Yes, we have a content guide which is sort of a general guidance for us, how to review what comes in. But we have something called a review guidance, which is what I said we have in three areas. And in the head loss area, that has taken into account everything that we have learned. It covers the testing that's done, and it also covers like what you do with the data afterwards, how you evaluate it, things like that; you know, test termination criteria, how you can extrapolate and see where this thing would go after 30 days, things like that.

DR. WALLIS: Well, that's the important part, isn't it?

MR. SMITH: Yes.

DR. WALLIS: I mean testing is one thing, but you have to be clear, what is the output of the test that is useful?

MR. SMITH: It's both very important. I mean the test has to be good, and what you do with the data also has to be good.

DR. WALLIS: You almost have to start with what you need from the test. You need to duplicate certain plant conditions. You want to get the maximum head loss, maximum possible flow or something.

MR. SMITH: That's correct.

DR. WALLIS: And specify what your output needs to be.

MR. SMITH: That's correct.

DR. WALLIS: And you are sure you are doing that?

MR. SMITH: Yes.

DR. WALLIS: Can we see that too, somehow? Can we see the guidance for what has to come out of the test?

MR. SMITH: I think the review guidance would be something that you would be very interested in looking at.

DR. WALLIS: Could we see that?

MR. SMITH: I've got that on my list as well.

DR. WALLIS: Because I was a bit surprised that nothing was said prior to this meeting we could look at.

MR. SMITH: It's public.

DR. WALLIS: They're very useful when you have these meetings, if we can look at what we are going to discuss beforehand.

MR. SMITH: This review guidance is public, right?

DR. WALLIS: Yes, but I'm not going to look through all the public information and find something. You have to give it to me.

CHAIRMAN BANERJEE: Well, Graham, we tried - I mean I guess this meeting was work in progress. We tried to get the slides in advance, but there was some reason why you couldn't, David, right?

DR. WALLIS: It's very inefficient. If you send me something after the meeting and I look at it and I have questions that could have been asked at the meeting, then we have to have another meeting.

CHAIRMAN BANERJEE: Well, let's limit the number of meetings.

MR. SMITH: I think the important thing is that we will have the review guidance for you, but it's important that it's available for the licensees and vendors, because they are the ones who really need to use it. So we'll get the information.

These are - this slide is a list of the key technical issues. I'm not going to say it's all of them, because there are a lot. But these are the main technical issues, the most significant areas that we identified issues with when we went out to review strainer testing at vendors.

And most fo the strainer testers or vendors have revised their procedures to address these issues.

This slide is on the head loss review

guidance that we were talking about. And I agree, this is a very important document. It was issued, I'm not sure when the original issue was, but we updated it in March - September, `07, okay was the original issue - we updated it in March to incorporate a lot of the lessons learned that we learned when we went out to see strainer testing.

As we said it's publicly available and it covers testing and evaluations. And we think that if the licensees and vendors use this review guidance that they are going to end up with a conservative test result and evaluation of the result.

ON the path forward, plants that have RAIs, we are reviewing the generic letter responses now. Plants are getting RAIs on this, and they are going to have to provide acceptable responses to the RAIs, which may require additional analysis or testing.

Some licensees that have had unacceptable test results using the more conservative tests have realized that they are going to have to do something. So what we are doing, generally these licensees are coming in for extensions, so when they come in and ask for an extension to do additional work in their plant, we ask them to test for success. So that's sort of a new - I guess that's a little term we came up with. And that means, what they are going to do is, they are going to go to their test vendor, and they are going to test various plant configurations until they come up with an acceptable test for their screener.

And then once they figure out what that acceptable plant configuration is they are going to go forward and modify their plant. So what we are doing in this case is, we are preventing them from going out, saying we are going to take X insulation out, testing that condition, doing that, and then coming back in a year and saying that they are going to have to do another modification. We are going to make sure that they are getting to the end of the modification process by doing the test to success.

Some plants are in the test to success they will either be doing analytical changes, or they will be physically removing debris sources from containment in general, insulation, or they may be installing debris interceptors or other modifications to reduce the debris getting to the strainer.

And in general the plants are committing to do this at the next available refueling outage.

CHAIRMAN BANERJEE: There will also be a change to the buffer.

MR. SMITH: There could be a change to the buffer, that's correct. Some plants are changing the buffer.

Now we have some movies to show you - actually not full-length movies, but short movies here. The first shows debris introduction at CCI. This shows very fine debris, which we believe is the most conservative, the finer debris, and you can see the debris going in.

DR. WALLIS: It's still a bucket technique?

MR. SMITH: It's a bucket technique, but you can see how this goes in, and it's basically a cloud, and it transports slowly to the strainer, and it's going to cover the strainer rather uniformly.

DR. WALLIS: Is it sinking?

MR. SMITH: Now, I will say, since you say it seems to be sinking, this is now particulate going in. Since these -

DR. WALLIS: This is in a plume which doesn't have much turbulence.

(Simultaneous speakers.)

MR. SMITH: In general the turbulence is relatively low, depending on the location in the sump flow. I mean there could be drainage coming down into the sump creating turbulence. But the velocities are very slow in the sump.

CHAIRMAN BANERJEE: Well there was some German test that was done. The water falls.

MR. SMITH: The water falling from the break.

CHAIRMAN BANERJEE: Yes, that creates quite a lot of turbulence.

MR. SMITH: Okay, what these guys do in their test is that -

DR. WALLIS: Who are these guys?

MR. SMITH: This is CCI, okay. And I think some of the HR went for that. After the debris goes in, if any debris settles on the bottom of the plume, they stir it up, with a drill-driven propeller. So this is one of those tests that you were talking about where all the debris eventually gets to the strainer.

DR. WALLIS: So these are ones done in Switzerland, are they?

MR. SMITH: Yes, Switzerland.

MEMBER CORRADINI: So the intent here is to keep whatever they put in fluidized and in the liquid?

MR. SMITH: That's correct. So it's conservative with respect to - none of the debris - there is always going to be a little bit of settling. But almost none of the debris is allowed to settle in the bottom of the flume, and it all makes it to the strainer.

MEMBER CORRADINI: So to go back to Tom's question about this, so when they do a test such as this their intent is to look at the configuration within some sort of reasonable bounds that give the maximum head loss?

MR. SMITH: That's correct.

MEMBER CORRADINI: And then they would - with a given strainer design?

MR. SMITH: Yes, and plant loading, yes, plant debris loading, yes.

MEMBER CORRADINI: And the plant debris loading is specified by some sort of cookbook formulaic predetermination of break size, area, stuff influence -

MR. SMITH: Zone of influence, yes.

MEMBER CORRADINI: How it essentially gets fragmented.

MR. SMITH: That's correct.

MEMBER CORRADINI: And that's all predetermined by some reg guides that they follow? I'm trying to understand how did they determine the initial conditions that they are trying to stimulate?

MR. SMITH: I'm not sure it's a reg guide on the debris -

MEMBER CORRADINI: What are they following so that you feel comfortable?

MR. LEHNING: This is John Lehning from the staff. Typically what plants have done is follow the Nuclear Energy Institute 04-2004-07 guidance, and the staff has written an SE on that. In some of them they have other modifications to that, but that is the basic method.

DR. KRESS: It's a large plate LOCA with an area of influence here?

MR. SMITH: Yes. Zone of influence.

CHAIRMAN BANERJEE: I mean if you want to go back to that point, I was reading the old ACRS letters on this, John, and there was quite a dispute on this zone of influence, impact velocities. Was that ever resolved? I don't know what state it was resolved at. I was just going over the history even before my time.

MR. LEHNING: This is John Lehning again. I wasn't at that meeting, but what our position was is that this spherical model and the air jet testing that was done is conservative. And there was an appendix to the safety evaluation that discussed the reasons that we came to that conclusion. And I know that there were differences of opinion on that during the ACRS meetings. And one of the things that we are looking at in a scoping study now in the boiling water reactors is that we know that air jet testing was done for that, and then now some two-face testing was done for the PWRs to refine some of those ZOIs, and one of the things that is part of that scoping study was to look at the differences between those two, air versus a two-phase. And I know there were other things with that, the issues the ACRS had. I don't know that those are a part of that, though.

CHAIRMAN BANERJEE: It might be worth going back over that letter. Because those issues related to I think some of the Sandia tests, and the two-phase - you know, the water impact or whatever. So it was interesting reading. I hadn't seen this letter. But it was obviously not a closed question or a closed issue.

All right, we can move on. So your point is well taken, Mike, but there is some sort of way to do it right now.

MR. SMITH: All right, we have one more film. This is going to show a chemical debris addition also at CCI, and this is basically just to show you the flow pattern in the test flume, and it illustrates - it's a little bit more complicated modeling, because this strainer has both a front and a back side. The back side is against the containment wall.

Now you won't see the backside for a minute, but we will get around there.

DR. WALLIS: So this is now being injected through a tube?

MR. SMITH: Yes, being injected through a tube, the chemical surrogate is being put in, and what we saw from this is that the chemical - and I have a couple of pictures that I will show later - that the chemical debris increases the head loss significantly, and it causes the fiber to really compress.

DR. WALLIS: Now it seems to be there are fibers on the screen already.

MR. SMITH: Yes, the chemical debris, almost all testers put that in later.

DR. WALLIS: The chemical debris doesn't sink; it just goes along with the flow.

MR. SMITH: Yes, it's pretty buoyant.

CHAIRMAN BANERJEE: And this is the WCAP surrogate?

MR. KLEIN: It does sink over time.

CHAIRMAN BANERJEE: Is this a CCI surrogate? Why do you put some in with a bucket and some in with a tube?

MR. SMITH: The vendors have - you know, they put different things in. Whatever probably works best for them is what they do. And as long as it seems to be going in in a prototypical manner that is going to create prototypical -

DR. WALLIS: This is a different kind of screen here? Looks like a vertical screen; is that what we're looking at?

MR. SMITH: This is a vertical pocket strainer.

DR. WALLIS: You're actually setting up a circulation in front of it.

MR. SMITH: And this may be how the actual flow pattern - because this - over here models the containment wall, okay. So they have a big strainer, and water flows in -

DR. WALLIS: Which I think is one of our concerns, that the way the stuff approaches the screen depends on the local geometry and all sorts of things which are very different in different parts of the plant.

CHAIRMAN BANERJEE: He says most of the stuff is still suspended by this vortex, right?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: It doesn't very much - at least I didn't see very much settling.

MR. SMITH: And again if any debris settles, they do stir it to get it back up in suspension and allow it to get on the strainer, so it's rather conservative from that perspective.

DR. KRESS: Where does the downstream water go?

MR. SMITH: The downstream water, it goes through the strainer, and it cycles back -

DR. KRESS: It resurfaces?

MR. SMITH: - into the upstream of the strainer, yes.

Most of the tests are done that way.

MEMBER ABDEL-KHALIK: Are transient data collected, or do they just generally wait until some kind of steady state?

MR. SMITH: In general I believe all the vendors are using a data collection system that collects the data every - you know, between one and 10 seconds. So they are collecting flow rate. They are collecting temperature. They are collecting head loss, at a minimum.

CHAIRMAN BANERJEE: That's available, but not necessarily being examined.

MR. SMITH: This is a bigger picture of the flume that we just observed a test being done. And this is not the same strainer. This is the strainer we saw at the first. And there is a pump over here that collects the water and pumps it back in here. So basically we saw the debris going in over here and collecting on the strainer. That's just to give you an idea of how the testing is done.

DR. KRESS: What actually was the chemical that was introduced?

MR. SMITH: I'm not sure what the chemical was. Matt, do you remember?

MR. YODER: This is Matt Yoder, Division of Component Integrity. For the test they used - the white chemical surrogate was WCAP aluminum oxyhydroxide.

DR. KRESS: It was a particulate?

MR. YODER: You could characterize it as a particulate. But this is - maybe Paul can step in. I don't think we would consider it a particulate. It's more a hydrated - I guess we'd consider it an amorphous hydrated precipitate, and it acts somewhat like a particulate, but we think it can drive head loss much higher than some standard particulates.

It really is a function of the filterability of the bed, so you can add chemical precipitates to a test and see no head loss response, or you can add chemical effects, precipitate, to a test and see very high pressure drops.

DR. WALLIS: How about repeatability of these? I mean I remember the tests that were done at Pacific Labs where you put the stuff in different ways in different order and you got order of magnitude different results, which seems rather bothersome, because it means you've got to do a lot of tests to make sure you've covered the range of possible results for the same stuff.

MR. SMITH: That's correct. And I think repeatability is potentially a good question. But what we do is, even though some vendors do several tests for each plant under the same conditions, so we have an idea of repeatability for them.

For vendors that don't do several tests, we look at if they have plants that have similar debris loads and how those compare.

The other thing that we do, you mentioned the order of putting the surrogates in, we believe that if the particulate is put in first it results in a higher head loss. So generally our review guidance says you should put the particulate in first unless you have just a very limited amount of fiber; then you can put it in together, because that would be according to -

DR. WALLIS: But of course if you put the fine stuff in first it goes through, and it goes around the loop, it comes back and has another go at the screen.

MR. SMITH: Yes.

DR. WALLIS: So it's not as simple as just what you put in first, is it?

MR. SMITH: Well, the particulate in general will pass through the strainer, and then a lot of it even passes through the fibrous bed several times until it gets taken out.

CHAIRMAN BANERJEE: Have any of these vendors tried to develop a crude sort of model to try to explain these results? Or do they just depend on just pure testing?

Like what Graham says is something you could put into some sort of a crude model.

MR. SMITH: We have this old 6224 correlation.

CHAIRMAN BANERJEE: Well, that's just a correlation.

MR. KLEIN: We're not aware of anybody who has developed a model because of the variability in plant-specific debris. I think it would just be very difficult.

MR. SMITH: No model other than the old correlation.

DR. WALLIS: So without a model you have to explain to us how you extrapolate to the plant.

CHAIRMAN BANERJEE: It was represented as peace, I guess.

MR. RULAND: As everybody here knows, this problem, ESI 191, frankly could be several lifetimes worth of research. And we have decided, based on our technical judgment, that these tests are good enough. They are not perfect, but I think based on our technical judgment these are good enough. And we cannot - we need to resolve this issue, and we need to resolve it with reasonable assurance.

So what you are seeing is the staff's judgment about what is reasonable assurance to decide whether the sumps are adequate or not.

Thank you.

CHAIRMAN BANERJEE: Hopefully a little conservative.

MR. KLEIN: I think one of the ways to

relate it to the plant is, it's a plant-specific debris mixture. The plants typically, the vendors test for the limiting condition whether that's a thin bed or a maximum type debris, and then it's introduced in a way that through testing we've observed produces the highest head loss.

MR. SMITH: And we use a plant prototypical of screen approach velocities, things like that, is what we ensure.

DR. WALLIS: This reasonable assurance for the stuff, that's very good. You are professional people; you need to be assured. How do you achieve reasonable assurance for members of the public?

MR. SMITH: Well, hopefully that's the same thing.

DR. WALLIS: Well, I'm not sure as to how you make it the same thing, because the public would have to have access to the same information you have. They'd have to think along the same lines.

MR. KLEIN: The public will have access to most of the information that is nonproprietary at the end of this process. So they will be able to look at test results; they'll be able to see the staff's assessment of an individual licensee and draw their own independent conclusion.

CHAIRMAN BANERJEE: Carry on - sorry, is there another question?

DR. KRESS: Suppose we're wrong on all this, and the plant undergoes a large plant LOCA, and you notice the head loss is approaching something unacceptable for net positive section head, is there something then that an operator can do? Like reverse the flow or some -

MR. SMITH: Some plants have a back flush procedure written into their beyond design basis procedures. I don't think all plants have done that.

But the other thing that has shown to be effective, is just stopping and restarting the pump sometimes. In the testing. It's never been done in the plant of course.

MR. LEHNING: This is John Lehning from the staff. In addition to that we look at the design basis case, typically, without any accident pressure, or even the air pressure before the accident occurs.

So in looking at that there are a number of other margins that exist beyond what most plants would even credit before they got to that point of losing MPSH.

DR. KRESS: Well, that would be part of this assurance that Graham raised on this.

MR. SMITH: Okay, this is basically a picture from the first film we saw. This is post drain down, so there is no water in the plume here. This is a relatively low fiber plant. They would have less than what we would call a thin bed. We found that a thin bed could be a lot less, what we used to call a thin bed was one-eighth of an inch of fiber. We know that we can get high head loss with a lot less than one-eighth of an inch of fiber now.

But after this test was completed and it was drained down, we could see clean areas in the tops and some of the sides of the strainers here. Most of what you see here is chemical and particulate debris. The fiber is really compressed onto these.

And this test I understand met the acceptance criteria, although we haven't seen the final evaluation for it yet.

CHAIRMAN BANERJEE: The white stuff is obviously not the fiber. It's the fiber than that back -

MR. SMITH: The fiber is under that. You can't see it, right.

DR. WALLIS: What we see here is the chemical on top of this?

MR. SMITH: You see some particulate and

chemical, yes.

MR. YODER: This is Matt Yoder just to clarify it. If you recall from the video we watched there was a lot of gray particulate; that was epoxies. So what you are seeing here is that epoxy particulate mixed in with the white WCAP-type chemical surrogate, and then that stuff is laying on top of the fiber. So that's why it looks gray with some white showing through.

CHAIRMAN BANERJEE: Now, before that stuff started to - some of that fiber, going back to Said's question really, did you all already get a very high head loss with just that tin fiber matt?

MR. SMITH: The head loss for this test overall didn't end up being extremely high. I think it was a little over a foot of head loss. I'm just recalling off the top of my head.

CHAIRMAN BANERJEE: Okay, but I guess the question was, was that foot then already there before this other stuff went on it? With just the tin fiber bed?

MR. SMITH: No, in this case the fiber and the particulate were added together, from the movie. Remember, they put the fiber and the particulate in basically at the same time.

CHAIRMAN BANERJEE: Built up sort of almost together.

MR. SMITH: Built up almost together, that's correct.

And the other thing to note here is that this particular licensee did not have to do a separate thin bed test because their amount of fiber was so small already they didn't have to do a separate test. But licensees that have a lot of fiber also have to test for a thin bed to make sure that doesn't give them a higher head loss, because if you get a lot of particulate built up in a smaller amount of fiber, it can create almost like a clay or dirt-like bed that creates a high head loss.

DR. WALLIS: Now there seems to be more junk on the bottom of this pocket than on the top.

MR. SMITH: Yes.

DR. WALLIS: And on the far end there is much less than on the sides. So clearly there is some kind of flow pattern and distribution going on inside the pocket. You can't just assume it's uniform. There is something going on which distributes stuff nonuniformly within the pocket itself.

MR. SMITH: It's possible. I would think gravity has to play some effect.

DR. WALLIS: Gravity has to play some effect. It's low velocity. It looks as if it does, because there is more stuff on the bottom.

MR. YODER: Matt Yoder again. So one thing to keep in mind is that this is after drain down. Some of this debris has fallen from the sides and top to the bottom.

But then the other thing to consider is, they are trying to credit this stuff, you know, maybe accumulating more on the bottom so you have more open area on the top, so that's one of the benefits of this design and of a lot of the designs that you can have some open areas and then have some other areas that are completely engulfed in debris, because you can still get flow through those cleaner areas.

CHAIRMAN BANERJEE: Yes, approach velocity at the face is much lower - higher than the normal velocity at the walls.

MR. SMITH: At the screen, yes.

CHAIRMAN BANERJEE: Because you have got much more surface area in there. So you've got stuff in, but then it might settle inside.

Anyway let's move on.

MR. SMITH: Okay, this is a picture we say. Basically this is the movie; same picture that we saw in the movie. This is before the chemical debris was put in.

And as you can see the fiber is really fluffy in this picture, and it covers basically the face of the strainer. You can see one place where the DP got kind of high and it compressed -

DR. WALLIS: It seems to have layers as if it were put on in stages . It has layers to it, striations. It's got layers.

MR. SMITH: I don't think it's put on in layers.

MR. YODER: I think what you are seeing there is, this is the same kind of a grid that we just saw in the other picture. What you are seeing there is the outer faces of that grid kind of forming. The lines that you are seeing there, I think that's what you are seeing, not necessarily layers of different batches forming.

MR. SMITH: It's a little bit hard to see because it is out of proportion because you are shooting through water. And it's actually a rectangular piece there; it just doesn't look like it. But there are pockets, so there's a grid there.

And at this point in the test the head loss is relatively low.

In the next picture, I'm sorry this picture is not good. But this is after remember we put the chemicals in in the movie. This shows what happens. And you can see that as the chemicals collect on the fiber it compresses the fiber and the head loss goes up significantly.

DR. WALLIS: How big was the fiber before this? Can you show on the movie, on the picture here, where is the outer limit of the fiber bed was?

MR. SMITH: I'd say the fiber bed was probably about an inch thick or so; does that sound about right?

DR. WALLIS: No, on this picture here, was it way out? The previous picture showed it -

MR. SMITH: It was probably out - something - you know -

DR. WALLIS: So it's a different scale or something? The previous picture showed it way out.

MR. SMITH: It's a different angle.

DR. WALLIS: It showed a thick thing like that. The nuts give you some scale. Now how can we look at -

MR. SMITH: The problem is, this picture is shot from more - looking directly into the fiber bed. With all the chemicals in there we couldn't shoot from the same angle; we had to shoot right in an angle like this, so I think it's hard to really tell.

DR. WALLIS: It looks as if it's shrunk; it looks as if the whole bed is shrunk.

MR. SMITH: The fiber definitely compresses when you get particulate or chemical debris it really compresses, and that's what causes the higher head losses.

DR. WALLIS: So why does it go into pockets? It has to do with the design of the screen?

MR. SMITH: Right.

DR. WALLIS: The screen has pockets in it?

MR. SMITH: The pockets were always there; they were just not visible because the fiber was -

DR. WALLIS: So the screen has pockets on it?

MR. SMITH: Yes.

So the next one we talked about -

DR. WALLIS: Well, that's qualitative. Now can you explain the result in a quantitative way. I mean this is a very interesting thing. Questions always arise about, what does this mean about what you do in the plant? Are you going to require that they assume the worst possible sequence of events or something or what?

MR. SMITH: I think that's what we are doing. The test is, we have the ability to know. We make it as conservative as we can.

CHAIRMAN BANERJEE: What does this third bullet mean, compared to CFD flows? I mean glows generated by competitional fluid dynamics?

MR. SMITH: What we do is, what this particular vendor does, I'll just give a quick explanation. The debris goes in way back here. The strainer is here. It's I think about 40 feet from the - this end of the flume to this end of the flume, so the debris has to go 30 to 40 feet to reach the strainer. This is one that allows settling.

What this vendor does is, they have taken their CFD that is used for transport analysis in the plant, and they have taken that CFD and they have determined what the velocities are at places close to the strainer, within 30 feet of the strainer. And they build this flume to make the velocities change as it's predicted by the CFD, and that's why the flume gets wider and narrower, just to make the velocities more representative of what would be in the plant.

MEMBER CORRADINI: So let me make sure I understand this then. So what they do is, they try to mimic their plant geometry with some sort of computational tool. Then they take the computed local velocities from the computational tool and try to reproduce them in this test plume?

MR. SMITH: That is correct.

MEMBER CORRADINI: And do they measure the velocity so they know they get what they think they get?

MR. SMITH: What they measure is, they measure volumetric flow rate.

MEMBER CORRADINI: No, I'm talking about in the flume. I want to know if they go through this whole loop I want to know if they actually measured what the computation said they should get.

MR. SMITH: They don't measure the velocity in the flume.

MR. DINGLER: Steve, this is Mo Dingler. For this one they actually measure the flow at each individual point to validate it since this was the first test they ran.

CHAIRMAN BANERJEE: I remember some very hokey velocity measurements for sections that in the past -

MEMBER CORRADINI: That's not judgmental, is it?

CHAIRMAN BANERJEE: That's not judgmental, no. I assure you it would be hokey under any judgment. So I'm sort of concerned about this personally, but I don't want to hold up the discussion because of this, what the prototypicality of this might be compared to -

MR. SMITH: I will say that the vendor attempts to put some conservatism into the - into their comparison between the two. And I think that we have questions. John might be better to -

MR. LEHNING: This is John Lehning from the staff. It is something that we are aware of and we are looking at carefully, and we've discussed this particular aspect with the vendor in several phone calls and made clear the idea that there needs to be some conservatism not only from velocity but from turbulence and other things like that.

CHAIRMAN BANERJEE: Okay.

MEMBER CORRADINI: So, I'm sorry, what is conservative relative to turbulence? How do I know it's conservative relative to the turbulence?

MR. LEHNING: This is John Lehning again from the staff. We would use the CFD calculation prediction of turbulence, and use that as a basis in a test to compare that.

CHAIRMAN BANERJEE: But you wouldn't -

sorry, I didn't mean to interrupt you.

MEMBER CORRADINI: No, no, go ahead. You are going to tell me the answer, so I just want to get the answer.

CHAIRMAN BANERJEE: Yes, I'm just wondering, I mean the CFD might not be very accurate prediction. So clearly to be conservative you'd probably want to enhance the turbulence in some way if that's possible.

MEMBER CORRADINI: Okay, that's what I thought.

CHAIRMAN BANERJEE: Is that what you mean by being conservative with regard to the turbulence, to assure more suspension?

MR. LEHNING: That's the idea. I think that the way the CFD calculations are typically done, they try to maximize those quantities and flow rates. So our thought would be, because these CFDs are used for transport overall not just for this that the turbulence ought to be conservative in that CFD, and then this test ought not to have less turbulence than the CFD would predict.

CHAIRMAN BANERJEE: Yes, the whole issue in this is of course what happens when the bottom resuspends materials, the sheer stresses and the fluctuations. So in some sense it was stirred up now and then, it would make me feel a lot more comfortable than letting it settle out over this distance.

MR. SMITH: One thing that we did with this test is, in discussing with how this test was run, we were very specific with how the debris needs to be prepared. We made the fine debris. We requested that the fine debris be introduced first so that it would not get hung up - like if larger debris had settled to the bottom it would not get hung up on that; it would have a better chance of transporting.

So we tried to add as many conservatisms to the test method as we could.

CHAIRMAN BANERJEE: So this test requires this settling in order to get an acceptable head loss?

MR. SMITH: I won't say that. I will say that this test uses settling to determine whether an acceptable head loss occurs or not. I'm not sure if they stirred everything up maybe it would still pass. Depending on the plant; I don't know.

MEMBER ABDEL-KHALIK: Now they try to match the velocities that they calculates with the CFD code. What is the characteristic dimension for this process?

MR. LEHNING: The way that they do that for plants, they try to look at several what they consider representative flow streams. So it is not necessarily reproducing the exact geometry there, but intending to look at directions where the debris may be approaching, and then trying to take an average value biased in a conservative way from their standpoint by weighting the higher flow velocity channels.

MEMBER ABDEL-KHALIK: But there has to be a length scale that determines this process, that governs this process. And how do you match that?

CHAIRMAN BANERJEE: There has to be a Reynolds number.

MR. LEHNING: I think that - I can't answer - I don't know exactly. Maybe they have a vendor representative that can talk about that. But I just know that the way they do it is by matching velocity rather than a length scale, and then by using the velocity and turbulence as a basis to say the transport is going to behave in about the same way as in the plant.

DR. WALLIS: So what is the Reynolds number in a test like this in various places?

MR. SMITH: We haven't calculated it.

DR. WALLIS: I mean you've got very low velocities.

CHAIRMAN BANERJEE: Very large length scales.

DR. WALLIS: So it's a much lower Reynolds number than in the plant because of the length scale. Does this really have a big effect on the flow pattern? These are questions you must have been asking, I'm sure.

CHAIRMAN BANERJEE: The concern is that too much stuff might settle out, really; that's the bottom line. Because in a plant you've got all sorts of vertical structures which re-entrain stuff, you know, going around bends, and this, that and the other,

CFD is very very unreliable, because probably they are using epsilon models which don't sustain the Reynolds, which give rise to secondary flows. So there is a whole bunch of stuff which brings this under suspicion. And the concern you are hearing, I think, is exactly that, that you know you migh8t be overestimating these types of settlings.

You may not; I mean it's hard to know. Because the vortices also trap these particulates, you know, you see them -

MEMBER CORRADINI: So let me ask you an empirical question. Let's say I didn't believe the computational quality, but I do two different scales, one larger and smaller scale, with the velocity scaling to show that you've got the same settling.

In other words, throw out the models. Let's take a protocol methodology that says, I've got scale one and I've got scale two. I match velocities. And I see they are based on matching velocities; the same drop out. Or they are not the same drop out. Some sort of empirical verification that things look reasonable. That is kind of what I think we are all going at.

CHAIRMAN BANERJEE: But even that is one dimensional.

MEMBER CORRADINI: But still at least you have an empirical observation that your thinking process empirically is holding water, so to speak.

MR. SMITH: I am not aware of any testing like that. The only thing that could be similar to that is, there has been testing done with various types of debris alone to determine at what velocity that would generally settle out at. Like it's been done with Nucon tread, various sizes, you know, RMI, particulates, things like that.

MR. LEHNING: Just to add on to that, there have been flume tests that have been conducted, and there have also been what is called integrated transport tests that were done on scale tanks that were intended to represent a containment.

But I don't know that it looked at length scales and Reynolds numbers to the extent that we are going into now.

MEMBER CORRADINI: But I think Sanjay, the chairman, said it right: the only reason we are fussing about this is, we want to make sure you don't get preferentially settling out because you reduce scale but rather, you are trying to preserve something so as you feel comfortable, you feel comfortable because you have it scaled right; that's all.

CHAIRMAN BANERJEE: Yes, we had no problems with your previous tests, because obviously you are suspending most of the stuff. Here there is a question of how much is dropping out.

MR. SMITH: I can tell you that - I don't think this will answer all your questions. But tests that have been run in this flume have ended up with extremely high head losses that have required the licensees to go back and reduce their debris loads. So debris is transporting, and it's getting on the strainer, and it's resulting in very high head losses in some cases.

CHAIRMAN BANERJEE: Okay, I think we should move on. You've heard what our concerns are.

DR. KRESS: When they go back and reassess their debris loads, are they looking at the zone of influence?

MR. SMITH: Yes. They may remove debris from within the zone of influence. Some licensees are installing debris interceptors instead of doing that, because they think that is a more economical solution. So various things are done.

But yes, they look at the zone of influence.

DR. KRESS: And they have to decide where the largest break LOCA is going to occur to do that?

MR. SMITH: What they would have to do is, they would have to remove from every potential zone of influence. So basically everything close in, you know, into the reactors or steam generators, would have to be moved.

DR. WALLIS: Can I go back to what you just said? You said they got very high head losses if all the debris went to the screen? So even with these enormous screens which are 100 times as big as before, if you put all the debris uniformly on the screen they get head losses that are too high?

MR. SMITH: Yes, that's correct.

DR. WALLIS: So they have to work then on depositing the debris somewhere else, or not having so much debris, or taking out insulation, or something?

MR. SMITH: That is right. Now I'm not saying that their screens won't work now -

DR. WALLIS: But if you make the worst possible assumptions.

MR. SMITH: Under the worst possible assumptions, they need to - right.

All right, this is a picture of what we would consider to be a nonprototypical debris addition. And what you see here is, this is finely prepared fiber, but it is very concentrated in the bucket, so it's agglomerated. And the potential is that it could fall down into the bottom of the flume and not transport to the strainer.

So that's the concern we had with this.

DR. WALLIS: Well, using the bucket at all is not so good. Because if you put in a large chunk of stuff then the whole plume goes down. I mean a plume from a bucket will tend to sink, because the weight of each one of these things adds weight to the plume. It's not the same as distributing it uniformly.

MR. SMITH: What we've seen is, you can use a bucket. For example the film we saw had that one in. As long as the debris is not - as long as the debris is not overly concentrated. As long as the debris is almost flowing like water; that's what we consider to be a more prototypical addition.

DR. WALLIS: Even then if you flow that in from a bucket you get then a jet from a bucket which is heavier than the surroundings; it sinks.

MR. SMITH: That's true. The momentum of the water is going to carry it to the bottom, yes.

But I think that even under those conditions, like where we saw it going from the bucket in the film, that it's a relatively prototypical -

DR. WALLIS: So pouring rapidly from the bucket is different from pouring slowly from the bucket?

MR. SMITH: That causes more turbulence. I don't know if that's good or bad.

DR. WALLIS: Are they instructed to pour slowly or what?

CHAIRMAN BANERJEE: Slowly causes less turbulence, but who knows. But you have asked the vendor to change the introduction, right?

MR. SMITH: Right, what we requested this vendor to do was to really test the concentration of debris, a lot more water with it, mix it up prior to putting it into the flume.

CHAIRMAN BANERJEE: You reduce the density so you try to reduce the settling?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: But in general introducing it as a plume is not a great idea, because that is not a very prototypical way of introducing the debris, and the plume itself has a density of its own that drives it down.

MR. SMITH: That's correct.

Okay, and conclusions, we think that these trainer testing methods have improved, and up to this point some licensees have demonstrated acceptable strainer performance as shown by conservative testing as we have talked about.

Some licensees have learned that their strainers won't survive these conservative tests that we are doing, and they are working to reduce their debris loads in the plant.

And some licensees are going to attempt to stand on the current test results by responding to questions that we've asked review of their submittals, and we are just going to have to take their responses on a case-by-case basis, and determine if we think the answers are acceptable.

CHAIRMAN BANERJEE: Now let me ask a question regarding the chemical effects. If let's say there are no chemical effects, and these tests were done, would they still get unacceptable head losses with these high debris loads?

MR. SMITH: I have observed tests without chemical effects that ended up with very high head losses.

CHAIRMAN BANERJEE: So it didn't require the chemical effects to do that?

MR. SMITH: Yes. But one thing is that I think, just from observing a number of tests, the chemical tests work similarly to the worst particulates, like CalSil or Microtherm or something like that. So once you get the bed formed in a certain way; you get all the little spaces filled up; I don't know the chemical effects would have a huge effect on that bed. It might not create a much higher head loss.

DR. WALLIS: Well, some of the chemical effects tests that have been reported by new research sponsored by NRC seemed to show the bed essentially being completely blocked, and the head loss rate went up by a factor of 100, and the flow rate went down by a factor of 10; essentially the thing is being -

MR. SMITH: Yes, I haven't seen one that caused the flow rate to go down on one of these complex strainers. In the vertical loops I think there is a lot -

DR. WALLIS: Because it's uniformly distributed?

MR. SMITH: Yes, it's a lot more uniform, so you get a lot higher head loss.

CHAIRMAN BANERJEE: Thank you very much. That was very information. Good progress has been made since our last meeting.

So is it now Paul? Go ahead.

TEST RESULTS - REVISION OF WCAP-16793

MR. KLEIN: Good morning. I'm going to get started on an update on the chemical effects.

I'd like to acknowledge the contributions of my co-reviewer in the area, Matt Yoder; and also the work that was done to support this presentation by the people at ANL. Next slide please.

Today I'd like to break this presentation into two major pieces. The first half discusses industry's integrated head loss testing including chemical effects, and we will talk a little bit about some of the industry test approaches, and also our assessment of the different approaches, and some of the technical issues that have been identified over time.

And the second half will focus on some technical support that we have received from ANL, and most of that testing was done in the 2007 and 2008 timeframe, so this is new information to the subcommittee.

CHAIRMAN BANERJEE: Is this all vertical, or did you do some horizontal as well?

MR. KLEIN: This was all vertical head loss testing, and then a series of bench tests as well.

And then we will summarize the current status at the end. Next slide.

Just a very quick progression of chemical effects. Initially the IST series identified the chemical precipitates could form in representative environments, but those tests were not - did not have an objective of measuring head loss.

So once we saw that precipitates could form in some of the environments, we needed to move into the head loss area. The initial tests that were done by ANL and also some of the industry vendors tended to be the vertical loop head loss tests.

And the early test results indicated you could get very high head losses when you apply chemical precipitate on top of a fiber bed.

Since that time the industry approach to chemical effect testing has been quite varied. I think Steve in his earlier talk had shown a slide of the main test vendors, and there is also two other vendors that have done tests for single licensees.

So today I'd like to walk through the industry test protocols. I've grouped them into five main approaches that we will discuss in the next five slides.

CHAIRMAN BANERJEE: How many - I know that CCI is in Switzerland. Are the AREVA tests done in this country?

MR. KLEIN: Yes, the AREVA PCI tests are done in Massachusetts in Alden Laboratories.

CHAIRMAN BANERJEE: And ACL I guess is in -

MR. KLEIN: ACL is done at Chalk River.

CHAIRMAN BANERJEE: Okay.

MR. KLEIN: CCI is done in Switzerland. The GEH tests have been done in New Jersey at a subcontractor.

CHAIRMAN BANERJEE: And roughly how many tests are done, I mean typically. Just to give us an idea in each of these vendors.

MR. KLEIN: How many tests?

CHAIRMAN BANERJEE: Well let's say ACL, how many systems?

MR. KLEIN: I think like ACL has done the Dominion plants, and I think one other plant.

CHAIRMAN BANERJEE: So that's roughly how many?

MR. KLEIN: It's pretty well distributed among those top five.

CHAIRMAN BANERJEE: Fairly uniformly?

MR. KLEIN: Yes.

CHAIRMAN BANERJEE: That's what I was looking for. And what about Wylie and Fauske? Are they just one test each?

MR. KLEIN: Yes, they are for one licensee. Wylie covered I think two plants, and the Fauske covered one plant.

CHAIRMAN BANERJEE: These were completely independent tests in some sense?

MR. KLEIN: Yes, there is a lot of similarity in for example the Fauske test was a flume test with WCAP precipitate added, so it was similar to what we've seen approach in some of these other ones, and we'll try to get to that in the next few slides here.

CHAIRMAN BANERJEE: Let's go on.

MR. KLEIN: Typically the way testing is performed is it I think as Steve showed, a nonchemical debris addition is done until a baseline debris bed is established, and then chemicals are either added directly or precipitate is added to try and account for the chemical effects.

So test method one is the - uses the WCAP 16530 methodology, and in this case the surrogate precipitate is prepared outside the test loop.

In this method one the objective is to transport all debris including precipitate to the test strainer. There is a list of the vendors that use that approach.

As Steve mentioned, a lot of times there will be agitation either mechanically or by flow, or even people go disturb the flume bed during the course of the test to make sure stuff is transported to the debris bed.

CHAIRMAN BANERJEE: You mentioned earlier, excuse me, the vertical test loops were to small scale with the little disk. Now you are talking about strainers. Now I would think you would have to do both, because the worst case presumably is completely uniform distribution, which is possible in a vertical strainer if you have good enough mixing presumably.

So if you are taking credit for vertical being different from horizontal, you've got to have some way of modeling the stratification and settling it seems to me; otherwise they should be the same.

MR. KLEIN: I think I am going to try to shift some of the data from the vertical head loss test, with the vertical head loss loop tests you have no settlement. You typically get all the precipitate that layers on top of the fibrous debris bed and saturates the bed. And I think that's why you can see much higher head loss response in those tests compared to tests where you have a much larger strainer segment, and the debris is dispersed, and the debris bed typically is somewhat different than -

CHAIRMAN BANERJEE: It says, sticking at the bottom and the top.

MR. KLEIN: You might have a nonuniform flow such that you have quite a variance in debris beds.

CHAIRMAN BANERJEE: But also within the pocket itself, there is some, even if the external turbulence is high within the pocket.

DR. WALLIS: If it has pockets. If it's just a vertical stream -

CHAIRMAN BANERJEE: Then what you are saying is -

DR. WALLIS: But it gets us back to the question we keep coming back to, which is the flow distribution in the real plant, and how uniform is the deposit on the screen in the real plant with the typical mixing that will occur in the real plant.

CHAIRMAN BANERJEE: Well, if you suspend all the debris -

DR. WALLIS: Which is the same as horizontal, shouldn't it?

CHAIRMAN BANERJEE: Well, within the pocket itself it may not be.

DR. WALLIS: If it's a pocket strainer.

CHAIRMAN BANERJEE: If it's a pocket strainer, yes. So I think those tests that you showed of the pocket strainers seemed -

MR. KLEIN: All the strainers are relatively complex shape. I mean they all have shelfs or whatever you want to call on them. Some of them are -

CHAIRMAN BANERJEE: If they are just vertical screens, I think what Graham is saying is right; it may not matter that much.

DR. WALLIS: So you throw out all the

results of the vertical head loss experiments?

MR. KLEIN: I think we use those to inform the results of the other testing. And the other testing, we make that as conservative - like we discussed before, we make that as conservative as we can.

DR. WALLIS: Does it ever approach the vertical head loss loop results there?

MR. KLEIN: I haven't compared it.

I think, well, we have seen some very high head losses in the larger scale tests, but typically no. Typically chemical effects do not drive head loss nearly as much as in the vertical head loss loop.

MEMBER SHACK: You clearly don't want to design a strainer with horizontal surfaces.

DR. WALLIS: So you've got to understand, why the difference, and why that difference would not occur in a plant - why the difference would occur, why the plant would not be like the vertical test. You have to sort of assure yourself, get a reasonable assurance the plant is not going to behave like the vertical test loops.

MR. KLEIN: Yes, and I think one thing to keep in mind, too, we always make the assumption that you get tons of chemical precipitate that form, and in reality in the plant that probably will not occur, because we are not crediting any type of solubility, and in fact, in some of these cases for the plants, you won't have the chemical precipitate to deal with, even though it's predicted by the WCAP model and you run a test and you measure head loss with that. So I think it's important to keep that in mind.

For example during the ICET tests the aluminum base precipitates really only showed up after the solution was cold from the test temperature, and we didn't see a whole lot of activity with the aluminum hydroxides at the 140 degrees.

DR. WALLIS: Well, that would be true equally well in the vertical test loop.

MR. LEHNING: This is John Lehning from the staff. I think that the real reason to have confidence in these differences between the vertical loop and these other prototypical strainers if the module testing that is done is just the full body of testing that we've seen between these vertical loop. And we've seen - or there have been conducted hundreds of tests in this other geometry, and we have seen these in basically all of these different tests, and we know that the module array testing in the big tank is designed to be, and is more prototypical of what's in the plant, and that has to do with nonuniformities in the flow and using the actual geometries of the strainers, and so that gives us that confidence.

CHAIRMAN BANERJEE: Well, I guess what Graham is really saying, and maybe this is the issue, that whatever you are doing, there should be a rationale for accepting certain results and not; and they should be clearly stated.

I'm sure that there are very strong effects of a horizontal system compared to a vertical system, but it should be clarified as to why you sort of think that one is more prototypical than the other.

MR. KLEIN: I think when we get to the completion of this we will have a very well documented basis for why we think chemical effects have been handled conservatively in these tests.

CHAIRMAN BANERJEE: Okay, let's move on.

MR. KLEIN: Okay, second slide.

The second test method is similar to the first in that the WCAP surrogate precipitate is generated outside the loop and added. The main difference here is that the settlement is permitted, so the technical issues become somewhat different here, and of course some of the key things involved, understanding that you have concerted flume flow characteristics, and that your settlement in you8r precipitate is not occurring in a way that would be unprototypical of the plant. So I think what we've seen for the most part, we have a very stringent criteria on precipitate settling, in any type test where settling is permitted. So I think you saw from some of the video as well that there was almost not initial settlement of precipitate solution when it's added.

MEMBER ABDEL-KHALIK: I'd like to go back to the issue that was raised earlier. On this slide what would you consider to be conservative flow characteristics for a flume?

MR. KLEIN: I think I will defer to John Lehning on that question?

MR. LEHNING: I probably am going to - this is John Lehning from the staff - I'll probably repeat myself. But we would look at the computation fluid dynamics calculation that had been done and assure ourselves that the velocity and turbulence and flow characteristics are conservative with respect to that CFD calculation for the purpose of transporting debris.

MEMBER ABDEL-KHALIK: What specific parameters do you compare that would tell you that this is conservative vis-a-vis something else?

MR. LEHNING: The main things are velocity and turbulence.

MEMBER SHACK: How much do they actually try to predict in this calculation? Are they taking credit for trapping settlement all through the containment? Or do they take all the load up to 30 feet from the sump screen, and you've got full debris there, and then they account only for the settling in that well defined and well characterized geometry?

MR. LEHNING: There are two parts to that. They do credit settlement in other areas of the containment in their normal debris transport calculation based on the CFD or whatever methodology they're using; then they have that loading, and they say we are going to add this to the test flume, and then based on the CFD flows, whatever settles out there in that region is also credited via the head loss measurement.

CHAIRMAN BANERJEE: So I think you have our concerns, John, about this.

With regard to the big stuff falling out, no issue with that. It's really the fine material, and to have that settle out due to a CFD calculation, there is so little really understood about this, even hindered settling and suspensions is very poorly understood.

And it seems that what you are hearing from us is it might be more conservative just to allow all the fine stuff to go to the screen than to have it settle out. That is for what it's worth.

MR. KLEIN: I think in general the fine stuff does transport. From what we've seen when it gets put in it's going down the flume, and it does get to the strainer, and that is the reason why we set certain parameters for the debris addition order, so the fine stuff will go in first, so that it wouldn't get hung up on larger debris that was already settled in the plume.

MR. LEHNING: So I think we understand that concern. That is something we are looking at carefully, and we appreciate that comment.

MR. KLEIN: I think too it's not necessarily a less conservative test if you end up with a thin bed of fine fiber that is transported to the strainer and then a chemical load on top of that. There have been several licensees that had high head loss with that test protocol. Next slide, please.

The third test method is somewhat different in that the debris bed is generated in a similar way but the precipitate is formed in the loop. This is the CCI-type approach. Instead of preparing a WCAP surrogate outside the loop and then adding that you add chemicals to the loop that cause the precipitation process, and then that is - you saw in the video that is transported to the strainer.

DR. WALLIS: When you have these chemical effects in the loop, or in the sump, is gas involved?

MR. KLEIN: Not that I'm aware of.

DR. WALLIS: In the aluminum reactions, isn't gas evolved?

MEMBER SHACK: Not in these particular ones that you are using for these particular reactions. If you are actually corroding aluminum, you are generating hydrogen.

DR. WALLIS: Sodium hydroxide, you presumably make gas.

MR. KLEIN: I think in these cases you are adding the aluminum as dissolved species with sodium aluminate, sodium silicate, and calcium chloride.

DR. WALLIS: You don't make bubbles when you have the chemical reactions?

MR. KLEIN: I don't think so.

DR. WALLIS: Never? Because bubbles will change things. They will make the particulate buoyant and have other effects.

MR. KLEIN: The transport of the chemical species to the strainer typically hasn't been a problem in the tests. There doesn't seem to be widespread settling of chemical precipitates in these tests, and if there is they - our expectation is unless they are trying to credit settling, they would get that precipitate to the strainer anyway.

CHAIRMAN BANERJEE: This concern about bubbles has been raised before. The issue really is, I agree that the chemical precipitates are not going to be affected much. Are there other debris which could be like flakes and things which settle - might settle out but do not due to that? Has there been any assessment of that?

MR. KLEIN: Well, with respect to bubble formation from aluminum corrosion, keep in mind that most of the aluminum is above the flooded area in containment. So your greater contribution is from what's in the atmosphere, being wetted by sprays.

CHAIRMAN BANERJEE: All right, let me just understand the timing situation. We want to also do the chemical effects PIRT as part of this presentation. So you've got quite a lot to get through.

MR. KLEIN: Twenty three slides to go.

CHAIRMAN BANERJEE: Yes, and we've got only about half an hour. All right.

MR. KLEIN: I will try to move more quickly through the remaining slides here.

One of the issues that came up with injecting chemicals of course is the way in which you add them can affect the precipitate characteristics. So one of the things we have been working with individual licensees with this particular technique is trying to get them to demonstrate that their test produced precipitate that was expected by the bench testing that supported the larger scale tests.

So we are evaluating this particular method on a case-by-case basis. Next slide.

The fourth test method you develop the chemical environment over a longer term. It's typically done by adding dissolved aluminum over time to try to match the plant specific projections for aluminum dissolution over time. This is done by a couple of different vendors as you see there.

Some of the issues: there was an issue with one of these vendors with transport of nonchemical debris to the strainer, which I'm not going to elaborate on since it is not related to chemical effects.

The other question that comes into play here is how well your debris bed filters the chemicals. And also for this type of approach where you are evolving the chemistry over time, the expectation from the staff is that you have a very solid technical basis to support your plant specific additions.

And in both of these approaches the affected licensees did a number of smaller scale tests to assess the corrosion rate of aluminum and develop their own projections for aluminum over time that was separate from the WCAP approach.

And this again is a -

CHAIRMAN BANERJEE: And the staff looked at this carefully?

MR. KLEIN: Yes, we have received reports from each of the test vendors, or each licensee, I should say, that provided the results of their tests. And then we had a series of discussions with each of them.

We are reviewing these on a case-by-case basis. The goal here is to make sure a licensee has demonstrated why their overall tests produces a conservative evaluation foe chemical effects.

Test method five is similar to a mini-ICET type test, the environments develop by leaching debris, either metallic corrosion or leaching from nonmetallic insulation materials over time.

Several issues related to this approach had to do with primarily debris bed formation. The objective fo the test was to develop a chemical effects bump up factor for this given test that could be applied to a previous array test in a tank that did not include chemical effects.

Overall the summary is that based on the number of issues that were involved, we indicated that - we've reached the conclusion that an alternate approach is needed in this case, so we've contacted the affected licensees, and we are expecting to hear back from them in October what the alternate approach may be. Next slide.

DR. WALLIS: What is the hope that the alternative approach will be okay? Are there some indications that there is one?

MR. KLEIN: It's more than a hope. We think that there has been enough information generated through the course of chemical effects testing, and there is review guidance available, that there will be a success path developed by that particular set of licensees.

Next slide. I'm sorry, current slide. You are given the varied industry approaches to chemical effects testing, and pretty much the dynamic nature of how these test protocols have evolved over time, and or tried to get some technical support in the chemical effects area.

And in particular we established contracts with environmental management support to contact Dr. Bob Whitman, and also with ANL. Dr. Whitman has been helping us with his chemistry expertise and also in helping to review some of the GL supplements that have been received by the licensees.

ANL's support has been more related to testing. They also supported the chemical effects review guidance that was developed.

In particular some of the things that we asked them to do given the number of different ways that precipitates are formed in the industry, approaches, we asked them to try and do some type of relative assessment in the vertical loop head loss test.

We also asked them to evaluate long term solubility of aluminum, in the relevant environments, including the potential for precipitation possibly occurring by rapid thermal cycling.

And we also asked them to evaluate the stability of the WCAP surrogate as a function of pH, since we noticed that in some of the industry flume tests even though it would start with a more neutral pH dissolution of CalSil or other insulation debris could cause the pH to drift more alkaline over time. So we wanted to make sure that we weren't adding what we thought was a very conservative surrogate, and then over time having it dissolve in higher pH.

DR. WALLIS: Weren't there some French tests in which the fiber glass dissolved significantly? I think I read about something there, they weighed the fiber glass before and after, and quite a bit of it had dissolved.

MR. KLEIN: I think you will see some dissolution of fiber glass, particularly in the higher pHs, like if you have a sodium hydroxide type buffer.

DR. WALLIS: That doesn't lead to precipitation?

MR. KLEIN: It can add to your chemical load; that's one of the things that needs to be accounted for when they look at how much precipitate is predicted on a plant specific basis. The spreadsheet looks at your pH and then looks at how those different materials performed in the very smaller scale tests that Westinghouse performed.

DR. WALLIS: But did you look at this other data from overseas?

MR. KLEIN: No, I don't believe so.

DR. WALLIS: I was surprised. It was one of the surprising results of the French tests seemed to be -

MEMBER SHACK: Actually one of the surprises of the integrated test is that the corrosion is less because the aluminum in the fiber glass - you get more fiber glass corrosion if there is no aluminum around. But when you have the aluminum it suppresses the fiber, so typically the industry calculations of chemical loads are conservative, because they don't take account of those kind of inhibiting effects.

MR. KLEIN: That's a good point, Bill. I think what we saw in the ICET series was almost a competition between aluminum and leaching from fiber glass. And if you got substantial amounts of aluminum from higher pHs it tended to form a coating on the fiber glass and slow down the dissolution process substantially so the amount of silica that leaches for example was much less than predicted.

DR. WALLIS: But then there were some

plants with no aluminum to inhibit this -

MR. KLEIN: We think overall if you look at the WCAP methodology and the single effects tests that they did, when you add that as a whole you have a very conservative predicted chemical load. And that has been confirmed by some of these test methods where instead of adding a predictive WCAP amount they put this material into elevated temperature, elevated pH environments for 30 days, and the amount of precipitate that formed was much much less than was predicted by the WCAP methodology.

Next slide, I believe. I just wanted to point out the work that ANL has done has been published within three different technical letter reports, and those are all publicly available; the session numbers are shown in this slide. Next slide.

I wanted to show just some samples of some of the vertical loop head loss tests with ANL. What this particular slide shows is the WCAP aluminum oxyhydroxide pressure drop as a function of time on the top; and then on the bottom is the WCAP sodium aluminum silicate. The top slide was generated in high purity water; the bottom slide is in tap water. And I think the main takeaway is within the test conditions of the ANL vertical loop a very little amount of aluminum transformed into a precipitate causes a very high head loss. Next slide.

I wanted to discuss the tests that were done, instead of adding dissolved aluminum with aluminum coupons because we wanted to try and benchmark that as well. So we had two different aluminum alloys that were used in these tests, the 6061 on the left, and the 1100 series on the right.

These are low magnification scale electronic microscope images, with back scatter electron techniques, so that the lighter areas that are shown there are trying to highlight some of the inner metallic particles that are within the alloy matrix. And we will discuss their contribution to head loss here in another slide or two.

The right picture here just shows how these coupons were inserted into the loop. You can see they were stacked vertically. At the top of the aluminum stack, there is some fiber glass, because we wanted to see potential interactions between dissolved aluminum and fiber glass over time. Because we think what happens in containment - or I shouldn't say what happens in containment - but what can happen in testing when you have dissolved aluminum, it doesn't all necessarily precipitate out on your fiber that is on the strainer; it can precipitate out on other areas as well, fiber that is in the flume, particulate that is in the flume. Next slide.

This shows the head loss results from the 6061 test, and you can see that over time - we put these in at 140 degrees, and I think the pH was about 9.3, to try to get accelerate aluminum corrosion. We measured that over time, and at different points in time the aluminum plates would be taken out or put back in, and then the temperature would be dropped to try and cause the aluminum precipitation.

And I think what we are trying to show here is that again it looks like about six or seven ppm of aluminum causes substantial head loss. But the one thing that we noticed in these tests that we didn't see in our earlier tests with the dissolved aluminum is that the fiber bed here shown on the right looked quite different. Typically I think we have shown you fiber beds that had a white precipitate on top. In this case the inner metallic particles that came out of the coupons caused a grayish color on the bed that was not observed before.

So those particles did have - they played a role in the head loss in two ways: they acted as an additional source of particulate; and we also think that they acted as a nucleation site for precipitation of aluminum hydroxide.

DR. WALLIS: What's that, the increase and pressure drop when you take out the plates at about 240 hours?

MR. KLEIN: At 240 hours you have already started the -

DR. WALLIS: It seems to be leveling off and then it gets another kick.

MR. KLEIN: I think it's the temperature drop.

DR. WALLIS: Oh, it was a temperature drop. Oh it was a temperature drop? Okay, thank you.

MR. KLEIN: Next slide.

CHAIRMAN BANERJEE: So what's the bottom line here?

MR. KLEIN: I think the bottom line we are trying to show on this slide here, which is, we tried to look for these different type of precipitates, or with just the aluminum corrosion by itself, the relative efficiency and increase in head loss. And I think what we are seeing is that the WCAP surrogate continues to be a very efficient product in driving head loss, and that it seems that some of the other industry approaches as well are reasonable or may be conservative compared to putting aluminum in solution and corroding that material and then causing a precipitate to form as you drop temperature.

That last bullet, WCAP sodium aluminum silicate in high purity water, really is not relevant to the industry test since they don't test in high purity water. Next slide.

DR. WALLIS: Well, this inner metallic thing indicates that you have got to be careful. I think every time you do a test you find something new. You think you've got aluminum, and you find it isn't quite totally aluminum, so there is another effect.

MR. KLEIN: So our goal is to always find something new.

DR. WALLIS: Yes, that's right. So don't let ANL do too many tests. They are going to find something every time.

MR. KLEIN: I'm going to talk in the next couple of slides about some of the solubility tests, and then how we factored in that aluminum two-pronged test to some of the solubility curves that we've drawn.

The goal in these tests was to do two things: it was to study the solubility. There already has been a fair amount of testing that was done by ANL and others in this area. But the one twist that we wanted to put on top of that was to cycle the temperature, so you can see on this plot on the right, which is just showing a typical temperature profile for one of these tests, we tried to go from the very initial high temperatures to almost room temperature over the course of a 30-day test, which is representative of typical ECCS mission time.

What we did in addition was, at various points along the way, tried to put a more rapid cooling cycle on to try to simulate fluid passing through a heat exchanger. Then we heated it back up to simulate it going through either the core or out into the break to the higher temperature fluid.

I think the bottom line here is that for the cycling that we did, although we know that temperature can cause precipitation, in these tests we saw that a rapid cooling did not cause a widespread precipitation event, because our concern was that with all the solubility data that has been generated, a lot of it is done with either control temperature changes or single temperatures. And so wanted to make sure we weren't missing something.

MEMBER ABDEL-KHALIK: what's a typical transit time of a coolant through a heat exchanger?

MR. KLEIN: It's relatively short order. I don't know, Steve or John want to jump in here?

MR. SMITH: I don't know what it is.

MEMBER ABDEL-KHALIK: So why would 30 minutes be appropriate?

MR. KLEIN: Oh, the 30 minutes included a 10-minute cool down, and a 20 minute heat up. The 10 minute is probably longer than you would have for a transit, but one of the reasons we think it's a conservative test is that there is also an aging process that occurs, so a more rapid cool down was very difficult to obtain experimentally, and then heating it back up without changing the whole test.

Our belief is there will not be a massive precipitation caused by a very short term cool down followed by an immediate heat up. We think if a precipitation event would have occurred, the delta T that was incurred by these tests followed by the amount of time where that solution was cold would have produced an event.

DR. WALLIS: I'm just trying to understand what you're saying.

CHAIRMAN BANERJEE: I guess your question is aimed at what happens between the heat exchanger and the core.

DR. WALLIS: I am trying to understand this. You showed here that you can cool over a period of 30 minutes and nothing happens.

MR. KLEIN: It's cooled over a period of typically about 10 minutes, and then heated back up.

DR. WALLIS: But when you do a test in a loop, if you cool the water the pressure drop goes up almost immediately

MEMBER SHACK: All this is true for a range of pHs and concentrations. We wouldn't guarantee this is necessarily true for all pHs and all concentrations.

DR. WALLIS: Is this why we have this sort of scatter plot in the next slide?

MEMBER SHACK: That's why you have the scatter plot in the next slide.

DR. WALLIS: Well, that's one of the things. When you see all this stuff, you say, well, it's very complicated isn't it. What are you going to do?

MR. KLEIN: I think the important thing to keep in mind is, this is interesting in an academic sense, and it could be important to a plant, but keep in mind that in the industry test protocols they are assuming precipitation occurs for the most part. They are adding the precipitate either as a premixed precipitate, or generating it inside the loop.

DR. WALLIS: I have no way of understanding if it's interesting or not academically. I know it may be interesting practically. So what are you going to do about this? Are you going to provide some conservative method or something?

MR. KLEIN: Well, I think the goal fo the solubility tests were to provide us a tool to help assess individual plant-specific analyses, so if a plant comes in and they say they have added WCAP surrogate to the full projected amount, or they have generated it inside a loop, we would accept that as conservative.

If a plant comes in and says, we don't think we'll form any precipitate, and here's why; we believe this will provide us the information we need to do an independent check on that, and if we aren't convinced then we would ask a series of questions that would ask the licensee to demonstrate why that's the case.

CHAIRMAN BANERJEE: I guess there is another implication of this that goes back to Said's question, that when you have it passing through the heat exchangers and then getting to the core inlet, whether there would be dissolved aluminum that could precipitate out due to that cool down. And that what you are really saying is the period is too short, right?

MR. KLEIN: Yes, we think the period is too short, and if you are concerned about the in-vessel chemical effects, the assumption is that all species are available; that nothing gets trapped at the strainer, so the full chemical load passes to the reactor vessel and then is available to play it out in there.

CHAIRMAN BANERJEE: But due to the cool down there isn't a precipitate formed after the heat exchange?

MR. KLEIN: That is not the experience with these tests.

CHAIRMAN BANERJEE: But that's what you are saying. Okay, let's move on.

MR. KLEIN: Okay, let's move on. Next slide. I'll cover this very quickly. I just briefly wanted to show some effects of pH at the top, and aluminum concentration at the bottom. And maybe the take away is that these things are important; that higher pH tends to favor dissolution of aluminum. And obviously as you go to lower concentrations of aluminum, that also favors dissolution compared to a precipitate.

Next slide. We've taken the body of information that was available from ANL tests, some of the industry talk over port tests, and the ICET tests as well. ANL tried to develop for us a plot of aluminum hydroxide precipitation as a function of pH and temperature. The Y axis here is a pH plus minus the log of the molar concentration of aluminum, which is not as easy to work with as some other units. So what we tried to do is plot a couple of additional plots on here at a temperature of 140 degrees and a pH of 8 -

DR. WALLIS: So this is a test matrix plot, this isn't a data plot is it?

MR. KLEIN: This is really a data plot from a number of different tests.

DR. WALLIS: It's data?

MR. KLEIN: Yes, these are all tests that have been performed by ANL or industry.

DR. WALLIS: So this is what you got at various temperatures?

MR. KLEIN: Yes, and the key thing we are trying to show is that - I should have maybe mentioned this first - the solid symbols here represent tests where precipitate formed. The open symbols represent tests where precipitate did not form, so that the aluminum stayed in solution.

And this data ends up being very useful when you are trying to understand potential solubility of aluminum in these environments. And you can see, the other thing to point out here is that the two tests where we ran the aluminum coupons labeled here as the 6061 and the 1100 test, tended to be above those other values, and we think that was due to the potentially acting as a nucleation site for formation of aluminum hydroxide on those inner metallic particles.

CHAIRMAN BANERJEE: So the ICET tests one and five -

MR. KLEIN: The ICET tests were plotted at I believe 140 degrees at the test temperature, and we didn't see evidence of precipitation at that test temperature. We saw it upon pulling it.

CHAIRMAN BANERJEE: So the circles correspond to the experiment which is being described in the previous slides, the flask sitting on top?

MR. KLEIN: Yes, those experiments as well as some experiments done by the owners' group to support a topical report as well as some of the data taken from the ICET tests where we had long-term 30-day data if you will of dissolved aluminum at different pHs at 140 degrees.

MEMBER SHACK: Every test that we could find in borated water, which is what we are interested in.

DR. WALLIS: The lines then illustrate something drawn by you as a criterion for practical use, or just a line that looks interesting?

MR. KLEIN: Looks interesting here I think. The lines were drawn initially I think before the aluminum coupon data was added to the plot, and we are just trying to show that there might be two different ways of fitting the data, depending on the temperature.

DR. WALLIS: What are these anomalous ANL loop things on the left here? Those white ones in the middle of all the blacks?

MR. KLEIN: I think those are probably cases where we would have predicted precipitate would have formed based on the given set of test conditions but it didn't actually occur.

DR. WALLIS: So what are you going to do about that?

MR. KLEIN: That's a good things.

MEMBER SHACK: It's the black things that occur where you don't want them that you worry about.

MR. KLEIN: We would have assumed in those cases that precipitate would form.

DR. WALLIS: The two black ones up there?

MR. KLEIN: It's the two black ones that we are going to take into account as we go to the next slide, and we try to put this into a more useful form for the staff here, where we are not plotting aluminum solubility as a function of pH, and then each of those lines represents a different temperature band, and it's important to know that in this case these lines are developed bounding all that data on the previous slides including the aluminum coupons, and what we saw is, when we included that data that affected our bounding solubility by about a factor of two.

Next slide. So to try and just summarize first of all the ANL tests. They did the vertical head loss loop tests, and we think that has helped us better understand some of the relative performance of the different test methods that the industry is using. We saw from those tests that the aluminum inner metallics can influence head loss in two ways as mentioned, and also in causing about the factor of two reduction in solubility as previously mentioned.

We think the longer term solubility tests will really help us particularly if individual licensees come in and try to make a solubility argument. Most of them I believe are testing with precipitate, although some may try that, and so we wanted to try and get out in front of that if you would and have some way to independently assess their claims.

And then the last thing that I didn't really cover in detail, that I mentioned previously, that we did some tests to evaluate the WCAP aluminum oxyhydroxide surrogate at more alkaline conditions for a test duration of what we thought could cover most of the - well, probably all of the industry tests where WCAP surrogate is used. And we saw that at the highest pH that we've observed in any of those tests in the plumes, there is a little bit of an effect, although the WCAP surrogate remained stable. And it still only takes a small amount of equivalent aluminum precipitating to produce significant head loss in the ANL loop under those conditions.

So in summary we have observed tests, chemical effects tests, at each vendor facility, both the main five and the other two vendors that have done tests for a relatively few number of licensees. We think that the whole body of evidence indicates that it is clear that the vertical head loss loop tests at ANL are more susceptible to large head losses from chemical precipitates compared to the larger scale more complex strainer type tests.

Most plants at this point are using test methods that are acceptable to the staff. There are some issues that remain, and there are some licensees that will be interacting with the staff here in the near term to try and reach a test protocol that we do find acceptable.

Overall the tests have confirmed that the WCAP methodology is conservative both with respect to how the precipitate behaves and more importantly just the sheer amount of precipitate that's predicted compared to what forms under tests where they are actually modeling the containment temperature and pH and temperature profiles.

We intend to perform a few chemical effect audits to assess the overall evaluation at selected plants. Earlier the staff had performed about 10 audits or so to look across the board at all the technical areas, for the most part licensees were still in process with chemical effects. We thought it was important to go back to some of these plants and look from the beginning to the end of how they assess chemical effects to make sure we are comfortable with the overall approach.

And finally we will be working with research on some of the remaining peer review items that John is going to discuss in the next presentation.

CHAIRMAN BANERJEE: I hate to ask you this question. But when we were in Germany they showed us that any zinc that was available in the form of galvanized iron or whatever would have an effect. Do you have an zinc in the system? And is our chemistry at all similar, or is it different?

MR. KLEIN: The chemistry is different in that I believe they do not use a buffer. So in the German tests that I'm familiar with they tested with acidic pH and under that type of environment and under flow conditions simulating fluid coming from a break they did get accelerated corrosion of galvanized grating that produced a zinc oxide product that drove head loss in that case.

In our particular buffered environments we've seen very very little corrosion of zinc, both in the ICET tests and in the Westinghouse test, so we think it is a different case compared to theirs.

CHAIRMAN BANERJEE: Okay thanks.

I think that Donnie if you agree we will take a break now and just come back and finish your last presentation after the break. And then because the Westinghouse - the WCAP presentation, they are going to just continue I can see. So we will just take breaks whenever.

So let's take a 15-minute break. Try to be back by 11:00. Thanks.

(Whereupon at 10:48 a.m. the proceeding in the above-entitled matter went off the record and resumed at 11:00 a.m.)

CHAIRMAN BANERJEE: Okay, let's go back into session. Now with the last of the presentations in this set, which will be made by John Burke, I guess.

MR. BURKE: Yes, that's correct.

CHAIRMAN BANERJEE: Although I see Rob Tregoning is around somewhere.

MR. BURKE: Yes.

CHAIRMAN BANERJEE: So this will be on chemical effects PIRT update, correct?

Please try to keep it to 15 minutes. Now Graham Wallis is the chair, so this is your opportunity.

(Laughter.)

MR. BURKE: All right, good morning. I'm John Burke in the Office of Research.

What I'm going to talk about today are the most recent research efforts related to GSI-191 in the area of chemical of effects.

And this is an update. The last time we met with the subcommittee was in 2007, and what we discussed, the chemical effects peer review, and the phenomenon identification ranking table, or the PIRT exercise, which was conducted in 2006 and 2007.

Today I'm going to briefly talk about the results of the PIRT exercise, and then a scoping study that we did on 10 topics from the PIRT.

Next slide. And just refresher, we did the PIRT in 2006. The PIRT was used to identify knowledge gaps that existed at that time. The focus was on phenomena not previously addressed by NRC-sponsored research. And through that effort 41 phenomena were ranked as having potentially high significance by at least one of the PIRT's panelists. And just - it was important to bring out here that none of those issues that were identified warranted immediate action. They were all considered long term action.

And the PIRT report, or the NUREG report for that effort is in final review and should be issued by the end of the year.

And another thing I wanted to mention is, from the last briefing we made in I believe it was March or May of 2007, the conclusions haven't changed, as we have finalized the report. So that's all I'm going to talk about that PIRT report. Next.

The 41 phenomena ranked as having the highest potential impact significance on ECCS performance were reviewed by the staff. And that was a joint NRR and research working group. And that working group did that in the spring of 2007. Next slide.

And the staff reviewing those 41 issues, the staff came up with 10 topic areas that warranted additional study. A separate NUREG report is being prepared to document the review of those 10 issues. Next.

And those are the 10 issues. And we have Pacific Northwest National Lab doing that scoping study. And that is - what I thought I would talk about here are three of the more interesting findings from that scoping study. I don't have time to talk about each of the 10, but I picked three that I thought you might find interesting.

And the first one is radiation effects. And the radiation effects if the effect of the post-LOCA radiation field on the sump chemical environment and the constituents. And what I mean by that is the radiation from the fuel and the reactor vessel, or the activated species in the containment pool or on the strainer.

The study concluded that the radiation effects on the sump pool pH were minor in comparison with the effects of the pH buffering.

However, knowledge of the radiation influence on the redox potential is limited, and the PNNL recommended a mixed potential modeling to further assess it.

CHAIRMAN BANERJEE: What does that mean, mixed potential modeling?

MR. BURKE: I will have to have my answer man over there.

MR. TREGONING: This is Rob Tregoning from the staff. Essentially you are looking at all the species in containment. And each one has an associated electrical potential, and you are modeling all of those potentials, and the integrated effects from combining all of those various individual species together. So that in a nutshell is what a mixed potential model is.

CHAIRMAN BANERJEE: But you have got the individual redox potentials?

MR. TREGONING: Yes.

CHAIRMAN BANERJEE: And - then I guess there is some sort of an interaction term that has to be taken into account?

MR. TREGONING: Yes, there are many interaction terms.

CHAIRMAN BANERJEE: Many, many interaction terms.

MEMBER SHACK: Depending on how many you have patience to work through.

MR. TREGONING: Depending on how many species you have that you are trying to model.

CHAIRMAN BANERJEE: But aren't there sort of codes way to do this, or something automatically?

MR. TREGONING: Yes.

CHAIRMAN BANERJEE: It seems like sort of a standard thermodynamics problem.

DR. KRESS: Actually, Melcor has a model for this.

MEMBER SHACK: I'm not sure they have radiation influence typically though.

MR. TREGONING: I don't know if I'd characterize it as standard. It's certainly something that has been done, certainly in BWR reactor environments this type of modeling was done and used as part of the justification for developing acceptable criteria for hydrogen additions to essential impede corrosion of sensitized stainless steel.

So it has been done in the past. But I wouldn't characterize that type of modeling, especially of a complex system like the post-LOCA environment is, as being something that is standard or typical. It would be a relatively complex analysis to say the least.

MR. BURKE: Okay, the next item was the biological fouling of the ECCS sump strainer, and that could be either bacterial, algal, fungal or other biological growth during the 30-day mission time.

There are many stressors to biological growth in the post-LOCA environment such as the rapid temperature change, or the presence of borated water, or lack of light, or the high radiation field, or low levels of carbon. However there are microbes that are known to exist under one or more of these stressors, and the growth rate of any potential bacterial growth is unknown under the combined stressors for a 30-day mission time.

So again, PNNL was recommending some additional studies in this area to determine what is that growth rate, or what could grow in that combined field.

And the last one I wanted to talk about today was crud release. And that is the effect - or the potential increases in the quantity of metal oxides in the sump pool released from the fuel cladding, or a reactor vessel component during the LOCA, and then the subsequent chemical and/or radiation effects of that increase.

The crud burst during a LOCA is expected to be a - is expected to consist of relatively dense solid particulates that like I said release from the fuel cladding. The quantity is expected to be small however compared with other debris particulate such as the insulation debris or the coating debris that we talked about earlier this morning.

The additional effect of the crud release is considered to be insignificant unless the other sources of particulate are inconsequential.

DR. WALLIS: What is the size of these particulates?

MR. BURKE: The crud particulate? I don't remember.

DR. WALLIS: If they are dense and big they presumably fall out. If they are dense and minute -

MR. BURKE: It was - they did their scoping calculations based on actual measurements of crud off of fuel assemblies. I don't remember the numbers.

DR. WALLIS: But they are not minute, are they? They are fairly chunky?

MEMBER ABDEL-KHALIK: Tens of microns.

DR. WALLIS: They're not micron sized, are they?

MR. BURKE: I would expect them to mostly settle out, yes.

CHAIRMAN BANERJEE: Now there was one of these 10 areas you've shown that I think the committee at one point was interested in also because of in vessel effects; that is the retrograde solubility and solid step position. Now what's the status of our understanding on that? That also affects this downstream blockage effects.

MR. BURKE: The retrograde solubility by itself was not considered to be that significant. But then if you combine - Paul Klein talked about that a little bit the other day, the studies at ANL that show that we would not expect any chemicals to precipitate out in the heat exchangers.

CHAIRMAN BANERJEE: When you get heating in the core, I think there was concern about calcium. I don't remember which things. This is 1-1/2 years back obviously.

MR. TREGONING: This is Rob Tregoning of the staff. The retrograde solubility analysis, one of the things we were trying to look at with that was seeing if we had substantially more - and I think Paul in the previous presentation demonstrated some testing with the effects of normal solubility, the effect of additional precipitates at lower temperatures.

We certainly knew a lot of these silicates, or a lot of silicates, aluminums, calciums, can be retrograde soluble as well. So we did some thermodynamic modeling to try to see what sorts of additional quantities we could get ast these higher temperatures.

And really what we showed is that there seems to be a pretty good balance between the retrograde and the normal solubility species. So we would see some - so the total species load didn't change that much, but the form may change at the higher temperature.

So if you had a certain - let me give an example - if you had a certain number of aluminum species for instance at lower temperatures, when you went up with high temperatures associated with the core, some of that existing species may dissolve, but then others would reform such that your total solid load was about the same. That was the one thing that we demonstrated in the modeling.

Of course the biggest amount of precipitation that you saw in these models were the borated salts, the things that you would get due to again essentially evaporation of water, and then leaving borated salts behind. That was the biggest loading that you saw in any of these models. It dwarfed the other chemical effects that you saw.

CHAIRMAN BANERJEE: There is also a concern related to that which I think Tom Kress raised which if you didn't get good mixing between the core and the lower plenum that you would eventually deplete the core of boron, right?

DR. KRESS: Yes, but I think someone pointed out that they produced sodium pentaborate instead of boric acid. And that sort of took away my concern about that.

CHAIRMAN BANERJEE: Okay.

DR. WALLIS: Now Rob you said that it as you say heated up. You dissolve something and you precipitate something else, so the amount stays the same. But I thought we were concerned about deposition on the hot surface, which is very different. It's all suspended if what you say is okay, but if the surface is hot, and if the precipitation occurs in the form of something sticking to the surface, that is very different isn't it?

MR. TREGONING: That is certainly a different phenomena; that's correct.

DR. WALLIS: And I thought that that was part of our concern, that some things might flake out in the core?

MR. KLEIN: Paul Klein from NRR. Part of the industry approach accounts for plating of species in the fuel -

DR. WALLIS: Accounts for this retrograde solubility when they do that?

MR. KLEIN: Yes.

MR. TREGONING: The models that we did didn't have any way specifically to model deposition per se, but we knew that that was an issue that had been covered in the WCAP in-vessel support. And again it's something that the industry is addressing as part of their generic letter evaluations.

CHAIRMAN BANERJEE: Okay, let's move on.

MR. BURKE: All right, then concluding, the staff continues to disposition all of the phenomena identified in the PIRT exercise. And the significance of several of these phenomena is currently being assessed. Again, none of these were evaluated as warranting immediate action. The initial scoping study has been conducted, and like I said we will have two NUREG reports that will be issued by the end of the year.

Additional evaluations may be necessary to assess the remaining uncertainties. As part of the disposition the staff is also considering plant-specific post-LOCA environments. Results from additional vendor testing conducted since the scoping study like an example of that would be the reports Paul discussed at Argonne. None of that information was used in this study.

And then conservatisms that have been used to address the generic letter response.

CHAIRMAN BANERJEE: Okay, thank you. If there are no more questions I'd like to thank the staff for very interesting and informative presentations.

And I think we should now move on to the next phase. Thanks.

And we've already got the material by the way that Donnie promised. So whoever wants to get hold of it -

DR. WALLIS: So we have to read it in five seconds?

CHAIRMAN BANERJEE: Well, read it over lunch.

And now I think we will hear from the BWR owners' group. Now what I think I'd like to do is still take a lunch break at 12:30. And then probably take a 45-minute lunch break. So we'll ask you to sort of move forward, and at some natural point we can take a break.

(Off the record comments.)

TEST RESULTS - REVISION OF WCAP-16793

MR. ANDREYCHEK: Thank you very much for the opportunity to be here this morning, and to make this presentation. This presentation is an update to what we presented back in March earlier this year.

I'd like to cover today a little bit of background information. Talk a little bit about the debris collection at the core inlet; fuel assembly testing that we have done, and we did this on an expedited basis to try to provide some information and demonstrate some information for that.

We will talk a little bit about forecasting, and forecasted pollution in GSI-191.

As a way of background, WCAP-16793 was developed to provide a basis for providing long-term core cooling for PWR designs. To demonstrate with reasonable assurances of long-term core cooling to satisfy the requirements of 10 CFR 5046, we were going to use available tools and information and draw from -- and address all PWR designs, the design of the open lattice structure of the PWR fuel, and design and test performance replacement pump containment sump screens that have been done by all licensees. And the results are to be applicable to the whole fleet of PWRs regardless of the design.

With regards to some background on sump screens, replacement sump screen hole sizes are on the order of approximately a 1/16th of an inch to an 1/8th of an inch. Most of them tend to be less than an eighth of an inch. Some debris that arrives at the sump may be smaller than the openings and penetrate the openings. Any debris that passes through the sump screens can therefore be transported to the RCS, the emergency core cooling system, and could potential there reach the core.

Debris that is not ingested - one thing to remember, the debris is not ingested into the ECCS until after we go into recirculation of the sump, which is approximately 20 to 30 minutes after the break.

At the time of switch over, again, 20 to 60 minutes after the break, the core is fully recovered. Typically we recover cores in PWRs we do a large break LOCA within approximately 180 or so seconds, and the peak clad temperatures began to turn over, and so clad is of course recovered at that time.

The core mixture level, i.e. the two-phase levels above the top of the core at that time, and the actual vessel level core flow rate and debris transport into the core are dependent upon the break location. If it's a code-like break we will tend to get less flow into the core.

If we take a look at the code-leg break, this picture, schematic, does depict a code leg break. The downcomer is full to at least the bottom of the code leg. The core level is established by the hydrostatic balance between the water level in the downcomer and the resistance to flow as well as the two-phase mixture in the core itself. And also, for

B&W plants, there is a potential for some flow through vent valves at the top of the downcomer.

For code leg breaks, depending upon the design of the plant, and depending on the number of trains of ECCS you have operating, it can have a range of between 1,000 to 3,000 gpm minimum ECCS flow, 6,000 - 8,000 gpm maximum ECCS flow.

Now the amount of flow that is needed to match boil off for a code leg break at approximately 20 or so minutes after the break occurs is on the order of about 350 gmp for a Westinghouse 4-Loop plant, large 4-Loop plant. It tends to be about a maximum that you would expect to see.

Excess flow dumps out the break location, and is recycled into the sump and back around through the sump screen. And once back in containment sump, again if it's recycled through the sump screen it has an additional opportunity to be filtered by the sump screen. Next slide, please.

For a code leg break most of the debris flow will go back up to through the break and be filtered. And the calculations shown here are rather simplistic calculation. So the break flow, we are looking at the flow going out the break. Once you've done the recirculation, 6,000 gpm which is the minimum

ECCS, for maximum - maximum ECCS flow - a little hard to follow there - minus 300 gpm break flow - or flow into the core. It means you are recirculating approximately 5,650 gpm.

So you are looking at about 94 percent of the flow that you can get is actually recirculating back around through the screen.

DR. WALLIS: This is assuming every thing is fine? Assuming the pumps are pumping, right?

MR. ANDREYCHEK: That's correct. That's assuming you got maximum ECCS flow. The next major bullet we look at the minimum ECCS flow. And again we are looking at approximately 1,000 gpm total ECCS flow under minimum conditions with 350 or so gpm matching boil off. If you got 650 gpm recirculated back into containment sump through the sump screen.

So we are looking there at approximately 65, 66 percent of the flow that is being recirculated back through the sump screen and being refiltered.

Any questions on that?

Next slide, please.

The hot leg break, all the flow, all the ECCS flow that is provided to the core flows through the core. It's the only flow path we have right now. And as a consequence all the debris that is available in the ECCS flow will be ducted through and to the core.

Next.

CHAIRMAN BANERJEE: You show a little background with the debris that has settled. Now this is very fine debris coming in past the screens, right?

MR. ANDREYCHEK: .

CHAIRMAN BANERJEE: So why do you think it will settle? Why do you show that?

MR. ANDREYCHEK: Well, if there is some very dense debris it will have a tendency to settle. And there were some calculations done, and there is a paper that was provided in fact about 1985-86 timeframe that demonstrates under ECCS flow conditions, debris having a density of approximately 95-96 pounds per cubic feet, and sizes greater than 40 or so mils will have a tendency to settle in the lower plenum. It's a public paper.

CHAIRMAN BANERJEE: I think that is fine, but if I recall your arguments from the previous - you were saying one cubic feet of some sort of material would get through that had a pretty low density, but 1,000 square feet -

MR. ANDREYCHEK: Can you save that question for about five slides, because I think we answer that question. I appreciate that question.

For the testing we are doing we don't take into account any debris settling, okay. So I think that also addresses, in another way perhaps, your question.

Next slide. So again we are looking for hot leg break, once the debris reaches the reactor vessel lower plenum, it can either settle in the lower plenum - that's your question - or it may be transported to the core.

The three areas of possible concern for transport to the core include the debris adherence to the fuel cladding surface which was discussed earlier today; collection of debris on the inlet to the core, and therefore resistance to flow in the core; or resistance to the flow at space at spacer grids due to the collection of debris at spacer grids in the core itself. I think those are the three that we would agree upon are the areas of concern. We are going to talk about all three of them.

If fibrous debris should enter the core, it will not tightly adhere to the fuel. There is a report that demonstrates this, it's NUKON OFC-1 report, which has been provided previously I believe. It took a rod heated to about 2,200 degrees

Fahrenheit, submerged it in a fibrous slurry. There was nuclear boiling of the heated rod in a slurry; another test. Filmed boiling of a heated rod in a slurry. And all demonstrated that fibrous debris does not adhere tightly. NRC did review and accept the NUKON OFC-1 report in a safety evaluation.

CHAIRMAN BANERJEE: What is the applicability of this? Because when you do this you are getting film boiling clearly, whereas if debris is transported into the core, you've got perhaps nuclear boiling certainly or no boiling at all, and you might have a much higher wall temperature than the slurry temperature.

So while certainly the report is probably acceptable for what it is, where you've got film boiling on a rod surface, I don't see what the applicability fo this is to the case we are talking here.

MR. DINGLER: We wanted to show this, that the fiber itself won't appear. We have as a couple more slides coming up assume scaling; we added a bump up factor for fiber that put us here, scaling in that that was talked about, and we call it DM LOCA, that shows that the amount that could get on the fuel assembly, we estimate that.

So I think that answers your question. Again, a good lead-in for the next couple more slides down the road.

CHAIRMAN BANERJEE: Well, I'll wait. But when you've got film boiling you've got a vapor lapse.

MR. DINGLER: We covered it both ways. One way, film boiling, we don't have, and then with the non-film boiling we used the calculation that shows that the debris deposited on the fuel will not get above a certain level.

CHAIRMAN BANERJEE: Well, let's move on.

MR. ANDREYCHEK: Okay, thank you.

With regard to the fuel assembly testing, fuel assembly debris and electrodes are included in broad and nozzle fuel assemblies.

Now in order to demonstrate what we are looking at we did bring some show and tell items today.

Yes, it is rather sharp. But that is a typical bottom nozzle debris. Be careful; that is heavy.

The purpose behind the debris catching device is on - I don't know what fuel design it is, whether it be a Westinghouse design, a CE design or a B&W design - is to capture debris that could potentially get into the fuel under normal operating conditions and cause wear and fretting and reach the fuel rod under normal operating conditions.

And fuel failure is certainly a high impact item that -

DR. WALLIS: So this is this way around?

MR. ANDREYCHEK: That is correct.

DR. WALLIS: The spikes are upward?

MR. ANDREYCHEK: That is correct.

CHAIRMAN BANERJEE: Some of the things I saw had little cross pieces around the holes?

MR. ANDREYCHEK: Yes, and I tried to get examples of that. The cross pieces, that's the protective grid for the Westinghouse design that actually either bisects or quarters those little holes.

CHAIRMAN BANERJEE: So you've got little thingies like that?

MR. ANDREYCHEK: That is correct, sir; that is correct.

And the next slide demonstrates that. This next slide is an attempt to show how the protective grid would fit right over the top of the bottom nozzle, and how it would in this case quarter. The little circle that is drawn in the upper right-hand corner of the hole, of the flow hole there, is an attempt to show this if this particle had a cylindrical cross section, what the maximum dimension would be that would fit through there.

Types of debris of course that we are looking at that might reach the core from the RCS would be fibrous debris, particulates, and chemical precipitates, two different types.

For postulated debris build up at the core inlet, we'd need to - if we wanted to determine if sufficient flow would reach the core and continue to remove the decay heat through the potential debris bed. So we must demonstrate that the available pressure drop that the core could take is greater than the pressure drop we'd see across any debris bed that we'd build up at the core.

So in order to look at this, what we are looking at is the available driving head is based on the, again, the hydrostatic balance between the downcomer and the core. The delta P available sequel to the elevation head minus the available minus the flow. So the available head - go to the next slide, please - I wanted to show these two diagrams to give you an idea of the overall layout of the plants. What we are looking at here on the left-hand side is the

Westinghouse and CE design; on the right-hand side is the B&W design. Next.

DR. WALLIS: So we are talking about a few feet of head or how much?

MR. ANDREYCHEK: Well, we are going to get to that in just a moment. We will have the equations in just a moment. I wanted to provide you with some of the inputs that we were looking at.

We reference all of the dimensions here to the bottom of the core. We talked about the fuel as 12 feet relative to the bottom of the core. The bottom of the hot leg is about 16.06 feet; the bottom of the cold leg is 16.16 feet. And the spill over elevation to the shortest steam generator tube is about 49-1/2 feet.

That gives us the basis for solving some calculations on the next couple of slides. For cold leg break we are looking at a liquid density of approximately 60 pounds mass per cubic feet, and this occurs well out into the transient at about 20 minutes. Core saturated with voiding in the fluid, or the liquid; core mixtures; and level is taken to be the top of the core. And with a core average void fraction of point five, we are going to calculate -

CHAIRMAN BANERJEE: Is that sort of - the liquid is coming in at what temperature? Is it saturated?

MR. ANDREYCHEK: Approximately saturated, yes, at 20 minutes, yes. Approximately.

CHAIRMAN BANERJEE: The coolers just bring it down to saturation?

MR. ANDREYCHEK: No the coolers will bring it down to maybe 20 or 30 degrees below saturation. So it's slightly cooler.

CHAIRMAN BANERJEE: So it's subcooled?

MR. ANDREYCHEK: Slightly subcooled, yes.

CHAIRMAN BANERJEE: And even if you have voiding, I mean in a sort of a boiling situation, the average void is not 50 percent; it could be much closer to maybe 20 or 30 percent at most. It will be much lower generally.

So let's say if your core was covered and there was a two-phase level somewhere, right at the top it might be about 30 percent which is what you would expect in a bubbly flow. If you had annular flow or something that would be different.

But if you had a level with bubbles underneath it, and not annular flow. So I mean this might be way too high, the average void fraction.

DR. WALLIS: It should be calculated.

CHAIRMAN BANERJEE: It should be calculated, not assumed. And we know how to do that calculation, and I would say it's - the core average void would be much closer to 10 percent or maybe 15. It'd be surprised if it was much over that.

DR. WALLIS: Well, everything is interrelated. Really you ought to assume, have a resistance at the bottom, and then calculate the flow rate in the voids. Everything is interrelated. You can't ever assume part of the answer and then calculate the flow rate.

CHAIRMAN BANERJEE: All you have to do is make sure he was not our consultant and yours, and he could just do it in five minutes. And probably do it much better than any computer code. Or read his book; that's even better.

MR. ANDREYCHEK: You know I tried to get a copy of his book a couple of years ago. It's out of print.

CHAIRMAN BANERJEE: A thousand dollars right now.

DR. WALLIS: A thousand dollars on eBay. You can go to eBay and get it.

MR. ANDREYCHEK: I know, I know. I saw the price on eBay. I was a little astounded. I was looking for the publisher price.

CHAIRMAN BANERJEE: I will lend you my copy, or rent it to you.

(Laughter.)

MR. ANDREYCHEK: Was it lend or rent? I'm not sure which it is.

CHAIRMAN BANERJEE: I'll lend it to you.

DR. KRESS: I have a corrected version.

MR. ANDREYCHEK: The .5 actually came from some calculations that were done for long-term core cooling. And I saw assumed for these calculations; they were based on COBRA TRAC calculations that we had to be honest, and they were assumed for these calculations.

DR. WALLIS: Without the pressure drop across this bed you would have more flow rate, wouldn't you?

MR. ANDREYCHEK: Yes.

DR. WALLIS: So alpha is dependent on how much bed you have? It's not independent variable?

MR. ANDREYCHEK: That's true, but if you bear with me what I'm trying to do here is not calculate the pressure drop across the core. I'm saying here is the maximum pressure drop we would expect to have available, assuming there is no debris.

As long as we are - and that's what I'm looking for. So a cold leg break.

DR. WALLIS: Well, it's the minimum alpha you expect.

MR. ANDREYCHEK: That's correct.

DR. WALLIS: The bigger alpha gives you more pressure drop?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: No, the higher the alpha is the more flow you would get because the driving head goes up.

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: So if you take it as alpha as one, you would have a much lower driving head.

MR. ANDREYCHEK: That's right.

CHAIRMAN BANERJEE: So that would be a conservative calculation.

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: Put alpha - sorry, alpha equal to zero. That would be a reasonable calculation.

MR. ANDREYCHEK: So if you had no voiding in the core, you are just basically saying -

CHAIRMAN BANERJEE: It's just sensible

heat.

MR. ANDREYCHEK: Correct. But if you bear with -

CHAIRMAN BANERJEE: We will bear with you.

MR. ANDREYCHEK: Thank you, appreciate it. We go through the calculation basically for a cold leg break. We are looking at approximately 2.5 psi available at a core average void fraction of .5. If it's a core average void fraction of something different, it would be something a little different, available driving head.

CHAIRMAN BANERJEE: Well, if you took it as zero, what would it be? You can do that sum. I guess, Dave, we can work that up, right? Put alpha equal to zero; see what happens. Keep going.

MR. ANDREYCHEK: Okay, thank you.

For the hot leg break there we're looking at the height of the steam generator tubes providing additional head, driving head; we are looking at about 13.9 psi.

DR. WALLIS: I've forgotten what you mean by the steam generator -

MR. ANDREYCHEK: Can we go back about four or five slides.

CHAIRMAN BANERJEE: The steam generators

could be voided, right?

MR. ANDREYCHEK: Not if we've got - if you will bear with me for a second, there you go. May I?

So if we have a hot leg break, flow is going to come out of the hot leg here. So flow is going to come in to the cold leg during cold leg recirculation. So what we are going to end up with is water. If you begin to develop resistance across the bottom of the core, the water will tend to flow backwards up into the steam generators to the lowest elevation of the U-tube. So you will develop water head, driving head, equal to the minimum elevation in the steam generators.

CHAIRMAN BANERJEE: So it doesn't go out of the break, the water?

MR. ANDREYCHEK: If it's a hot leg break it can't. It has to go through - everything has to go through the core, until you go up to the very top, because you are injecting water into the cold leg. So the only path to the break in the hot leg is either through the core to the break, or up over the top of the steam generator to the U-tube spilling over to the hot leg.

MEMBER MAYNARD: To get the maximum driving head you are assuming that the bottom of the core is totally blocked.

MR. ANDREYCHEK: Or blocked sufficiently that we begin to develop flow, build up water head up into the steam generator.

MEMBER MAYNARD: If you're getting flow through the core that you are not going to have back flowing up to the top of the tubes.

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: So you're saying that as it can't get to the hot leg it just drives itself over -

MR. ANDREYCHEK: Correct.

CHAIRMAN BANERJEE: And eventually if it drives itself over to the other side, then you balance the head on both sides?

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: So then you have no head.

MR. ANDREYCHEK: That would suggest you have nothing driving it into the core, and then we run into a situation which you studied in your book on counter-current flow limiting phenomena, because you'd have water coming in the hot leg down on top of the core which gives you a very different question to answer. And I'd rather not get into that.

CHAIRMAN BANERJEE: Well, you just fill up the steam generator, right, eventually?

MR. ANDREYCHEK: You'd have to overflow the u-tubes and go into the hot leg.

CHAIRMAN BANERJEE: Yes, so at that point the two sides balance? Or am I getting something -

MR. ANDREYCHEK: No, they balance; we agree.

CHAIRMAN BANERJEE: So then you have no head due to that. Because you fill both sides.

MR. ANDREYCHEK: You can't fill both sides.

CHAIRMAN BANERJEE: Why not? There is not enough water?

MR. ANDREYCHEK: No, you flow out the break. You basically begin to flow water out the break.

CHAIRMAN BANERJEE: Right, so you've gone over the top.

MR. ANDREYCHEK: Right.

CHAIRMAN BANERJEE: And now you are going over the break.

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: So you are saying you can't fill this up because there is going to be counter-current flow of air?

MR. ANDREYCHEK: No, bear with me. All I'm saying in this calculation is, the maximum driving head that I have available to put water into the bottom of the core is equal to the minimum height of the steam generators to the bottom of the core, which is 13 -

CHAIRMAN BANERJEE: Maybe the maximum, but in reality let's say the inlet of the core is really blocked. Now you are starting to drive up stuff into the risers of the steam generators. You are going to fill it to the top; it's going to spill over the top. It will be a two-phase flow region, and eventually that area is going to fill unless you are putting air back into that side, right?

MR. ANDREYCHEK: No, we are not putting air up into the steam generator at all.

CHAIRMAN BANERJEE: Then where is - what are you, putting steam into it?

MR. ANDREYCHEK: No.

CHAIRMAN BANERJEE: Once it spills over the top it goes into the outlet plenum, right?

MR. ANDREYCHEK: It goes into the hot legs into the outlet plenum, yes.

CHAIRMAN BANERJEE: But the - all that water has to now get out of that hot leg, which can get filled?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: And what I don't know is what will happen to the down side of the steam generator. So in an extreme calculation you could assume it was full.

MR. ANDREYCHEK: I see where you are going.

CHAIRMAN BANERJEE: If it's full, then you have just balanced it, so it doesn't matter. Once it goes over the top, if you fill both sides of a steam generator what does it matter.

MR. ANDREYCHEK: I think I understand, but I don't see how you would -

MEMBER MAYNARD: But if it goes over the top of the lowest tube, then the water is either going to go out the break or go into the core.

MR. ANDREYCHEK: Right.

CHAIRMAN BANERJEE: Well, the water could just fill up the downside of the steam generator.

MEMBER MAYNARD: No, there is nothing to hold it.

CHAIRMAN BANERJEE: The only way is if you have a counter-current flow to hold it.

MR. ANDREYCHEK: But there is no counter-current flow in those steam generators, because it is going out the break.

CHAIRMAN BANERJEE: You are not going to fill it due to some magic mechanism?

MR. ANDREYCHEK: I don't see us filling the steam generator tubes on the downhill side.

CHAIRMAN BANERJEE: Suppose it starts filling over. Now unless you have something to - you are saying these tubes don't fill; they will half fill and water will run down them?

MR. ANDREYCHEK: No, I'm saying that they will fill on the cold leg side totally. And because the tubes are a multiplicity of pipes, there are a number of pipes, you are going to reach the minimum, the lowest tube first; you will begin to flow over the minimum height too. And you've still got the other tubes that aren't necessarily getting water yet. You will basically overflow the top of the tube, and it will flow into the hot leg.

DR. WALLIS: And that's as high as you will go.

MR. ANDREYCHEK: That's exactly right.

DR. WALLIS: It just spills into the hot leg.

MR. ANDREYCHEK: It spills into the hot leg, yes.

CHAIRMAN BANERJEE: It spills down the downside, right?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: Okay, so that means these tubes are partially filled only; that's what you're arguing? Some water is coming down them, sort of dribbling down them or what?

MR. ANDREYCHEK: It could be very quickly coming down them. But I'm not counting that for a head driving water into the core.

CHAIRMAN BANERJEE: Well, but there is water on the downside.

MR. ANDREYCHEK: Yes, there is.

CHAIRMAN BANERJEE: As there is on the upside. All I'm saying is that an extreme calculation can be that there is as much water on the downside as the upside which exactly balances the head.

MR. ANDREYCHEK: I can't see that.

MEMBER MAYNARD: You can't do that unless you don't have a break. You'd basically be filling up the hot leg side.

CHAIRMAN BANERJEE: I am not sure that you can't do it without - it depends on how the - you know something has - you could - a small tube, you could just fill it with water like a tap coming down.

MR. ANDREYCHEK: Yes, I understand that.

CHAIRMAN BANERJEE: And how much?

MR. ANDREYCHEK: We have a very different system in the sense that we've got thousands of tubes, and you are talking about one or a number of smaller tubes. But the rest of the tubes are still vented because we haven't filled them up to the top where they spill over.

So I don't think we've lost the head at all.

CHAIRMAN BANERJEE: When you fill up one tube, then you fill up the next, then you fill up the next. I guess what you are saying is, some tubes will be empty.

MR. ANDREYCHEK: That's correct.

MR. DINGLER: And then once they are filled or flowing by gravity out the break also.

CHAIRMAN BANERJEE: Anyway, we'll accept this for the moment. Carry on.

MR. ANDREYCHEK: I think I understand your question better now.

DR. WALLIS: It's a good thing that a loop seal isn't in the hot leg.

MR. ANDREYCHEK: That's correct.

DR. WALLIS: You might get a different

situation.

MR. ANDREYCHEK: That is correct.

CHAIRMAN BANERJEE: Then for sure you'd get it.

MR. ANDREYCHEK: So we - that's basically - there's the slide. So what we have available if you accept my use of alpha void fraction of .5 as 2.5 psi driving head for a cold leg break. And for the hot leg break we have approximately 14 psi maximum, given the height of the steam generator.

DR. WALLIS: With an alpha over 20 you might find you didn't have this pressure drop.

MR. ANDREYCHEK: You are entirely correct.

DR. WALLIS: So I think you need to work that out.

MR. ANDREYCHEK: Okay.

DR. WALLIS: I'm doing a rough calculation just to see where it goes. Go ahead.

DR. WALLIS: You'd get something through. Because if there is no flow you'd get alpha one.

MR. ANDREYCHEK: That's right.

MR. DINGLER: And we have the calculation because that is part of the license basis. We just didn't bring it for this one.

MR. ANDREYCHEK: So the head loss to the

debris bed must be less than either one of these two values to provide reasonable assurance that flow required to remove core decay heat will continue to reach the core.

Next slide. The pressure drop is a function of both the debris type and the debris amount. And bas3ed on everything we've heard so far today, certainly the amount of debris and the type of debris that reaches the core could be combinations of multiple types of material and amounts.

We know that that needs to be accounted for in a test program in order to come up with a prudent approach to doing the test.

CHAIRMAN BANERJEE: Well, I've got a rough number. If your alpha, if you were full of liquid you would something on the order of one-third to one-quarter of the driving head, correct, the 4.2? It would go down to about one psi.

MR. ANDREYCHEK: I accept that.

CHAIRMAN BANERJEE: Okay.

DR. WALLIS: Remind what the area for flow is across this cold plate, the total area? We used to know that and I've forgotten it.

MR. ANDREYCHEK: The total area across - if you are looking at the total area below the core itself it is approximately 100 square feet -

DR. WALLIS: No, it's only about 50 because you've got 50 percent of the -

MR. ANDREYCHEK: That's correct. That's correct.

DR. WALLIS: Fifty square feet. I remember something like that.

MR. ANDREYCHEK: And then the core itself is approximately 50 square feet.

DR. WALLIS: And some of these screens are thousands of square feet.

MR. ANDREYCHEK: That is correct.

CHAIRMAN BANERJEE: So the concern we had is that you have a second screen. One basically in series which is much smaller than your first screen.

MR. ANDREYCHEK: Understood. Understood. Okay, next slide.

When considering pressure drop from debris, the particulates will generally be smaller than the fuel filter openings, and those are the - you've seen the grids which can be used as approximately fuel filter openings. Consequently we need to have a fiber bed present in order to collect particulates within the core entrance, or even within the core itself. Otherwise the particulates will pass through the core, and we won't get quote blockage.

The foaming slides provide the basis for investigating the amounts and types of debris that we're going to look at.

DR. WALLIS: This means that the particles are not in anyway sticky. They won't stick to the hole, and you can get holes blocked by small particles.

MR. ANDREYCHEK: By sticky particles, yes.

DR. WALLIS: I mean it could happen in your arteries and things like that, if something sticks. If it doesn't stick.

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: What are the - I've forgotten now - with the cross pieces what is the equivalent hole diameter there?

MR. ANDREYCHEK: Well, again, the largest spherical diameter or cylindrical diameter is approximately .07 for a Westinghouse design.

CHAIRMAN BANERJEE: But was that because your screens are one-eighth to one-sixteenth, correct?

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: So I'm just trying to do that. One eighth is -

MR. ANDREYCHEK: Point one two five.

CHAIRMAN BANERJEE: Point one two five. So these holes are smaller than the holes in the sump screens.

MR. ANDREYCHEK: There are only two sump screens that I'm aware of that have been installed that have a one-eighth inch diameter.

CHAIRMAN BANERJEE: So most of them are what, one-sixteenth?

MR. ANDREYCHEK: Most of them are point one or smaller; point one inches or smaller.

CHAIRMAN BANERJEE: So even if it's point one, these holes are smaller?

MR. ANDREYCHEK: Potentially, yes.

CHAIRMAN BANERJEE: Than the point zero seven, correct?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: So you've got a screen upstream with bigger holes than the core inlet holes.

MR. ANDREYCHEK: Potentially.

CHAIRMAN BANERJEE: Not potentially; that really is what you are telling me.

MR. ANDREYCHEK: Okay.

CHAIRMAN BANERJEE: Okay. Keep going.

MR. ANDREYCHEK: Additionally, testing of sump screens -

DR. WALLIS: So metallic insulation smaller than point one inch could get through the screen but wouldn't get into the core?

MR. ANDREYCHEK: The flow rates that we are looking at, based on -

DR. WALLIS: Wouldn't be transported?

MR. ANDREYCHEK: That's right.

DR. WALLIS: You just talked about fibers. You have to dismiss the other one as well.

MR. ANDREYCHEK: If I look at particulates, and particularly from reflective metallic insulation, the density of that is so high that it doesn't transport well to the sump screen. That was shown in USIA-43 that closed out in 1985.

CHAIRMAN BANERJEE: I think the discussion we are having about the sump screens up until now is that much of the very fine stuff gets there, right?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: Probably; I mean we don't know for sure. But some part of this very fine stuff will get through, and of course we don't know exactly what gets through, but in the previous discussions we had we said that - at least it was maintained that about one cubic foot -

DR. WALLIS: Per thousand square feet.

CHAIRMAN BANERJEE: - per thousand square feet would get through, and this was of a very low density. If I remember it's less than 2.5 pounds per feet cubed, if my memory serves me right. So this stuff would probably not settle; it would just go through.

MR. ANDREYCHEK: And that's fibrous debris typically.

CHAIRMAN BANERJEE: Okay. And we were not talking about the heavy little particles or whatever.

MR. ANDREYCHEK: No.

CHAIRMAN BANERJEE: Because they would be out anyway.

MR. ANDREYCHEK: That's correct. We were talking about -

CHAIRMAN BANERJEE: They would probably get to the core.

MR. DINGLER: And that's why we even got the lengths and the diameters of what we were seeing coming from actual bypass testing, and we have those presented on a data slide for you.

MR. ANDREYCHEK: When we get to the testing, you will see, we will be able to describe briefly what we've done in terms of fibrous debris.

CHAIRMAN BANERJEE: I guess what you are

doing is, you are setting a sort of stage here for the later data. But if you had shown us the data to support this stage it might have been easier to accept it.

But let's assume that you will show us some data.

MR. DINGLER: You're right. In other words we didn't know what to do, do the data first and then background, or reverse.

CHAIRMAN BANERJEE: Data is always good. With this stuff it is difficult to accept without having the data. And we look at the data, and we come back.

MR. ANDREYCHEK: I would appreciate your patience please.

So from the testing of the sump screens we have seen that small amounts of fibrous debris may collect particles to chemical precipitates, produce large head losses which has been called the thin bed effect.

Similarly large amounts of fiber mass may collect large amounts of particles and chemical precipitates and general large head losses, and similarly is called a thick bed.

Therefore our testing needs to consider

both small amounts of fiber as well as large amounts of fiber. Next slide.

If sufficient amounts of particulates and chemical products are not available to collect in a fiber bed, the voids in the fiber bed won't be filled, and the flow through the bed will continue and core coolant will be maintained. And that is also drawn in part from some of the screen testing data that was done where you have a fiber bed without any particulates; without any chemical precipitants. And you still get a reasonable amount of flow at minimal pressure drop through the bay. And I think, Bill, you've seen that in some of the testing you have done at Argonne.

Therefore, at large volumes of particulates and chemical precipitants will also be investigated.

CHAIRMAN BANERJEE: Yes, and also the previous testing that they presented with horizontal screens is not really applicable to this. This is much closer to the Argonne, because this is like a vertical loop, correct?

MR. ANDREYCHEK: That's correct. It's reversed. Instead of the flow going down, it's going up. We agree. Yes.

So what we looked at for - to approximate the hot leg break, the maximum flow into the core is provided, which also provides the maximum hydraulic drag in the lower plenum to drag materials up into the core entrance. We also know that concentration of chemical products builds over time, and that was demonstrated in the integrated chemical effects testing that was done several years ago by Los Alamos and the University of New Mexico.

Next slide. And with regards to head loss in calcium phosphate or calcium-based products, calcium-based products could form early in the accident at elevated temperatures. The head loss testing that was done at Argonne demonstrated that with the NUKON fiber bed and approach velocities to the fiber bed at approximately a tenth of a foot per second, the aluminum based chemical products generate larger pressure drop at the same concentration than the calcium based chemical precipitates.

And Bill, I want to make sure that that is the correct statement. I believe that is consistent with the information you folks put out previously.

MEMBER SHACK: I have to think about that, although it's hard to imagine anything more effective than your WCAP surrogate.

DR. WALLIS: Because it is bad to have a lot of CalSil and a lot of STP.

MR. ANDREYCHEK: We are not going to disagree with that. So the information we have available demonstrates the use of aluminum surrogates provides for a conservatively large or high head loss across a fiber bed.

Next slide, please. Now before we go into the actual testing itself, I'm going to talk a little bit about LOCADM. That was a topic that we talked about briefly last meeting in March.

It's an automated spreadsheet calculation, of post-LOCA material deposition on fuel cladding. The model conservatively assumes that all of the fiber and chemical products that have passed through the sump screen and transported to the fuel in a packet as it were of water, or liquid, that then boils, everything in that packet of water is deposited onto the fuel surface. It's a very conservative approach.

We verified the hand calculation, or the automated calculation, by comparison of calculation test data. And what you have here on the slide is the LOCADM calculation. Which is this line compared to the data, and this was compared to a model that was -

DR. WALLIS: This is deposition on the

fuel?

MR. ANDREYCHEK: Yes, sir.

DR. WALLIS: I'm not quite sure what you mean by conservative. Conservatively it all goes in and deposits, but where does it deposit? If it deposits all on one fuel rod, presumably that fuel rod is going to overheat.

MR. ANDREYCHEK: Well, it deposits -

DR. WALLIS: Everywhere.

MR. ANDREYCHEK: Everywhere in the boiling region, based on -

DR. WALLIS: Uniformly?

MR. ANDREYCHEK: - based on the amount of boiling that is going on, and it's uniformly over a region of the core that is in boiling.

DR. WALLIS: So it varies from channel to channel? The hot channel gets more of this stuff?

MR. ANDREYCHEK: That's correct. That is correct.

The LOCADM code does account for local power radial distribution in the fuel. And it does look at the hot channel.

DR. WALLIS: So this fouling resistance is at the worst place, is that what it is you are plotting here?

MR. ANDREYCHEK: In this particular case we took a look at this particular piece of data and said, what would our code predict relative to the data given the conditions on the -

DR. WALLIS: On this particular test?

MR. ANDREYCHEK: - on this particular test, yes, sir.

CHAIRMAN BANERJEE: Now, I'm just trying to organize the presentation, because we don't want to go too far beyond the 12:30 time.

MR. DINGLER: I think we've got this afternoon on this.

CHAIRMAN BANERJEE: Right, right, and with a lunch break. When are you actually going to get to your experiments? Which slides?

MR. ANDREYCHEK: The very next slide.

MR. DINGLER: The next slide. Do you want to take a break?

CHAIRMAN BANERJEE: No, I don't want to take a break now. If you've got new data, where is that starting?

MR. DINGLER: That is coming up in the next couple of slides.

MR. ANDREYCHEK: Next couple of slides, sir.

CHAIRMAN BANERJEE: Okay, all right. And your testing and stuff, when is that starting? We want to have enough time for all the tests you have done to look at that, so is that slide 39 or 40, or when is that?

MR. ANDREYCHEK: The summary of the data is on 42.

CHAIRMAN BANERJEE: On 42? These are your new tests?

MR. ANDREYCHEK: That is correct, sir.

CHAIRMAN BANERJEE: Okay, so we want to make sure we have enough time for that. So before we - there were certain issues that were raised at the last meeting which I think we need to make sure we address at this meeting. One was this bypass amount, that was an important issue, which we would like to see your data on. Second issue was if you did get a fairly uniform bed formed at the inlet, what sort of pressure losses would you get, and the sort of testing you've done related to that.

So we want to be sure that we have enough time on that, and not get hung up on hand calculations and all that sort of stuff. The key thing we are looking for is new data, not new calculations.

MR. DINGLER: The bypass data is slide 37 and 38, and then our results of our last tests -

CHAIRMAN BANERJEE: The new testing you have done?

MR. DINGLER: Yes, 40 to 42.

CHAIRMAN BANERJEE: Okay, so let's move on, and make sure we get there.

MR. ANDREYCHEK: Okay. If there are no other questions, I'd like to go to the next slide.

The fuel assembly debris capture tests that are being done. There is a head loss test protocol developed to support WCAP-16793, and the testing is going to investigate combinations of debris materials, fibrous particulate and chemical, and we are also going to look at the potential for thin bed loading.

DR. WALLIS: What is silicon carbide?

MR. ANDREYCHEK: Silicon carbide is a material that stays in solution; it doesn't settle out very well. It's small in diameter.

DR. WALLIS: This is not like the real stuff is it?

MR. ANDREYCHEK: I'm not sure I understand what you mean.

DR. WALLIS: The stuff that's in the sump?

MR. ANDREYCHEK: It's small diameter that gets into a fiber bed and will give you a very high head very quickly. So it's a conservative approximation.

DR. WALLIS: But it is different stuff? It's chemically different from the stuff in the -

MR. ANDREYCHEK: Absolutely; no argument on that.

CHAIRMAN BANERJEE: Now why is it - are they already doing this for the pressure losses through the sump screens?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: So they're using silicon carbide?

MR. ANDREYCHEK: Some members have, yes.

CHAIRMAN BANERJEE: And NRC is accepting that.

MEMBER SHACK: And this is just a surrogate for random particle of debris off the floor.

MR. ANDREYCHEK: That's correct.

MEMBER SHACK: If you got CalSil you use CalSil, but if you -

CHAIRMAN BANERJEE: Ah, I didn't realize that.

MEMBER SHACK: - have other garbage particulate you are using this just because it's -

CHAIRMAN BANERJEE: Thank you for the clarification. I thought you were substituting this for CalSil.

MR. ANDREYCHEK: No, and in fact we'll talk - the test protocol does allow for both calcium silicate and Min-K to be used in addition to silicon carbide as a surrogate material.

DR. WALLIS: Presumably it doesn't have any on it. This is a silicon carbide?

MR. ANDREYCHEK: Yes, sir, silicon.

DR. WALLIS: It has an E on it.

MR. ANDREYCHEK: My error; I misspelled it. I left my dictionary at home.

CHAIRMAN BANERJEE: Leaving the "e" out, to this debris preparation you have to add then materials like CalSil?

MR. ANDREYCHEK: That is correct.

CHAIRMAN BANERJEE: So it's just missing that?

MR. ANDREYCHEK: That is correct.

Okay, with regards to debris characteristics, the fiber lengths that we're testing is approximately 77 percent of the fiber is less than 500 microns. Approximately 18 percent is between 500 to 1,000 microns, and 5 percent is greater than 1,000 microns.

Now you are going to ask where we got those numbers from, and we'll address that in just a moment, so please bear with me.

Particulates are silicon carbide, and again, Graham will talk about the dimensions of the silicon carbide there being on the order of 10 millimeters plus or minus - or micrometers, excuse me. Ten micrometers, excuse me.

(Laughter.)

MR. ANDREYCHEK: You know, I'm getting nervous speaking in front of you folks here. Bear with me just a little. Give me a little bit of slack please.

DR. WALLIS: Well, the trouble is, it's in print here. People can quote anomalies. This is 10 micrometers, is it?

MR. ANDREYCHEK: Yes.

(Comments off the record.)

MR. ANDREYCHEK: Again, the small size does provide for maximum lifting and penetration into the fiber beds. And the chemical surrogate is aluminum oxyhdroxide.

CHAIRMAN BANERJEE: This is your usual surrogate that you use?

MR. ANDREYCHEK: Yes, sir.

DR. WALLIS: I don't think it's a maximum lift. It's a large lift.

MR. ANDREYCHEK: A large lift, yes.

DR. WALLIS: It's not a maximum.

CHAIRMAN BANERJEE: And what about the CalSil or whatever?

MR. ANDREYCHEK: For the first series of tests we ran, Dr. Banarjee, we did not use calcium silicate. We just used the fiberglass, the silicon carbide and the aluminum oxyhydroxide.

CHAIRMAN BANERJEE: That's the first set?

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: Thank you. Carry on.

MR. ANDREYCHEK: The initial tests we intended to use a vendor - a different vendor of nozzle bottom configurations, populate flow rates, and again the fiberglass particulates and chemical surrogates.

DR. WALLIS: You are talking about these tests as if they are something in the future; is that right?

MR. DINGLER: Right now we have conducted three tests, and we are well into two One was just conducted Friday and we still have the data to be prepared.

DR. WALLIS: So there are a lot more tests coming?

MR. DINGLER: And we have 14 more tests to go.

CHAIRMAN BANERJEE: So are you going to tell us before the end of the day about what you are planning to do?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: So you've done three?

MR. DINGLER: We are going to tell you about two. One we didn't get the data enough to put some slides in the presentation. We will tell you about the two. We are also going to tell you where we plan to go from now.

CHAIRMAN BANERJEE: Carry on.

MR. ANDREYCHEK: Okay, the output from the initial tests, it would be a selection of the limiting fuel design for further tests; correlation of a pressure drop between the various bottom nozzle designs for a given vendor. And we intend to investigate and evaluate the adjustments to the plant that are needed or warranted as testing is performed.

CHAIRMAN BANERJEE: What about the spacer plates and the grid plates and things? Are you going to do some testing with that?

MR. ANDREYCHEK: Yes, we will. And if you bear with me again just a moment we will get to that.

CHAIRMAN BANERJEE: Could we add that to this?

MR. ANDREYCHEK: Yes, sir.

MR. DINGLER: That on page 39.

DR. WALLIS: Now when we were in Germany we saw some tests, didn't we? We saw actually -

CHAIRMAN BANERJEE: I think things got stuck more in the space plates and things.

DR. WALLIS: Is that stuff that is available? We asked for it to be available.

MR. ANDREYCHEK: We have not seen it.

DR. WALLIS: We saw a test where they had a screen, downstream they had this bottle of the bottom of a core. And we saw this fuzz deposited on the bottom of the core plate.

CHAIRMAN BANERJEE: It wasn't the core. It was on the grid plates, and I don't know what industry testing is shown here, but I would have thought that if there is this one utility which has done some tests, I don't know if you can speak about those, but I would have thought they would have seen the same phenomenon.

DR. WALLIS: I would think they would.

CHAIRMAN BANERJEE: Yes, they would, which is that the grid plates would get pretty jammed.

MR. ANDREYCHEK: Let me ask a question if I may, if you can share the information. I believe -what was the material, the fibrous material they were testing at the time?

CHAIRMAN BANERJEE: As far as I know it was fiberglass, but I'm not sure. Or was it something else? Somebody will know the answer which I don't.

MR. GEIGER: Ervin Geiger, NRR. Yes, the use typical mineral wall. I did have all those tests, but I think they were proprietary, so I couldn't really share them with anybody.

CHAIRMAN BANERJEE: And the other proprietary tests which you know about were conducted by a utility in the U.S. What do they have?

MR. GEIGER: Of course they didn't test as many spacer grids. They just had the first spacer grid. And I think they will get into later what they observed, but they tested a number of spacer grids. And Westinghouse had made the same observation that you had, fiber distributed throughout all the spacer grids. But I think they will come to it later.

MR. ANDREYCHEK: In the interest of trying to address a concern about what was actually in the test, would you jump to slide 39 please?

CHAIRMAN BANERJEE: That would be great.

MR. DINGLER: And what we want to do is show you, we are testing a four-foot assembly with these things, and I'll let him explain each one of them. But that is a mock up of our test facility right there.

MR. ANDREYCHEK: This is what we actually did, actually had tested.

CHAIRMAN BANERJEE: That is very helpful.

MR. ANDREYCHEK: You have the bottom nozzle, which was passed around; protective grid which sits right above the bottom nozzle, right here; first support grid, which is a couple of inches above it. And these are actual distances. We have another support grid, which is approximately the right direction; intermediate flow mixer, which is a smaller grid but has a lot of devices to redirect flow, strip the bubbles off the surface of the fuel; support grid; another top support grid; and the top nozzle.

And then the flow is ducted out of the top up here and back into the mixing tank.

DR. WALLIS: This is full scale, one assembly.

MR. ANDREYCHEK: It's not full height, but it's full scale, yes, it's the right size as I'm looking at the cross section, it's the right size; it's the right number of rods, so on and so forth.

MEMBER ABDEL-KHALIK: And the gap between the assembly and the walls?

MR. ANDREYCHEK: The gap between the assemblies and the walls for this test was modeled as one-half the prototypic gap in the reactor plant which is 20 mils, and one-half of the 40 mils, which is prototypical. But we did model that gap. And it's actually set - it's set using ultrasound devices to measure the distances to make sure we got it set correctly.

CHAIRMAN BANERJEE: Where are these experiments being done?

MR. ANDREYCHEK: They are being done in Pittsburgh at the Westinghouse Science and Technology Center.

MR. DINGLER: Then we will have some other tests by AREVA Fuel which they can't see at another facility.

MR. ANDREYCHEK: We have to put our blinders on.

CHAIRMAN BANERJEE: We can always clear the room of Westinghouse, and then we can clear the room - we've done that.

MR. ANDREYCHEK: And for the purposes of getting closer identification, this was the core support simulation. Bottom nozzle. This is about four inches. Bottom nozzle. Protective grid, and the first support grid.

MR. DINGLER: So we wanted to give you that before we go on, so you understand what we are testing.

CHAIRMAN BANERJEE: And you are testing eventually different sort of configurations for the debris filtering bottom.

MR. DINGLER: As you can see in the NRC presentation, Westinghouse has a guardian grid for CE. They have a P grid, an alternate P grid, and some plants have an open without any P grids.

AREVA has four different ones, a trapper fine mesh, a trapper medium mesh, and I can't remember all of them, but there are four different types for AREVA, plus the openings of five plus four for that. I just want to make sure we get the most conservative on those to test them.

CHAIRMAN BANERJEE: Right, so you do what appears to be the most conservative, and then other people would have to show that they - that it is conservative for them?

MR. DINGLER: What we're finding, based on again limited tests of three, two I want to show you that the bottom assemblies may not make too much of a difference. As you saw in the German test it's catching elsewhere. So we are evaluating that after each test, and seeing which way is the best to go to get the most bang for our dollar on testing.

MR. ANDREYCHEK: Next slide. We already did this one.

Okay, so what we are testing is we are using, we will be testing more with aluminum nozzle design, bottom nozzle design, like Mo just described, with hot leg flow rates. We'll be looking at fiberglass particulate, the chemical surrogates. Then we will be looking at the same with calcium silicate added, and then finally the same three debris sources with Min-K, a micro-porous insulation type.

Sorry that we didn't get to that earlier.

CHAIRMAN BANERJEE: Right, so it's like three or four series of tests?

MR. ANDREYCHEK: That is correct.

MR. DINGLER: That is correct.

MR. ANDREYCHEK: And we have had NRC

involvement in this. Test protocols have been shared with the NRC, and we have addressed their comments. And we did have a visitation from the NRC last week, a visit to the facility and witness a test.

And if I can identify the guilty parties as Paul Klein, Steve Smith and Irv Geiger were the visitors.

You wanted to see some bypass data. This is the sump screen bypass data when we did an industry -

CHAIRMAN BANERJEE: This, these series of tests of course assume a certain amount of bypass or whatever; is that it? Or do you vary the amount of bypass?

MR. ANDREYCHEK: We are varying the amount of fiber, and we will talk about that on slide 42 about the two tests that were run, and how the fiber varied.

MR. DINGLER: When we went out and we surveyed the plants, and we asked them to tell us what bypass they got. They went everywhere from actual testing to calculated to using a generic bypass that's in one of the SEs. So in other words we've asked the plants to give us that information so we didn't make any assumptions about what we got. So we got about

53, 52 plants that gave us information.

CHAIRMAN BANERJEE: So when you say generic number of bypass per 1,000 foot square of screen area are not used, what do you mean by that?

MR. ANDREYCHEK: At the last meeting in March I suggested approximately one cubic foot of bier per 1,000 square foot was a reasonable number. What we found in looking at the data was that the volume of fiber bypass was not something that we could use reasonably. A better number to use, a better measure to use, was mass; how much fiber mass bypass do you have?

And that translates into what the debris loading would be, much clearer to me at least, on what would be the debris loading on the screen. So we are presenting data on slide 42 based on fiber mass loading.

CHAIRMAN BANERJEE: Does this mean that plants who have gone from very high screen areas to make sure they have no pressure losses have done a good job on that front are going to have much higher debris loadings now?

MR. ANDREYCHEK: I don't think so.

MR. DINGLER: Not necessarily. What we are finding out is in the debris loading, the fiber loading and the particulate - I'll use one plant for specifics that I'm very familiar with - that we saw when the bed got on the screen within probably 20 turnovers, the water turned from mucky Missouri water to clean drinking water. So it filtered out.

So in other words it depends on your debris loading and that, so when the plants did their bypass testing, if a plant did actual bypass testing they found that the debris loading going to the core was relatively small. If they didn't do the bypass testing, they made an assumption. One plant assumed 110 pounds of particulate per assembly bypass. We know that is - that is not necessarily what you see, but that's the data that was presented. We know one plant gave us 68 pounds of fiber for assembly. We know that is not quite adequate either, because I know the debris of that plant, and it's similar to the others, and that's way outrageous.

So when we found out that was calculated, or it was assumed.

CHAIRMAN BANERJEE: So the question really is if you are saying that things are very murky, and then it was clear in 20 turnovers, you've got a screen with say point one inch holes, and now you've got another screen with a much smaller surface area with point zero seven inch holes or whatever.

Now wouldn't you expect the murky stuff to get caught in the second screen?

MR. DINGLER: And that's what we're testing for.

CHAIRMAN BANERJEE: So you'd have to start with the murky stuff?

MR. DINGLER: And that's what we're assuming, that the murky - because the bypass, you take the integral, you take the amount, you take the total amount of bypass, and we are looking at that.

CHAIRMAN BANERJEE: Well, the total amount, it depends on when you are taking it. But it's the Missouri water you want to test, right, not the drinking water.

MR. ANDREYCHEK: That's true, and I think when we get to slide 42, and we start looking at the data, we'll talk about the sequence that we added material, and I think that will address your question.

CHAIRMAN BANERJEE: Because you've got a much finer screen actually downstream.

MR. DINGLER: The one I'm talking about, that sump screen is smaller, the main sump screen is smaller than the fuel sump screen.

MEMBER SHACK: But still it's the first

pass through the screen that you are interested in; not the 20th pass.

MR. DINGLER: And what we are finding is, the NRC said that they found that the most head loss was particulate at first. We are introducing this particulate first, then fiber, and we are seeing a big difference in just that too on the head loss.

CHAIRMAN BANERJEE: There are people with screens smaller than 50 square feet open area?

MR. DINGLER: No, I meant the hole opening. I have a screen that is smaller than the fuel assembly.

CHAIRMAN BANERJEE: The core is always the limiting -

MR. DINGLER: That's an old one.

CHAIRMAN BANERJEE: I mean in the early stages the core is always the limiting screen.

MR. DINGLER: Yes, that's correct. Yes.

CHAIRMAN BANERJEE: That's the concern, I guess, whether the core takes all the stuff or the screen takes out the stuff.

MR. ANDREYCHEK: I think you will find - and again, Steve, if I'm missing something here, you can correct me - but typically the lower the approach velocity the less that you actually get passing through the screen. The screen becomes very effective at collecting material.

MR. SMITH: That's correct. This is Steve Smith from NRR, your question, your original question, do the bigger screens have more fiber passing through. And in general the bigger the screen the more fiber will pass through. But also in general the higher velocity the more fiber will pass through. So bigger screens generally have lower velocity, so they generally play against each other.

CHAIRMAN BANERJEE: Thank you. That's actually very useful. Appreciate that, thank you.

DR. WALLIS: I had a question about this slide, though. You are stopping your classification here at .0394 inches. I would think what is interesting is any fiber that is longer than .07, which is the hole diameter of the bottom of this core filter plate.

So I would want to know, are the 5 percent of them that are maybe .1 inches long? You don't have that.

MR. ANDREYCHEK: We don't have a maximum dimension there.

DR. WALLIS: I would think that would be important. Because all you need is a few of them to start blocking the hole, then you can build up like a bed.

MR. ANDREYCHEK: I understand the concern. I don't think that that - if you will let us get into the data, and I think you are going to see that it doesn't really matter. What we are looking for, and we didn't necessarily - first off, you are not going to get large fibers, long large fibers through the sump screens.

DR. WALLIS: I don't know. I don't have any measurements.

MR. ANDREYCHEK: I realize that. I realize that. You have to have a smart fiber that orients itself -

DR. WALLIS: Yes, but there are some that get oriented with the flow.

MR. ANDREYCHEK: I'm not going to argue that. But what we have is this data. This is what was given to us; this is what we have to work with.

DR. WALLIS: But is it good enough?

MR. ANDREYCHEK: I think it is, and bear with me and I think you will see why.

DR. WALLIS: Let's suppose the 10 percent were .15 inches, or bigger. Would that concern you?

MR. ANDREYCHEK: I think the answer is, no, it wouldn't. Based on the data we've seen; bear with me, please.

CHAIRMAN BANERJEE: Why don't we note that as a point to be addressed, and now let's move on to this table. Don't go past this table.

MEMBER SHACK: This table is the data that the plant supplied you?

MR. ANDREYCHEK: That's correct.

MEMBER SHACK: Their estimate of what bypasses their screens?

MR. ANDREYCHEK: That's correct. And typically three categories were used, depending on the vendor. This is what was reported to us.

CHAIRMAN BANERJEE: I guess what we are asking is, when you are presenting us this data from the plants, what stage of their filtering with these sump screens was this data taken at? Because what is of importance is what gets through in the very early stages. Is this when it is late stage? Or an early stage? I guess one needs to qualify this.

MR. DINGLER: It was taken on a periodic like every 10 minutes, every 15 minutes, periods, it was taken, a sample was taken and collected.

CHAIRMAN BANERJEE: So is this data available for us to take a look at? Could you make it available?

MR. DINGLER: We can't make it available. You can ask the NRC.

CHAIRMAN BANERJEE: Right, right. I mean can you make it available so we can eventually look at it via NRC, or via DFO or via whoever it is.

MR. DINGLER: That's got to go through the NRC. I can't make it available.

CHAIRMAN BANERJEE: You can't make it available to the NRC?

MR. DINGLER: As the owners' group I cannot, no.

CHAIRMAN BANERJEE: Unless they send you a request for it?

DR. WALLIS: It occurs in one shot. I mean you get the stuff coming along, you've got a shot at bypass, and then you get a filter built on the screen and there is no more bypass is my understanding.

MEMBER SHACK: But his argument was, this was a cumulative number. So 90 percent of it probably was on the first pass, but he's got it summed over the 20 passes, so at least it's a conservative number from that point of view.

CHAIRMAN BANERJEE: Okay, that makes sense. So these are numbers which are somewhat -

MR. DINGLER: What they did was, they individually measured each length.

DR. WALLIS: So if the operator back flushes the screen, then do you get another shot at bypass the next time he turns the pumps on?

MR. DINGLER: I can't comment on that, because we haven't done any tests on that.

DR. WALLIS: That's exactly what happens.

MR. GEIGER: This is Erv Geiger. Just one clarification. In the licensee submittals on this topic, typically under the downstream effects, they do address the bypass that they've measured and so on and the distribution of particle sizes and so on. So we do get that information, and if we don't we can issue an RAI to get an idea of exactly what kind of a fiber bypass they had and particulate and all fo that. And we have been seeing that.

DR. WALLIS: You don't have active screens that clean themselves. Because as they clean themselves, they make more bypass.

MR. GEIGER: And I don't think anybody has taken back flush as a credit for anything, so.

CHAIRMAN BANERJEE: Okay. Well, let's assume that these are relatively conservative numbers. We can revisit it later on.

MR. ANDREYCHEK: Okay, thank you.

MR. DINGLER: Here is where we start talking bypassing. Do you want to continue on this or stop for lunch?

CHAIRMAN BANERJEE: I think what we want to do probably is we'll break for lunch when you finish the bypass part of it, and wait until after lunch for the testing.

MR. DINGLER: Okay, I just wanted to make sure how far you want us to go.

CHAIRMAN BANERJEE: That will be a good point to break.

MR. ANDREYCHEK: This slide show the bypass data that was reported to us by licensees. Thirty one or so licensees have reported that they get under two-tenths of a pound fiber bypass per fuel assembly.

DR. WALLIS: One pound per fuel assembly.

MR. ANDREYCHEK: Say again.

DR. WALLIS: One pound, which is about half a cubic foot or something.

MR. DINGLER: And what we found is that the high - the one pound and over one pound was assumed or calculated but not actually tested. So we are going back -

DR. WALLIS: That is a lot of -

MR. DINGLER: And when you look at the total data that we got, it looks out of place, very out of place.

MR. ANDREYCHEK: If you look at a frequency distribution, that one sticks way out on an end somewhere.

MR. DINGLER: Anything over about point three, point five, gets out of range; point six, somewhere in there.

CHAIRMAN BANERJEE: This is total fiber, correct?

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: But now there is this group D, which seems very different in some ways from your other groups.

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: Right? With much shorter fiber. What is this - are there certain characteristics to these plants which make for shorter fibers?

MR. ANDREYCHEK: I'd have to go back and look at the details on that. I don't have that information right at hand.

MEMBER SHACK: I mean they don't use some particular distinctive sump screen design that you know of for example?

MR. ANDREYCHEK: Again, it's been awhile since we put this together. I would be speaking out of turn if I gave you something. I'd rather not; I'd rather check it and get back to you.

MEMBER MAYNARD: We don't know whether it's a plant design or a screen design.

CHAIRMAN BANERJEE: And how much insulation you have, what type of insulation you have, there are all sorts of things.

I guess what would be useful to us at least is to give us some characteristics of what A, B, C, D, E, F are. I mean, not R, the alphabet R. Are they some of these low fiber plants? Are they using very peculiar screens or different screens? That would be very useful to know?

DR. WALLIS: Or a different mixture just to break up the fibers.

CHAIRMAN BANERJEE: Also, you know, when you are looking at this distribution without solid distributing them over the type of screens being used, there are low bypass screens being used, for example. Are they pretty low bypass screens. You know there are different designs, so there should be some correlation.

For example, that over one pound could be particular to a certain type of screen.

MR. DINGLER: I can speak to those, because we did calculate for thin list screens to manufacture, because we didn't have all the information. But we did look at in our survey was it calculated, was it actually measured, or did they use some other method. And they listed those. And the ones that are over the one was not the actual calculated, and they didn't take tests. They were assumed for by another method.

So we do know those, and that's why I feel comfortable saying to you guys, those are outliers and we have to go back and talk to them.

CHAIRMAN BANERJEE: Right, now on this A, B, C, D, whatever, I don't know exactly how you delineated these plants. Maybe they are by screen type, or by screen type and debris type.

MR. DINGLER: To be honest with you it's when we received the data.

CHAIRMAN BANERJEE: Yes.

MR. ANDREYCHEK: It's by plant, not by screen manufacturer or anything else. It's just Plant A came in first, so they got to be the first one on the table.

CHAIRMAN BANERJEE: So D is just there -

MEMBER SHACK: Fourth guy on the list.

(Laughter.)

CHAIRMAN BANERJEE: I see. So it would be useful at least then if you could also put in this table how much bypass they found. It would be useful to know what A,B,C,D were. Were they low fiber plants? Was there some particular screen design? And then how much bypass, to understand the correlation if any between these numbers.

MR. ANDREYCHEK: We have used it, but we didn't present it.

MEMBER MAYNARD: I think specifically to know what's different about the D group. It doesn't matter - what's unique about it.

CHAIRMAN BANERJEE: Right, we need to understand where this stuff is looking so different.

MR. ANDREYCHEK: I understand.

Okay, we go to particulate survey. We are looking again at particulate mass per fuel assembly. Typically we were looking at less than 14 pounds per fuel assembly, something like 36 plants came in between 14 and 25 pounds. We had two plants greater than 25 pounds, or two plants.

The reason we put it in this context was to give you an idea of the frequency distribution that we were looking at, and where the plants tend to come in at.

And also we used this to identify which plants we need to go back and talk to and say, well, how did you come up with these numbers? What did you do here? And realized that this is going to affect you.

MEMBER SHACK: It seems like enormous numbers again.

MR. DINGLER: We had one plant had 110 per assembly.

MR. ANDREYCHEK: A hundred and ten pounds per assembly.

MR. DINGLER: It was assumed.

CHAIRMAN BANERJEE: Now you are looking at - I need to go back to this table. The A to F, they are simply, one two three - these are just seven plants that came in.

MR. DINGLER: We had 50; we didn't have room to give everything.

CHAIRMAN BANERJEE: So this is just a sample?

MR. ANDREYCHEK: That's correct.

DR. WALLIS: A hundred a ten pounds per assembly wouldn't fit in your test loop, would it?

MR. ANDREYCHEK: We'd need a sludge pump.

CHAIRMAN BANERJEE: Okay, I think this might be a good time to take a break, since it's 12:30.

MEMBER SHACK: I think these guys are smoking in there.

CHAIRMAN BANERJEE: You are not allowed to smoke in these plants. So I think we will break now.

DR. WALLIS: Are we off the record?

CHAIRMAN BANERJEE: No, we are not off the record yet. So let's go off the record.

(Whereupon at 12:32 p.m. the proceeding in the above-entitled matter went off the record and resumed at 1:17 p.m.)

AFTERNOON SESSION

(1:17 p.m.)

CHAIRMAN BANERJEE: So let's go back into session. And you're up, both of you.

MR. ANDREYCHEK: Thank you.

When we broke for lunch, we were just about ready to start discussion data. We've showed the slide -- what did you do there? There you go.

We showed the two slides previously of the overall test facility for debris capture of fuel assembly, and then the closeup of the bottom nozzle.

So if you can go to the next slide.

MR. DINGLER: I'm on sheet 41.

MR. ANDREYCHEK: Forty-one is all right. Everybody okay with that? Okay.

The two tests that we ran that we are discussing today, we tested a low particulate, low fiber plant, and a high particulate, low fiber plant. The scaling was based on 193 assemblies in the core. Again, hot leak flow rates of approximately 8630 gpm, a total particulate mass to the bottom of 180 pounds mass for the low particulate case, 270 -- 2700 pounds mass for the high particulate case.

Fiber mass was 22.2 pounds -- 22.5 pounds for both cases, and the total chemical precipitate mass was 28 pounds mass for both cases.

MEMBER MAYNARD: You say scale. You actually have like 28 pounds mass?

MR. ANDREYCHEK: Total for the core.

MEMBER MAYNARD: For the core?

MR. ANDREYCHEK: That's correct.

MEMBER MAYNARD: And for one assembly --

MR. ANDREYCHEK: Right. And the next page is going to show you the scaled down version.

CHAIRMAN BANERJEE: Is that divided by 193?

MR. ANDREYCHEK: That is correct. That's why we have the 193.

MR. DINGLER: And then made it into grains?

MR. ANDREYCHEK: That's correct. There's an additional --

MEMBER SHACK: I was going to ask you guys, you still using pound mass?

MR. ANDREYCHEK: Well, for the fiber and for the chemical, but for the particulate, since it was so large, we kept it at pounds mass.

For the particulate in the first case, we're looking at 3 pounds mass per assembly, or modify that by 454 grams to come up with it.

Fiber was 53 pounds -- 53 grams -- see, you've got me confused now.

In both cases, in the chemical was 66 grams in both cases.

The flow rate per assembly for this assembly is 44.7 gpm. Which material was added. We added the particulate first. In the case of the three pound mass case, it was added one slug.

Now the way it was added was we took the three pounds, mixed it in fluid, and added fluid to a recirculation tank. The total volume of fluid in the facility is approximately 250 gallons. So we mixed -- took some of the fluid out, mixed the three pounds of mass, put it back into the facility, so it was already somewhat dispersed. It wasn't clumped, it wasn't a big dry mass that was added. It was already in solution, and that kept it from agglomerating.

In the second case, the second test, we used four additions of three pounds mass, again doing the same type of a mixture, taking some of the fluid from the facility, mixing it up, and then adding it back in, so we would not agglomerate the mass, the particulate mass.

DR. WALLIS: All this was done before you put the fibers in?

MR. ANDREYCHEK: That is correct.

DR. WALLIS: All right.

MR. ANDREYCHEK: All the particulate was added, and the facility allowed to recirculate several times before we started adding fiber, so we had a good mixture of particulate throughout.

MEMBER ABDEL-KHALIK; I'd like to go back to the issue of internal consistency of these calculations that was raised earlier.

At this flow rate of roughly 45 gallons per minute per assembly, 20 minutes after the reactor trip, you're not going to get any boiling from that assembly.

MR. ANDREYCHEK: You may not. You're probably correct, yes.

MEMBER ABDEL-KHALIK; So that the driving pressure difference will be significantly less than whatever the value that you calculated for the hot leg break and for the cold leg break, the 14-1/2 or the 2-1/2.

So how do you reconcile these analyses? How do you make them internally consistent?

MR. ANDREYCHEK: Let's deal with -- you were dealing with the hot leg flow rate, okay. And for the hot leg flow rate, flow case, we are assuming -- we agree there's no boiling. So what we're looking at is the elevation head difference between the top of the steam generator and the hot leg. That's -- excuse me, or the bottom of the core. That's the delta P that we're dealing with. We're not dealing with boiling. We're just saying given that you're having hot leg -- have a hot leg break, all of the flow from the ECCS must go through --

MEMBER ABDEL-KHALIK; That's a gravitational pressure difference between the hot leg and the cold leg?

MR. ANDREYCHEK: Not for a hot leg break.

MEMBER ABDEL-KHALIK; Okay.

MR. ANDREYCHEK: Not for a hot leg break. Basically for the hot leg break, let's assume -- let's see if we can draw a simple analogy.

Fundamentally for a hot leg break, you've got a flow in the core and the break.

MEMBER ABDEL-KHALIK; Right.

MR. ANDREYCHEK: Okay. Now whatever comes in is going to go out the break. When you begin to build up a resistance to flow at the end of the core, such that you have a surplus of flow compared to leaking it out the break, because you are basically just dealing with form loss is getting out the core with the hot leg break, and then flow around and back out again at whatever flow rate.

When you begin to build up a resistance at the entrance to the core, you've got to ask yourself where's the water go? And for a hot leg break, the water has got to go into the cold leg, build up in the cold leg and start to go up into the steam generator, and that's the 13 or 14 psi we're talking about. The water head that builds up to the top of the U-tubes in the steam generator.

CHAIRMAN BANERJEE: There are two comments on that, of course. One is that that head is not available to the core; right?

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: Second, even if it is completely blocked, what I was saying was that it would -- it's a very uneven phenomena because you'd have a few of these tubes which are at the lowest elevation.

MR. ANDREYCHEK: Uh-huh.

CHAIRMAN BANERJEE: Would spill over. Now I don't know how high this flows up, but my feeling would be that once they spilled over, let's say one tube, for example --

MR. ANDREYCHEK: Okay.

CHAIRMAN BANERJEE: -- I think you would get that tube full on both sides, you know. It's -- it depends on the flow rate, but if it was one tube, I'm pretty damned sure you'd get it full on both sides, so the head would vanish.

Then you'd have to establish that you would not really -- you just use that flow path, and you would activate another tube and push stuff up.

You see what I mean? It's not that obvious to me that you can count on that head. But I haven't sat down and looked at it.

MEMBER MAYNARD: The thing -- it's really -- since you have a hot leg break, it's the top of that tube at the top of the bend is cut off there. The water is just spilling out at that point. It has to be spilling over the tube and down into the hot leg.

CHAIRMAN BANERJEE: Let's say you fill up one or more tubes. The one that goes over the top establishes the flow. Now depending on the flow rate, you might be filling the down side as well as the up side. And I haven't sat down and looked at what is the flow rate to keep the tube full on both sides.

You see what I mean?

MR. ANDREYCHEK: Yeah.

CHAIRMAN BANERJEE: If it's only one tube, you just fill the tube on both sides.

MEMBER MAYNARD: But still you're going to have that -- they're just looking at what is the pressure available at the bottom of the core. So even if it fills both of them up or the -- still the driving head at the bottom of the core is going to be on the bottom of the debris bed. Not necessarily the pressure on the core, it's what the pressure is at the bottom of the --

CHAIRMAN BANERJEE: All I'm saying is the driving head -- see, the reason you're filling this is there's nowhere to go. So once it starts over one tube and it starts to go, it will drop on all the other tubes; right? And this tube will be just filled. And it will give you a flow path.

MEMBER MAYNARD: But that leg is open to the --

CHAIRMAN BANERJEE: The down side won't -- it may be full. I have to sit down and do the calculation, look at the true numbers and stuff, but it could be that all you've got is a couple of tubes siphoning, and the pressure is down. You see, this is the argument I was making; right?

MEMBER MAYNARD: You're talking about other gpm. So it's certainly going to fill those tubes.

CHAIRMAN BANERJEE: Yes. So it just -- I can't sit down and work out -- it would seem to me that the determining thing is the pressure drop through those tubes. If you have, let's say, four or five tubes of this elevation, sit down and do the calculation. I haven't done it. That's why I was saying that once we sit down and do it, we figure it out.

MEMBER MAYNARD: Once it goes out through here, comes up back here, recycles and comes out, it will go out --

CHAIRMAN BANERJEE: It will rob the break, but you can -- I'm just saying what is -- how many tubes would be filled on both sides? So let me give this argument.

Initially it starts to fill; okay?

MR. ANDREYCHEK: Right. Uh-huh.

CHAIRMAN BANERJEE: That's true. Okay? Now one or two tubes start to go. I've done this reflux condensation test myself.

MR. ANDREYCHEK: Uh-huh.

CHAIRMAN BANERJEE: So I know what

happens.

MR. ANDREYCHEK: Sure.

CHAIRMAN BANERJEE: You fill them, you spill, and both sides get full, and you just establish a siphon. Now it just drops. So you're getting flow out of there. Instead of going through the core, it's happily going through this spot and out of the break. The head is not going to be affected. You see what I mean? It's just a siphon.

DR. WALLIS: If you can establish a siphon. What they're hoping is that you'll never get high enough to get the spillover.

MR. ANDREYCHEK: And what we've said is that the limit on the pressure drop is the point where we begin to spill over. That's the limit on the pressure drop.

DR. WALLIS: Not necessarily because you fill the siphon.

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: Yes, once you get it over the top, the pressure drop will just drop -- zap, to zero. Whatever is the pressure loss in that tube. At least that's the way I see it. That's the argument I was making.

MR. ANDREYCHEK: You create a scenario

that that might well be the case, and we've set out -- we've established a limit that says we're not going to get there. This is our limit. This is the pressure drop.

CHAIRMAN BANERJEE: So the point is this. Let's say you had a complete cold blockage. At some point you're going to siphon those tubes because the water has nowhere to go.

MR. ANDREYCHEK: Well, what you're saying, you're going to fill, you're going to spill because you can't get water into the bottom of the core. We would agree. If you've got complete blockage at the bottom of the core.

CHAIRMAN BANERJEE: Now what you've done is you've activated an alternative flow path --

MR. ANDREYCHEK: We agree.

CHAIRMAN BANERJEE: -- which is just siphoning away happily, and you'll get no significant pressure loss other than the pressure loss in that tube itself.

MR. ANDREYCHEK: Well, I would suggest that what you've got is a head loss and you're driving water up, and it comes down, out the tube. Now if you've got a three-loop or a four-loop PWR, or whatever, two-loop PWR, what you're going to have is certainly whatever is in the -- whatever flow is given to the broken leg will flow out the broken hot leg. But the rest of the water isn't -- has to go into the upper plenum and then is available --

CHAIRMAN BANERJEE: But, you know, what will happen is that -- I've done this experiment, that's what I'm saying. It will -- as you have given it a low resistance flow path --

MR. ANDREYCHEK: Uh-huh.

CHAIRMAN BANERJEE: -- the water will just go through there. It won't go up the other things at all.

MR. ANDREYCHEK: We agree.

CHAIRMAN BANERJEE: It won't go anywhere.

MR. ANDREYCHEK: We agree. But we're not getting to that point. We're not establishing the siphon in effect. We're staying below that.

CHAIRMAN BANERJEE: With a complete flow blockage, you will.

MR. ANDREYCHEK: But we are not getting a complete flow blockage. That's what we're arguing against. We're not going to get there. We're setting limits for the amount of debris that could be put into the core such that we don't exceed the pressure drop.

What you are suggesting is beyond the

limits that we're setting, and we don't want to go there. We want to set limits so that we don't get there.

CHAIRMAN BANERJEE: Well, obviously, we would like to see the core not being blocked.

MR. ANDREYCHEK: That's correct. And that's what we're saying, we want to make -- our limits establish conditions for debris that preclude us from blocking the core.

CHAIRMAN BANERJEE: Well, what I think Said, me, all of us are arguing is that maybe for a period you might get this high head, but it's not a -- once you get that, it's not sustainable, you see. What would happen is that, yes, you might drive the head up if you really block the core. Then you'd just get alternative paths which would give you a low head path.

Now this is for the hot leg break; right?

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: What happens with the cold leg break? Are the tests of much less pressure drop available?

MR. ANDREYCHEK: Yeah.

CHAIRMAN BANERJEE: So are you going to talk about that as well?

DR. WALLIS: There's much less pressure drop there, too.

CHAIRMAN BANERJEE: Yes.

MR. ANDREYCHEK: It went from 97 percent there -- or 94 percent, two-thirds of debris that's recycled, and that's the -- we have not -- the test program says that the hot leg break gives us the worst case for debris deposited into the core, and that's what we're looking at.

CHAIRMAN BANERJEE: The highest flow rates?

MR. ANDREYCHEK: The highest flow rates, the highest potential for depositing debris in the core, for matching the core boiloff, the amount of time that it takes to get debris into the core is much longer.

CHAIRMAN BANERJEE: Let's do this, because I think we are not going to solve this problem now. I think we need to take a look at different scenarios, cold leg and hot leg, and see really which is the limiting situations and it may well be that this is it. But there could be alternative scenarios which could give you worse situations. It's hard to know even if you're throwing out a certain percentage of the debris or the cold leg. It may still be in a situation because of much lower head that you could be more -- I don't know. I'm just saying it's what looking at these scenarios in some, you know, quantitative way to make sure.

And even with the hot leg break, if you truly do get complete blockage, you've got a low resistance flow path eventually that will be established over the area tube and you'll just get --

DR. WALLIS: He's already agreed he's got complete blockage instead. It's not that; he doesn't want to get there.

MR. ANDREYCHEK: That's right, we don't want to get there.

CHAIRMAN BANERJEE: But then there's the question of what is that amount of blockage which will give you the flow. You know, that's the issue there.

DR. WALLIS: And that's what the testing is for.

MR. ANDREYCHEK: Exactly.

DR. WALLIS: So that debris loading will always keep us below that.

CHAIRMAN BANERJEE: Well, I don't think you do, because you get water coming in from the top.

MR. ANDREYCHEK: Right. And then we get into a countercurrent flow-limiting situation.

CHAIRMAN BANERJEE: So that's at these heat rates?

MR. ANDREYCHEK: That's right.

CHAIRMAN BANERJEE: And you are not going to get necessarily water coming in because all you will activate is the steam generator connected to the hot leg, and all your water is just going to go out of the hot leg without going through the core.

MR. ANDREYCHEK: But you've got more than one hot leg. At least two legs.

CHAIRMAN BANERJEE: It doesn't matter. You have no driving pressure to get it up the steam generators. Once you establish a siphon, zap, everything falls.

DR. WALLIS: But then it comes back over the siphon to the other hot leg.

CHAIRMAN BANERJEE: It depends. It will only go out of the steam generator -- well, never mind. We'll sit down and work the scenario.

MR. ANDREYCHEK: Okay. We're getting back to the data now.

DR. WALLIS: Your scenario is not really very complete.

CHAIRMAN BANERJEE: We don't know if it is. I think what we have established is please look at --

MR. ANDREYCHEK: Okay.

MR. DINGLER: What we have, we just don't have the data.

DR. KRESS: If they stopped their calculation short of that head, say chose seven feet or 10 feet, then you don't have to worry about spillover, unless your fluctuations in flow are greater -- see, if you've got fluctuations in flow and you stop just at that very top, you are going to spill over, and set a siphon up, I think.

CHAIRMAN BANERJEE: It's going to be exactly what I said.

DR. KRESS: Yes, I know, but I think for some margin, you have to stop that head a little short of that point.

CHAIRMAN BANERJEE: To me what would be satisfying is to take the 1 psi that you have available on the cold leg break, take all the debris through the core and show it works.

DR. KRESS: Ah, you can't beat that.

CHAIRMAN BANERJEE: If you do that, it seems a nice limiting scenario.

DR. KRESS: Yes, I agree.

CHAIRMAN BANERJEE: You know, then we

don't have the screw up -- sorry, fuss around with all this stuff.

MEMBER ABDEL-KHALIK; You know, the 8630 gallons per minute, that's the runout capacity of the pumps?

MR. ANDREYCHEK: Pretty much so, yeah.

MEMBER ABDEL-KHALIK: So let's say the core is not fully blocked, but partially blocked, and you're injecting water into the cold leg, so some of it will go through the core and out through the hot leg, and some of it will actually go into the steam generator tubes.

MR. ANDREYCHEK: Okay.

MEMBER ABDEL-KHALIK: The question in my mind is so you have two parallel paths in this case that the pump is feeding, and the question is what is the relative flow rate between the two under various blockage conditions.

MR. ANDREYCHEK: Well, first off, when you say what's the relative feeding tube path, the steam generator acts like a holding tank, as it were, to take some of the flow that can't be passed through the core. It's building up, if you want to look at it this way, perhaps -- bear with me on this -- gradually. It's not feeding two paths that are dumping out to the environment.

MEMBER ABDEL-KHALIK: Why not?

MR. ANDREYCHEK: Because you're not feeding over the steam generator at that point. You haven't filled up the steam generator.

MEMBER ABDEL-KHALIK: I mean you have one entry point --

MR. ANDREYCHEK: Uh-huh.

MEMBER ABDEL-KHALIK: -- and one exit point, which is the hole.

MR. ANDREYCHEK: Okay.

MEMBER ABDEL-KHALIK: And you can get to the hole in one of two ways: going through the core, out through the upper plenum, out through the hot leg and out through the break; or you can go through the core by going cold leg into the steam generator, out the hot leg, back into the break.

MR. ANDREYCHEK: If there's a sufficient amount of resistance in the core, and we're saying we're going to limit the resistance at the core entrance so that we don't get there.

Yes, you'll build up some water, but if you don't get there because you can't feed it, there's not enough resistance at the core entrance, then you don't get to that point.

CHAIRMAN BANERJEE: I think what -- to sort of move on, say, I think the point has been made that we need to explore a number of scenarios and look at what is really the bounding scenario.

Now it could be that this is truly bounding. The one that could be intuitively bounding would be, as I said, just to take that -- take a void fraction of essentially zero -- zero, I would say, if you really want to bound this, which gives you a pressure loss of -- available pressure head of 1 psi or something, and put all your debris in, and if it works, then we are all happy boys or girls. Right?

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: It may not need very much more than that. Or at least that's my feeling right now, but it needs to be dealt with in a considered way.

MR. ANDREYCHEK: Okay.

CHAIRMAN BANERJEE: Looking at all the scenarios and looking at what might be a bounding scenario. Bounding set of scenarios, if you wish.

MR. ANDREYCHEK: Okay.

CHAIRMAN BANERJEE: Let's move on from that.

MR. ANDREYCHEK: Okay.

CHAIRMAN BANERJEE: And there will be -- sorry.

DR. WALLIS: What was the pressure drop in these two types?

MR. DINGLER: We cannot give that information out --

DR. WALLIS: But you can see it's under 13?

MR. DINGLER: Yes.

DR. WALLIS: But you only need 2-1/2 for -- you've only got 2-1/2 for the cold leg break?

MR. DINGLER: We need 14 for -- 14 is the max. For a hot leg break. If we close this as proprietary, then we can give you the information.

DR. WALLIS: But you said you need 2-1/2 for the --

MR. ANDREYCHEK: For the cold leg break.

MR. DINGLER: This is hot leg.

DR. WALLIS: So this would block the cold leg break?

MR. ANDREYCHEK: Yes, it would.

MR. DINGLER: If we had cold leg flows and stuff like that. Yes.

DR. WALLIS: And you can't tell us how much it's under 13?

MR. DINGLER: We can if we close the meeting.

DR. WALLIS: And you can't tell us which of them was higher?

MR. DINGLER: We've got to close the meeting.

CHAIRMAN BANERJEE: Well, if you like, Graham, what we can do is let them run through the presentation --

DR. WALLIS: You can tell me personally, can't you?

CHAIRMAN BANERJEE: No, no, we are going to --

(Laughter.)

CHAIRMAN BANERJEE: -- close, if you wish.

DR. WALLIS: Can you tell me personally?

CHAIRMAN BANERJEE: What I suggest is we try to finish a little bit earlier and I'll close the meeting for 15 minutes, then you can give us --

MR. DINGLER: I apologize, but --

CHAIRMAN BANERJEE: That's fine, but this is proprietary. Whatever. We'll take care of it, okay?

So what we want to do now is to talk about your observations for this set of tests, noting that there could be other scenarios.

MR. ANDREYCHEK: Okay. So what we observed was that we had seen that behavior -- we did not observe that. The fiber provides certainly collection sites for debris, and from what we observed, it appears to be the driver for the head loss that we observed.

Specifically we noticed almost no head loss increase when we flipped the particulate, in even the high particulate case.

The chemical precipitates tended to behave as another source of particulates. The initial results would indicate to us that the chemical precipitates did not increase head loss.

DR. WALLIS: Now did all the fiber get -- clog the holes? Did all the fiber end up in the holes?

MR. ANDREYCHEK: Actually if you take a look at the very last bullet, it says it as though the fiber appears to be distributed in grids along the height of the bundle. So it --

DR. WALLIS: So it didn't get all stuck at the bottom?

MR. ANDREYCHEK: It did not.

MR. DINGLER: Let me show the picture

again.

DR. WALLIS: Well, that's an important observation if anyone is going to calculate anything. They need to know where the fibers go.

MR. ANDREYCHEK: That's right.

MR. DINGLER: Based on two tests.

DR. WALLIS: Do you have any photographs of where the fibers were or anything? Did you take any --

MR. ANDREYCHEK: That's what I'm going to show right here in this picture. What we saw, we certainly saw fibers down here at the bottom surface and in the hole. We saw fibers on the protective grid. We saw some fibers here at the first grid, fibers here, fibers here, fibers here, and some, a little bit lesser, perhaps, fibers up here at the very top.

There tended to be -- when we have -- when we go to look, we did an optical probe that we could insert into the bundle. But when we began to remove some of the fuel rods simulations to look inside the bundle, it appeared to us that there was a reasonably equitable distribution of fiber and particulate and chemical surrogate material throughout the bundle.

Now there was also some particulate that stayed in solution, and I believe one of you gentlemen asked about gap, and we modeled the gap at the bottom nozzle as it would be in the plant. And the gaps between the grid straps all the way up the height were modeled as they would be in the plant. And so what we see is bypass flow up through some of those gaps. As you begin to collect the one flow restriction, you begin to -- you know, fiber bypasses and particulates bypass, and you go to the next one, and so on and so forth.

CHAIRMAN BANERJEE: Do you have any pressure taps on these walls?

MR. ANDREYCHEK: Yes, we do.

CHAIRMAN BANERJEE: You can actually look at the pressure losses.

MR. ANDREYCHEK: Yes, we have.

CHAIRMAN BANERJEE: Yes. And tell where the stuff is going; right?

MR. ANDREYCHEK: Yes, we have.

MR. DINGLER: And that's the data that we're still evaluating.

MR. ANDREYCHEK: That's correct.

MEMBER SHACK: Now let me just get the sequence. You add the particulates first, and what do you see happen just at that point?

MR. DINGLER: Very little head loss.

MR. ANDREYCHEK: That's correct.

MR. DINGLER: Almost zero.

MEMBER SHACK: Okay, and now it's recirculating in the tank. That's correct. Now you dump the fiber in.

MR. DINGLER: That's right. And our head loss starts increasing.

MEMBER SHACK: Okay.

MR. ANDREYCHEK: And if you notice on slide 42, we start adding fiber in small batches. We're looking at five grams a pop, let the loop turn over a couple of times. We add another five grams, and then another five grams, and then another five grams. We do that eight times, and then we add a little larger, it's 13 grams -- 13 grams -- to get us to total fiber mass addition. And that allows us to build up -- we were looking again -- the reason --

CHAIRMAN BANERJEE: These are relatively low fiber plants then; right?

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: Okay.

MR. ANDREYCHEK: That's correct. Now we did -- the last test we ran, we haven't had a chance to reduce the data, used about 90 grams of fiber, a little higher amount of fiber.

CHAIRMAN BANERJEE: And how much pressure loss are you getting, frictional pressure loss due to the increase in pressure loss, if you like?

MR. ANDREYCHEK: Well --

CHAIRMAN BANERJEE: Can you say that, or is it proprietary?

MR. DINGLER: It's proprietary.

CHAIRMAN BANERJEE: Okay.

MR. ANDREYCHEK: Sorry. I just wanted to give you --

CHAIRMAN BANERJEE: No, that's fine.

MEMBER ABDEL-KHALIK: Does this loop have a PD pump?

MR. DINGLER: What do you mean by a --

MR. ANDREYCHEK: Positive displacement?

MEMBER ABDEL-KHALIK: Positive displacement pump.

MR. ANDREYCHEK: No, it does not.

MEMBER ABDEL-KHALIK: So it's a centrifugal pump?

MR. ANDREYCHEK: Yes, sir.

MEMBER ABDEL-KHALIK: So how do you control the flow?

MR. ANDREYCHEK: We control the flow by

using a flow restriction that tightens down on the flow path so that we are not chewing things up any further in terms of -- or clogging a valve, or if we have for a flow measurement device, we're using a magnetic flow device, so we don't have a turbine meter that will get clogged by fiber.

MEMBER ABDEL-KHALIK: And presumably these are constant flow rate experiments; right?

MR. ANDREYCHEK: That's correct.

MR. DINGLER: And we maintain -- tweaked the things so it maintains constant.

MR. ANDREYCHEK: That's correct. There's a flow restriction on the feedback loop that allows the restriction to open up in the flow path such that it does not restrict flow, and we maintain a constant monitor flow, and we track it and see if the flow remains constant over the test.

CHAIRMAN BANERJEE: There's not a -- there's no bypass flow around the pump?

MR. ANDREYCHEK: No. No. There is a pump to keep things in the 200 or so gallon mixing tank in solution so we don't get settle-out in the tank, but that's separate from the circulation through the test facility proper.

DR. WALLIS: At the end of the test, all

this material is trapped, is it? There's no more circulating around, there's no --

MR. ANDREYCHEK: No, there's still particulates through the system.

DR. WALLIS: So it's still going around at the end of the test?

MR. ANDREYCHEK: Uh-huh. And there still may be some fiber in that.

DR. WALLIS: Do you have a measure of that?

MR. ANDREYCHEK: No.

DR. WALLIS: So we don't know how many got caught and how many are still going around?

MR. ANDREYCHEK: No, we don't have that measure, no.

MEMBER SHACK: And when you add the chemical particulate, you don't really see any significant pressure increase over what you got from the fiber?

MR. ANDREYCHEK: We have not. In fact, what we've seen is --

MR. DINGLER: We've seen a little, but not much. You know, what you saw was a big jump, we're seeing -- well, it starts leveling off before we add the chemical and it just slightly then levels off again, so we see no --

MEMBER SHACK: Is this just going up as bypass flow on the sides of the --

MR. DINGLER: It may. Based on what we're seeing, I don't think so. In other words, you can see some of that what I was told in the filters and stuff like that, so.

MR. ANDREYCHEK: In fact, in some of the cases we've seen actually a pressure decrease when the chemicals are added. The pressure drop actually went down.

MR. DINGLER: And some of this we saw in the big sump screens, too. When you added a particulate first, then the fiber, the chemical in the limited number of tests I saw, five, six or 10 of them, had very little sharp increase. If you add the fiber first, we saw a big increase within the chemical. So it looks like on that that it's the particulate and fiber. There are still increases ahead, but it's still -- we didn't see that big jump that we saw with the one that you saw.

DR. KRESS: How do you explain the decreased pressure?

MR. DINGLER: We're still evaluating the data. We can't right now.

MR. ANDREYCHEK: It's a good question. We asked the same question.

DR. KRESS: Of course you would.

CHAIRMAN BANERJEE: But you saw that you also see it on the sump screens?

MR. DINGLER: Saw what?

CHAIRMAN BANERJEE: The same sort of behavior on some sump screens.

MR. DINGLER: Yeah.

CHAIRMAN BANERJEE: When you added the chemical particulate, did the pressure drop actually way down?

MR. DINGLER: No, we saw not a steady increase.

CHAIRMAN BANERJEE: I see.

MR. DINGLER: A sharp increase. In other words, again, I've only seen five to seven, five to 10 sump screen tests, and when you add the fiber or the particulate first, then the fiber, the chemical didn't show a big increase. That's what I've seen in five to 10 tests.

CHAIRMAN BANERJEE: Paul Klein, do you have a comment to make?

MR. KLEIN: Paul Klein. I just wanted to make one observation that we've seen in some of the strainer tests when you add the precipitate. You can get bad redistribution during that process and it can affect head loss. So it's possible that you might open bore holes, for example, in the bed, or if you don't have -- I think in some of these low fiber initial tests, you may not have an effective filtering bed for chemical precipitate, so you can add it, but the fiber might already be saturated with some of their earlier particulate, and they're just not much effect compared to the ANL test loop.

MEMBER ABDEL-KHALIK: So if you have a flow anomaly in the lower plenum, does that mean that single bundle experiments may not be representative of what happens in the whole core?

DR. WALLIS: Well, probably the answer is yes. Now if you have -- in your test, did you get a uniform distribution across or did you get some of these holes essentially open because of this bore hole phenomenon? I would wonder if you can get a really unifom --

MR. DINGLER: We didn't see the bore holes.

CHAIRMAN BANERJEE: Can't see?

MR. DINGLER: We can't see them, that's right. But based on when we pulled it out, there are some tests that the NRC will give you that saw more of a uniform compaction bed on the bottom of the -- on the bottom nozzle that it passed around than what we're seeing.

DR. WALLIS: When you pull it out, it's like pulling out a piece of felt, is it? Or what is it?

MR. ANDREYCHEK: Actually, in order for us to disassemble the facility, we -- the rig is set up so that we actually pulled the entire assembly out of the flow chamber, and then we lay it down sideways so we can begin to disassemble it.

What we've -- let it set overnight so that water drains off and whatnot, so we don't basically draw suction and pull stuff off of it. We try to do -- be as reasonable as we can at pulling it out, but what we see is that some of the material stays in place on the bottom. Is it all the material that's there at the end of the test? I couldn't tell you for sure. I don't know. Again, we can't see into the facility.

CHAIRMAN BANERJEE: But it's not compacted like into a felt?

MR. ANDREYCHEK: No, not that we saw so far on the three tests.

CHAIRMAN BANERJEE: But I think we've seen some tests where it was --

MR. GEIGER: What we pulled out from the holes, it was like little clumps of felt, like little cylinders of felt, and even around the upper parts you could -- you know, it is like clumped up -- clumped to get the fibers fairly tightly so it was like felt, and it was just filled with particulate and things, too. But I mean if you looked at the eddy currents and things, I mean there were currents going every which way through the fuel and around it.

CHAIRMAN BANERJEE: But it wasn't blocking up all layers -- were all layers blocked?

MR. GEIGER: It looked like it has a uniform layer across it. Yeah. Because unfortunately we don't have photographs, but it was all -- because the carbide is a very gray material, so it was a very uniform gray. It almost looked like somebody had spray painted it with, you know, a gray paint.

CHAIRMAN BANERJEE: Yes, it would be nice to see some photographs of things, but I'm sure you're in the early stage now.

MR. ANDREYCHEK: Yes.

CHAIRMAN BANERJEE: You're seeing these things.

So let me understand what you are observing. You do some visual observations after the tests are finished. You do some pressure loss measurements while the tests are going on, and then after the visual, do you do any analysis of what you pull out to see how much particulate, how much fiber, whatever it is, of what's happening there?

MR. ANDREYCHEK: We've not done that.

CHAIRMAN BANERJEE: Do you intend to take a look at stuff clogging the tapes or something?

MR. ANDREYCHEK: Our current plans are to look at the pressure drop data and evaluate the pressure drop data only.

CHAIRMAN BANERJEE: Only the pressure drop.

MR. ANDREYCHEK: Only the pressure drop data.

CHAIRMAN BANERJEE: And what about the visuals? You'll do some visuals, right, to see where it is and --

MR. ANDREYCHEK: We'll do some visuals. We'll document with photographs as to what's collected where and how much, visually only. We're not trying to scrape the material off and weigh it at any given elevation. And part of the reason for that is is that in order to get at the material inside the inner bundle, we basically dislodge pieces of it when we pull the bundle apart in order to get at it and clean it.

DR. WALLIS: I would think the bed would be thicker where the holes are, because that's where the flow is. The flow is bringing the fibers in and they will build up and so bulge into the hole, won't they?

MR. ANDREYCHEK: Go back to the bottom one. There you go.

I think you have a good point, but what we see as you begin -- this is what I believe is happening -- is you begin to build -- that's your fiber here. We've got these flow holes along the side and these holes in the skirt, as it were, so flow will tend to go through the gap that we've maintained and to go up and around.

So while you're right, you will tend to collect fiber perhaps initially --

DR. WALLIS: Where the flow is, yeah.

MR. ANDREYCHEK: -- where the flow is coming up, you are also going to have your least resistance flow path that wants to take it around and take it up the side and then back into the bundle.

And that's what is the mechanism, I believe, based on my preliminary evaluation of the data, that gets us to --

DR. WALLIS: Well, the reason I'm asking these sorts of questions is because I'm not sure what is at the pressure. If the pressure dropped, you could have a situation where you have one hole, one hole which is blown through.

MR. ANDREYCHEK: Uh-huh.

DR. WALLIS: And you have a blanket over all the other holes.

MR. ANDREYCHEK: Uh-huh.

DR. WALLIS: That could be what's determining the pressure drop, just the flow, the resistance of that one hole.

Now if it's one hole or two or three, that's a statistical thing, and you wouldn't expect it to be the same in every experiment, if that's the mechanism.

So if you don't have a uniform bed, I would be concerned about the randomness of which hole happens to be open and how many, if that's what happens.

MR. ANDREYCHEK: I guess I would ask to understand what the concern is, whether it's one or three holes.

DR. WALLIS: My concern is there's flow coming in, which is sort of not uniform, not necessarily.

MR. ANDREYCHEK: Okay.

DR. WALLIS: And so there may be -- the mechanism may be you block up holes one after the other, and you leave one or two that never get blocked.

MR. ANDREYCHEK: Okay.

DR. WALLIS: That could be what happens. In that case, whether you leave one or two or three is going to make all the difference in the world to the pressure drop, and that's a statistical thing which may not be as deterministic as you could determine in one experiment. You see what I mean?

CHAIRMAN BANERJEE: So, in other words, if you keep repeating this same experiment, let's say, if that's what happens.

DR. WALLIS: If that's what happens, you'd get different results. Sometimes you get one hole, sometimes you get two.

MR. ANDREYCHEK: But I think -- and bear with me; maybe I'm not understanding it correctly -- but that would suggest that the only way you're going to get flow is through that hole?

DR. WALLIS: No, no, I said that might be the way you get the flow. You get flow through the rest of it as well.

MR. ANDREYCHEK: Exactly.

DR. WALLIS: But you could have some which are completely open.

CHAIRMAN BANERJEE: A few open holes will give youm as I say, a flow path that has low resistance.

MR. ANDREYCHEK: Over that particular span, but again if we're looking at over the entire height of the test rig, we're tending to get repeatable total pressure drops across the entire height. I'm not so sure that one grid matters that much.

DR. WALLIS: It doesn't matter, it's what governs the pressure drop. Is it a uniform bed, or is it a bed that which is pretty well blocked in some places and very thin or open in others?

MR. DINGLER: As Mr. Geiger says, it's uniform, but it wasn't a heavy compacted uniform bed.

DR. WALLIS: How is that, sir?

MR. DINGLER: In other words, what we're seeing is it was lightly -- a very small bed, again --

I can't remember the data at this point.

What we saw in another test by another utility, it was a much thicker compacted bed. We need to look and see why is that different? Is it because we're testing four foot and they were testing not four foot? I don't know at this point. That's a data point that we have to look at.

CHAIRMAN BANERJEE: Well, there is also a question of how much fiber load your plant has and --

MR. DINGLER: And they had less fiber than we did, so we've got to figure out what's going on.

CHAIRMAN BANERJEE: Well, that's interesting. Anyway, so we're really reviewing your test protocol right now and what you're doing. And so the key issues, I suppose, are related to what are the tests you're planning, and what are you measuring. So I think you've already got some feedback that you might look at what might be really the limiting scenarios, and with regard to the measurements, the only thing that you're measuring right now is the pressure losses, and Professor Wallis and some others suggested it might be also useful to have a look at what things are circulating around, what percentage of the material you're catching and what you're not catching.

Now it could be that you could look at what is continuing to circulate to give you a measure of what has been caught on the grids. You know, I don't know how you could do it. These are just suggestions. I mean that was one thing that came out.

MR. ANDREYCHEK: It sounds like a filtration efficiency.

CHAIRMAN BANERJEE: Yes.

MR. ANDREYCHEK: For practical purposes.

CHAIRMAN BANERJEE: Right. So, you know, that could be something that you might look at.

MR. WALLIS: I've just been trying to do some rough calculation here, and it looks as if you have enough fiber to build up a bed which might be something like an inch thick. Is that -- am I completely wrong here?

MR. ANDREYCHEK: Based on what volume?

MR. WALLIS: You said two pounds per cubic foot, density of 2-1/2 roughly. If I take that and spread it over this area with 53 grams, I found I can get something like an inch thick.

MR. ANDREYCHEK: See, I think there's -- that's one of the reasons that we've gotten away from using a volume of fiber, because the volume --

MR. WALLIS: But it's the idea of what's happening. I mean it's very different to me if you have an inch thick of fiber than if you have, you know, a thousandth of an inch.

MR. ANDREYCHEK: I understand, but what you're looking at is a piece of fiberglass, low density fiberglass, and saying this is what it weighs, this is the size of it.

What we're dealing with is finely chopped-up fiber. So now, you're right, and to be honest, you were looking at a void -- if you take a look at this -- using paper we have given you previously on compaction, we're looking at something that's probably 60 percent compacted of the density of glass. And the density of glass is about 159 pounds per cubic feet, so we're dealing with the density of this --

MR. WALLIS: It's a --

MR. ANDREYCHEK: This is about 90 or so pounds, approximately, if we're dealing with the density of this finely chopped-up stuff. So when you start looking at that perspective, then I think if you were using that as a basis, you'd come up with a much thinner --

MR. WALLIS: Much thinner bed.

MR. ANDREYCHEK: Yes.

MR. WALLIS: Okay.

CHAIRMAN BANERJEE: The thing is the density of fiberglass, which you quoted, or somebody last time, was giving us 2.4 pounds per cubic foot. This is as manufactured fiberglass.

MR. ANDREYCHEK: Uh-huh. That's NUKON insulation, yes, sir.

CHAIRMAN BANERJEE: Correct. So -- but that's porous.

MR. ANDREYCHEK: That's correct.

CHAIRMAN BANERJEE: So you'd get flow through that. So when it compacts, you could get it down to that of ordinary glass, which would be --

MR. ANDREYCHEK: One hundred fifty-nine pounds per cubic feet if it were straight glass.

MR. WALLIS: You won't get a compression like that in any of the --

CHAIRMAN BANERJEE: You might get it a compaction factor of three or four, or whatever, but more likely you're going to have a couple of times and all the spaces are going to get filled up with particles; right?

MR. DINGLER: And that's one of the reasons we try to stay away from cubic feet because what --

CHAIRMAN BANERJEE: Yes, but I think what Professor Wallis is trying to establish is what is going to be the dimensions of this bed. So let's assume that we had all of it and it's double the density and fill it up with just rough calculation. So with 2.4 or 2.5 or 2 -- you're arriving at what, a one-inch thick bed; right? What was your number, Graham?

MR. SMITH: This is Steve Smith, NRR.

I did some quick calculations when we were up visiting, and you are correct, the first 40 grams that went in, if you put it over the 8-1/2 inch square, that would be about an inch thick, and then the 13 grams on top of that would be additional.

However, this fiber is -- and that would be based on as manufactured, and it's not that, so it's going to be something less than that. We don't know exactly what it's going to be.

MR. WALLIS: It's 14 pounds of particulates is quite a volume, too.

MR. SMITH: Well, it's quite a bit less because it's much denser. But this is being spread out not only over this 8 x 8 square fuel, it's in six or seven places in the fuel. So theoretically maybe an eighth of an inch spread out over the entire thing, and then it gets compressed, so that's more likely the volume that you're looking at.

MR. ZIGLER: Mr. Chairman, allow me a comment and a clarification, please, sir.

CHAIRMAN BANERJEE: Yes, go ahead.

MR. ZIGLER: My name is Gil Zigler. I'm with Alliance Science & Technology. I've been doing head loss testing for a number of years.

The results of their experiment is perfectly comparable with the type of fiberglass shards used for head loss testing that they did.

When you are down to the size distribution that was used in this test, those head loss test results are perfectly normal.

So please do not confuse, Dr. Wallis, if I may say so, test results used with fiberglass strands as with test results used with fiberglass shards. They are two different complete animals in their behavior patterns.

CHAIRMAN BANERJEE: Well, the longer ones that Graham was talking about, the strands, over a -- I don't remember, 1000 microns, would give you very different behavior from the shards?

MR. ZIGLER: Absolutely, sir. You can see that on the results in BWR testing in the OECD NEA results that we did back in the late '90s and early 2000s on it, and that's where an experimeter from Finland did some wonderful testing on different size hole size for bridging capabilities, and that's what we're seeing here, is their test results are perfectly consistent with the kind of debris that they used for their testing.

CHAIRMAN BANERJEE: With the size distribution of --

MR. ZIGLER: Absolutely, yes. The test results are perfectly compatible.

Thank you, Mr. Chairman.

CHAIRMAN BANERJEE: Well, that would probably open up this question of the size distribution now, but let's move on.

So what that brings up again is in addition to measuring the stuff which is circulating around, probably we need to also understand how you established the size distribution which Professor Wallis was worrying about right at the beginning, you know, which we said we'll revisit at the end, so we'll go back to that.

Anyway, so let's continue.

MR. ANDREYCHEK: Okay. So how are we going to use the data, and our intent for the use of the data is to establish an acceptance criteria for the amount of debris that can be delivered to the RCS postaccident. Total bypass mass of fiber, total bypass mass of particulate, and total bypass mass of chemical precipitate.

If a plant can't meet these limits or acceptance criteria, then they have several actions that they can choose to take.

One is to reduce the debris loading that would reach the reactor coolant system by either reducing debris generation or reducing the transport. And, of course, reducing debris generation has two aspects to it.

One is to remove material, and the other is to demonstrate that it is a higher resistance to jet impact loading than previously allowed, particularly in NEI-0407.

The other is to perform some plant-specific tests that demonstrate the pressure drop with their plant-specific debris mix under the flow rates needed to be considered, give them sufficient amount of margin to the driving rod.

CHAIRMAN BANERJEE: Well, the last point is that they should conduct their own tests?

MR. ANDREYCHEK: They may choose to do

that. That's correct.

CHAIRMAN BANERJEE: Making their own bundles.

MR. ANDREYCHEK: Or, more specifically, using their plant-specific debris mix.

CHAIRMAN BANERJEE: Oh, I see. Okay. Yes.

MR. ANDREYCHEK: That would be my -- one option they have available to them.

MEMBER ABDUL-KHALIK: Would the acceptance criteria that you list on this slide presumably correspond to the maximum available pressure drop?

MR. ANDREYCHEK: That's correct.

MEMBER ABDUL-KHALIK: Now that pressure drop comes about because you have a mixture of all three. So how do you establish limits for each one individually?

MR. ANDREYCHEK: We would be looking parametrically, as we already started looking at the amount of fiber, or changing the amount of particulate, low fiber, low particulate, then high particulate, and then we'll look at parametrically the chemical effects and calcium silicate as well as MEN-K.

MEMBER ABDUL-KHALIK: So how would a plant use that information to combine, you know, an X amount of fiber plus a Y amount of particulate plus a Z amount of chemical precipitate?

MR. ANDREYCHEK: It would look at what the results are and see where they fall underneath the -- where they fall under the data blanket that we've generated.

MR. WALLIS: So you're developing a three-dimensional surface of some sort?

MR. ANDREYCHEK: Of bins.

CHAIRMAN BANERJEE: Of bins. Bins in 3-D.

MR. WALLIS: Well, that's a surface. That's really a surface.

CHAIRMAN BANERJEE: It's a cross-surface.

MR. WALLIS: A cross-surface.

CHAIRMAN BANERJEE: And in the order, does it matter? I mean, or are you sort of ordering the things which we've just heard seem to matter, right? It seems, adding the fiber or the particulates. Is that a parameter that's important or not?

MR. ANDREYCHEK: We are -- we are not playing with the order of sequence. We are following the NRC guidance for screen testing, which says particulate first, then fiber, then chemical. That's been what the accepted --

MR. WALLIS: When this was done with the vertical test facilities, people tried to do this, establish a surface where there was a nice formed surface with these three variables, but it turned out the surface had bumps and protrusions depending upon how you did the test and whether or not you got a thin bed and that kind of thing. It wasn't a nice smooth surface. You could make the surface stick out a bump here or there depending on how you did the test. That was in the vertical tests.

MR. DINGLER: And if you go to sheet 43, based on three tests -- and we've still got to look at it, in that we didn't see a thin bed.

MR. WALLIS: You didn't see it.

MR. DINGLER: We didn't see a thin bed. And we particularly added material in very small increments to make sure we passed through it.

CHAIRMAN BANERJEE: But I guess that must depend on how long -- you know, it goes back to that question that Professor Wallis had about the size distribution. If you had a lot of long fibers that could potentially set up a thin bed, so the size distribution becomes quite critical. I don't know. We have to review this a little bit more and think about it.

It's good that we are getting this information and, you know, after about a week or two of digesting it, I'm sure we'll get some --

MR. DINGLER: And one thing I can say that's not proprietary, on the two tests we did, it looked like the increased particulate kept the fiber the same, the increase in head loss was minimal. So it looks like higher particulate is not driving the head loss as much as the fiber.

CHAIRMAN BANERJEE: You haven't yet done higher fiber; right?

MR. DINGLER: We -- --

CHAIRMAN BANERJEE: You have, but you haven't got the results.

MR. DINGLER: We haven't got the results. We had a higher fiber loading in all the other two. We just haven't got the results yet.

CHAIRMAN BANERJEE: So eventually you'll be giving us quantitative data to look at, right, in your report. Okay.

Can we move on? Is it okay?

MR. ANDREYCHEK: Okay.

CHAIRMAN BANERJEE: And now we are off the head loss and we are on to something else.

MR. ANDREYCHEK: We are on to something

else.

There was a question about hot spots the last time we met. This slide briefly summarizes the hot spot discussion. The source of heat from decay heat --

CHAIRMAN BANERJEE: Just before we go on, there are two things that I should flag right now. One is that at some point we should have a sort of a test matrix to look at, if that's possible. You've said it qualitatively in words.

MR. ANDREYCHEK: We have.

CHAIRMAN BANERJEE: You have certainly got one, and in that I guess we need to know what flow rates you're using and what particle loadings you're using and what fiber and chemical and whatever else you're adding to it.

MR. DINGLER: In our protocol we had that. We jumped two tests. We changed the sequence so we had data because we weren't going to come in front of you without some data.

CHAIRMAN BANERJEE: You are very wise.

(Laughter.)

CHAIRMAN BANERJEE: But now that you've got this kid glove treatment --

(Laughter.)

CHAIRMAN BANERJEE: -- that would not have been the case if you came without any data.

MR. DINGLER: I figured that would be it.

CHAIRMAN BANERJEE: So now with this data, of course, we feel much more reassured. We would like to see -- I think we would like to see the whole test matrix that you're planning, and certainly we can give you some comments or give the staff some comments on that.

The second thing that I think we would like to see, if it's possible in some way, is this -- all the data that you showed in your table -- I guess it's on page 36, where you showed a few plants.

Now somewhere you've got a compilation of all this data. That would be, I think, useful to look at, but in addition to that, we commented that maybe some brief description of what the plant was -- high fiber, low fiber -- this sort of thing would be useful.

MR. DINGLER: What we'll do, since I'm not -- at this point I didn't ask permission to give the plant names, so A, B, and C, and then list this, and then high fiber, low fiber.

CHAIRMAN BANERJEE: Yes, high fiber, low fiber, high particulate, low particulate. And then you had some data on the quantity of bypass related to that plant. So we want distributions in this, but we haven't got was it over one pound, less than one pound, whatever.

MR. ANDREYCHEK: It's on page 37.

CHAIRMAN BANERJEE: Yes, but the information on page 37 and 38, if it could be related to your A, B, C.

MR. DINGLER: Yes, we will do that.

CHAIRMAN BANERJEE: Okay. We are just asking for information right now, for informational purposes.

So I think with that, and then the test matrix, that would give us some, you know, background to go on.

MR. GEIGER: Now did you make measurements to see what your distribution of likes were in your fiber batches?

MR. ANDREYCHEK: Yes, we did.

MR. GEIGER: But you didn't give us that?

MR. ANDREYCHEK: No, again --

MR. GEIGER: Oh.

CHAIRMAN BANERJEE: So then can you answer that question?

MR. ANDREYCHEK: Yes, we can.

CHAIRMAN BANERJEE: As well for the closed session?

MR. ANDREYCHEK: Yes, we can.

CHAIRMAN BANERJEE: Okay, so what we are going to do is let's try to get through the rest of this by 3 o'clock if we can, that's 45 minutes, and then we'll close the session for half an hour, maybe. Or do we need more than half an hour for the closed session?

MR. DINGLER: I don't think so, unless you guys ask a lot of questions.

CHAIRMAN BANERJEE: Well, there might be.

(Laughter.)

CHAIRMAN BANERJEE: Because, you know --

MR. WALLIS: When do we get the final story? I mean you're working on this, you've got a lot more experiments to run. Eventually you're going to put it all together, you're going to rewrite the NUREG. We want to see it sometime before it goes out and is used.

CHAIRMAN BANERJEE: Well, of course we would have the right to see it.

MR. WALLIS: So this is sort of a progress report today.

MR. ANDREYCHEK: Yes, it is.

MR. WALLIS: And we haven't had written material to review, we haven't been able to look at the details and sort of see if we believe them or not. So we need something substantial some time.

CHAIRMAN BANERJEE: Well, I think the purpose of this is we are going to have to write a letter to the Commission --

MR. WALLIS: That we've made progress, but we've got a lot more to come or something?

CHAIRMAN BANERJEE: Well, I think we can identify as we did in last year's TRACE letter that, you know, progress -- the progress that has been, what is being planned, and whether we endorse the plan or not. I mean that's the open question that we'll have, or our comments on the plan.

So at some point I guess we should -- and the staff may help us -- identify what progress has been made towards resolving this issue. You know, we should clearly state that, and then what is still to be done.

MR. WALLIS: We can't write something which says we can see that they now have enough material to resolve the GSI.

CHAIRMAN BANERJEE: But that's not the purpose.

MR. WALLIS: Well, I thought we were going to get there some day.

CHAIRMAN BANERJEE: We are still hoping to.

(Laughter.)

CHAIRMAN BANERJEE: But I think all we can do at this point is to say that this is where we are, this is what still needs to be done, and whether we agree with it or not, or what our comments on it are, and that's really what we can do in our letter.

And I guess this will be still -- is it part of the Commission briefing in November?

MR. GEIGER: Yes, it is.

CHAIRMAN BANERJEE: All right.

MR. GEIGER: We get to talk to the commissioners about it.

CHAIRMAN BANERJEE: Okay. So we should have a coherent story.

MR. DINGLER: You mean Bill has to have one?

CHAIRMAN BANERJEE: No, I have to have one.

(Laughter.)

CHAIRMAN BANERJEE: Which is difficult.

MR. WALLIS: Are you talking to the

Commission?

CHAIRMAN BANERJEE: I think we are, yes.

MR. WALLIS: On Thursday?

CHAIRMAN BANERJEE: No, in November.

MR. WALLIS: Oh, November, okay.

CHAIRMAN BANERJEE: Yes, we have time.

(Laughter.)

CHAIRMAN BANERJEE: We really do want to make sure we have a coherent story. Okay.

Please continue.

MR. ANDREYCHEK: Okay, thank you.

With regard to hot spots, again the source of the heat for the hot spots is decay heat in the fuel, and it's decreasing over time postaccident.

These hot spots can arise only if flow is restricted locally. Local temperature increases would be mitigated by boiloff in regions around the hot spots. Heat will be dissipated by grids which will tend to act like radiators or conductors, as well as axial conduction to sustain the quench and replacing boiloff will maintain clad temperatures below the 800 degree F that we've identified as a cladding peak temperature limit post-LOCA once we've recovered the core and gone on to research from the sump.

We have some conservative calculations in clad temperatures that demonstrate the coolability of the clad with deposition on the clad surface and blockage at the grid.

In addition to that, the LOCA DM calculations that we do calculate what kind of deposition we'd get at a very conservatively low thermal conductivity rate that shows that, one, we don't get a lot of deposition, and what deposition we get still provides a clad temperature well below 800 degrees Fahrenheit.

These other sensitivity calculations that we did looking at assuming no flowthrough of grid strap and conduction through the -- actually along the fuel rods as well as through the grid strap proper, give us some indication that we have acceptably low temperatures.

Next slide, please.

This slide is a 1-D clad hot spot calculation. What we are looking at on the right-hand side, we have assumed a .36 inch diameter fuel rod. We assigned a heat flux from a calculation, an ECCS calculation, on the inside surface to model the cladding thickness. We have added an oxide layer and a crud layer, and then we added the precipitant as a parametric in 10 mil increments.

We used the decay heat for the heat flux right at 20 minutes post-LOCA, so we had a high heat flux which would tend to decrease over time, due to the natural decay of heat.

And we said, okay, what temperatures would we get? The top table gives you the value of a .36 inch diameter rod, and you can see that we are looking at, with 15 mils thickness, a maximum temperature of 560 degrees Fahrenheit, with a thermal conductivity of 0.1.

DR. KRESS: What did you use for H?

MR. ANDREYCHEK: The H was approximately 580 Btu or -- I'm sorry, 600 or so Btu degree F on the outside surface. I can give you the specific numbers. I don't have them. But it's in the neighborhood.

DR. KRESS: Close enough.

MR. ANDREYCHEK: Okay. And the same is true when we looked at different rod diameters, which is in the table below on the left-hand side. We looked at a .7, a .416, and a .4220 D rod, looked at what the effects of thick rods, and certainly when we get to 50 mils, it would be about 714 degrees Fahrenheit for a .4220 D rod, with 50 mils.

DR. KRESS: Was there concern about H being influenced by deposition of fibers and things on spacers so that local H is lower?

MR. ANDREYCHEK: We were looking at something about midspan, to be honest about it. We were looking -- and we did not couple a blockage at a grid with a flow above the grid in the bundle. We were not looking at multiple --

DR. KRESS: Isn't that part of the concern? That blockage of the grid could prevent the flow going past the bundle?

MR. ANDREYCHEK: Well, it might have been at one time, but again, what I'm looking at -- and when I looked at the testing that we just did when we looked at what kind of flows we get, we certainly get a pressure drop, but we're getting flow at each of the grid spans. So I think the test data, when we couple that with the calculations we've done, tend to mitigate that concern.

DR. KRESS: But you have cross-flow, don't you?

MR. ANDREYCHEK: Exactly.

DR. KRESS: That wasn't simulated in your test.

MR. ANDREYCHEK: It is not, no. Although because it's an open lattice amongst the fuel assemblies, we do -- within the fuel assembly proper, we see the flow running through the bundle.

When we look at the -- a two-dimensional model we were using to look at what happens between the grid straps, these temperatures plotted on this curve are behind peak temperature -- underneath or behind a grid strap. We're looking at the conduction available. Actually we're not seeing a temperature better than about 425 degrees Fahrenheit with a .1 thermal conductivity through this blockage. And I would suggest that that is a very, very small thermal conductivity because even though we've seen from the testing we get some mass collection there, again we are not seeing that it's totally blocked.

DR. KRESS: When you calculate this, you have to look at the width of the grid that the conduction takes place?

MR. ANDREYCHEK: I'm sorry. Say that again, please?

DR. KRESS: When you're talking about part of the grid straps, you have to assume there's kind of no flow to cool above it, for some length above it. It seems like you have to assume some length in this calculation. I was wondering how you arrived at that.

MR. ANDREYCHEK: Well, again, because of the fact we're getting flow across the bundle, I don't see that we -- I don't think that's an appropriate assumption.

DR. KRESS: But the width is just the thickness of the grid.

MR. ANDREYCHEK: Of the grid strap. And we have a two-inch thick grid strap.

DR. KRESS: Okay. It's two inches.

MR. ANDREYCHEK: Yes, sir.

DR. KRESS: That answers my question, the two inches.

MR. ANDREYCHEK: Okay. And I do have some numbers for you. The conductive heat transfer at the OD was 650, a little higher than what I had originally estimated. The oxide level was approximately .1 inches -- I'm sorry, 100 microns, and the crud was 100 microns.

DR. KRESS: Now in this calculation, the thicker the crud and deposits are, the better off you are?

MR. ANDREYCHEK: Actually, no, because what we looked at was using the thermal conductivity -- we were using the oxide thermal conductivity as .1 -- it was 1.27 Btu and the crud was .03, so you do have a little bit of --

DR. KRESS: The thicker it is, the more

area you've got to transfer the heat.

MR. ANDREYCHEK: Yes. Yes.

DR. KRESS: So the thicker, you're better off.

MR. ANDREYCHEK: Yes. I guess you're right in that case, yes. But we're still talking not large area increases because we're only looking at .004 inches in the diameter increase. So we're not talking large orders of magnitude area increases.

Boric acid precipitation for a postulated hot leg break, for all practical purposes, because the flow rate is through the core, there's no opportunity for boric acid buildup. As along as we're getting flow through the core, the core is being flushed and the boric acid is not a buildup.

For a postulated cold leg break, the only flow into the core is based on makeup of the boiloff, and boric acid and sodium borate carryover in the steam from the boiling process is low. Therefore, you do get the buildup of the boric acid and borates in the core.

The current licensing basis calculations are in place to define the time for operators to initiate action to dilute the core.

Next slide, please.

To assure the licensing basis calculations remain valid, the following considerations are taken into account:

One, half of the lower plenum of the reactor vessel remains available for mixing. It's typically what's used in Westinghouse and I believe some CE plants. AREVA has a different criteria that involves a different flow area, and I'm not familiar enough to go into great detail discussing that.

The existing EOP, emergency operating procedures, direct plant operators to initiate hot leg recirc or core flushing flow to maintain a flushing of the reactor volume.

Based on what we currently know, once the plant operators initiate hot leg recirculation, core fluid is diluted and mixing of boric acid solution in the core is maintained below precipitation limits.

Potential impact for debris on boric acid solution mixing is to be addressed in another PWR Owners Group program outside of GSI 191, and that project authorization is PA-ASC-0264, and that program -- Mo, you might want to make a statement about what that program is and how long it's been -- you know, what its intent is.

MR. DINGLER: There was a question based

on current licensing that we have plants on power upgrade. We had some questions on the boric acid there, so this program was taken out to evaluate that current license, and now GSI-191 debris input is going to be used as an input to that program to evaluate the boric acid, you may call it dilution, you may call it stagnation, whatever you want to call it, as an input to that program, and they're developing a peer review panel. The peer review WCAP was submitted to the NRC on information. Donnie and I -- Donnie Harrison, talked, we talked at lunch about how to find it, to send in this information only to document control room. We'll try to find out who it was sent to, but that program is going to use the GSI-191 to make inputs and then do the whole licensing issues on boric acid and solve that once and for all.

Right now it's a two-phased program. One is define what the issues are, phase one, and get with the NRC staff to make sure they're onboard with the phase one, and then phase two is after they get a course of action is to go ahead and solve the issue. That's the current plan for that program right now.

CHAIRMAN BANERJEE: I'm sorry, I may have missed it, but the last meeting, there were some discussion about mixing between the core and the lower plenum. Did you address this right now, or that's something --

MR. ANDREYCHEK: Well, the way that it's being addressed is that we do have -- we do take credit for one-half of the lower plenum remaining available for mixing purposes.

MR. DINGLER: And then when we go to hot leg recirc on the OP space, we flush the core back out. And based on what we know today, that will still react because there is a potential that this debris could be -- and also staff has some questions on the methodology for the last 15 years or whatever. We got this other project to put it to bed once and for all.

CHAIRMAN BANERJEE: The fact that the core, let's say if you assume there was substantial blockage of the core inlet, there is no potential impact on the -- I mean how do we know that half the lower plenum is available for mixing? That was a question that was raised. It's just coming back to me. I wonder how you're answering that.

MR. DINGLER: What we believe is -- well, what the plant has got to do is take credit for the path, is they've got to look at the amount of debris coming in and make sure that's not over one-half. That's one item.

The other one is we're looking at when we go back to hot leg recirc, will that flush some of the stuff out of the core, or the debris in that. So we're looking at that and opening things back up a little for us. And that's how we're taking credit for it right now.

You know, based on what we know, we do not believe there's an issue.

Now based on this additional project, as you all know, when you do further investigations, something may come up. But we don't know at this time. I'm sorry, but, you know, based on what we know today, we're still operable, still functional.

CHAIRMAN BANERJEE: Okay. Let's move on then.

MR. ANDREYCHEK: Okay. Just a note on defense in depth with regard to the current licensing basis for boric acid solution calculations, we don't take credit in current licensing basis calculations for some buffering agents that will neutralize boric acid and raise the solubility limits of boric acid. There's no boron carryover and the entrained liquid around the loop for cold leg break. It stays concentrated in the core. No boron carryover in the steam out the -- through the hot leg and out the steam generator for a cold leg break and we're using Appendix K decay heat levels which maximize the boiling, and that therefore maximizes for cold leg break the amount of flow into the core which would tend to increase the concentration quicker since you're boiling off faster.

We also consider the assumptions, defense in depth, we considered the following conservative assumptions used in the GSI-191 degree transport, and that is that all debris are assumed to arrive at the core inlet at the time of switchover, i.e., even in the testing we're doing, we're saying we get a tremendous amount of debris in a very short period of time right to the core. So we're building the bed, the debris bed, as quickly as possible, and the decay heat decrease with the time reducing the velocities in the reactor vessel lower plenum, again, for a cold leg break.

So we have got some conservatisms in the boric acid considerations that aren't explicitly accounted for in the licensing basis calculations.

So in summary, WCAP-16793-NP and supporting work, we believe has demonstrated reasonable assurance of long-term core cooling.

MR. DINGLER: The word will.

MR. ANDREYCHEK: Will.

CHAIRMAN BANERJEE: I think "has" is perhaps --

MR. DINGLER: Hey, we're positive here.

MR. ANDREYCHEK: Will. Will. That fuel assembly is currently being performed to establish debris limits for plants. For plants that demonstrate that they satisfy those limits are done, there's no additional work that they need to do. And plants that do not satisfy the limits can take remedial actions, among which remedial actions are to reduce the amount of debris generation associated with their plant, reduce the debris transport by a number of means, and perform plant-specific head loss testing, specifically using their plant-specific debris loading.

CHAIRMAN BANERJEE: Thank you. I'm going to consult for a moment as to whether we should just take a break now and then come to the closed session, or whether we should have the closed session and then take a break, because there is a visitor from the Union of Concerned Scientists, and I don't want him to sit out in the hallway. If necessary, we can take a brief break now, and then close the session later. Let me talk to him and see if he wants to --

MR. GEIGER: Why don't we at least take

the break, and then --

CHAIRMAN BANERJEE: Okay. So let's take a break now, and then right after the break, we'll either close the session or we'll have the statement and then we'll close the session.

Fifteen minutes.

(Recess.)

CHAIRMAN BANERJEE: Please get organized, and we are going to go back into session, so we are going to have a presentation by Mr. Lochbaum of the Union of Concerned Scientists. Mr. Lochbaum is here, so go to it.

MR. LOCHBAUM: Thank you for accommodating me on what was clearly a tight schedule, and I will try to be brief.

What I wanted to show you today was a DVD of an event that occurred over a decade ago at Point Beach, and I think that event has some relevance to the GSI-191 issue. It's a very short video.

CHAIRMAN BANERJEE: Can we enlarge this and blow it up?

MR. LOCHBAUM: Once I get it running. This is -- in May of 1996, a worker preparing to weld a lid on -- the shield lid on a dry cask at Point Beach ignited some hydrogen gas, caused a hydrogen burn event. The following day that cask was lowered back into the spent fuel pool at Point Beach. This is a video from the NRC's Public Document Room we obtained under the Freedom of Information Act of the cask shield lid being removed from the cask after it had been lowered back into the spent fuel pool the following day.

The -- this is -- they put a camera in a remote submersible rig and this is sitting essentially right at the cask flange, a very close-up view of the cask lid being removed.

The video I extracted here is four minutes. I'll leave the DVD with you. The full thing in the PDR is about three hours long and tests everyone's patience.

But for some background on that event, the hydrogen was created by an unexpected chemical reaction between the borated spent fuel pool water and an epoxy coating applied to the inner surface of the dry cask.

The first indication of that unexpected chemical reaction was the hydrogen burn, when the guy doing the welding lit it off, and it caused the three-ton cask lid to go up in the air a bit, come down cockeyed, but there was no injuries. It was a considerable surprise, I imagine.

As the lid is being removed in the next minute or so, you will see, in addition to the hydrogen gas that was produced by the unexpected chemical reaction, there was an awful lot of white precipitate matter just floating around once the cask bottom reaches the surface. It's an incredible amount of material that was also created as a byproduct of that chemical reaction, and I didn't realize it until I reviewed this tape of just how much material was there.

MR. WALLIS: These are bubbles are hydrogen, are they?

MR. LOCHBAUM: No, it could be nitrogen or it could be air, too, because they refilled the cask once they lowered it back into the pool.

MR. WALLIS: This is after the event?

MR. LOCHBAUM: This is after the event, the following day.

MR. WALLIS: It could be helium.

MR. LOCHBAUM: It's the white material you start seeing floating out now in quite copious quantities. Later in the video, not in this segment, they actually bring the camera up and look at the lower surface of the cask lid as it's been lifted up, and it's an amazing amount of material still stuck -- you can see some of the edge there, some of that white material. There's an awful lot of material stuck to that cask lid.

And I think the lesson that this event, I think, plays to GSI-191 is I have to assume that as they were loading -- this is a VSC-24 cask, holds 24 fuel assemblies. Even if you are able to move 12 assemblies an hour, which is a tremendous pace, it takes over two hours to load one of these things.

In that two-hour period you are moving a fuel assembly one by one into that, I've got to assume that the hydrogen bubbles or this white snow wasn't there or somebody would have noticed it.

So it seems most likely that the reaction that produced the hydrogen in this white precipitate was at a very slow rate while the cask was being loaded. I just can't believe that workers missed that much debris floating around, which means that the chemical reaction either started or accelerated after the lid was put on, after the cask was lifted out of the spent fuel pool.

There's a picture of the top. It's just a tremendous amount of debris. And it just doesn't seem credible that that was being created as the cask was being loaded, and it was the stuff -- that chemical reaction started after the lid was placed on, after it was moved out, either because the temperature went off, because it's no longer being cooled by the overall spent fuel pool cooling system and it was just convective cooling, or because you partially drained the water as you do in sealing the lid on.

So it was the introduction of air or both, the higher temperature and the air as a catalyst that caused the chemical reaction that produced this material in the hydrogen gas.

The relevance of that event to GSI-191 is we've heard a lot of testing that's been done or will be done, and this was also predated -- the testing predated this event, and nobody wanted this to happen, and yet it did happen.

So we're a little bit concerned that the testing that's been done so far is at ambient temperature, some temperature -- we saw some slides this morning, where they did some cycling from 140 degrees down.

In a GSI-191 type event, the water that's sprayed from the broken pipe and from the containment spray system can be well above 140 degrees.

It may not just be the chemical reaction between whatever is submerged in that water. It could be whatever material -- what equipment, coatings, and so on that were sprayed in the process of that accident that produces this debris.

It's not -- and this, again, this is a cask, it was intended to be put in borated water. It had a very small set of variables. There's only so many materials, so many coatings applied to that cask. The vendor, the licensee, and the NRC staff all missed the chemical reaction that this event demonstrated.

During the actual use of the cask, the loading, there were no evident signs, I'm assuming, I think it's reasonable to assume that there were no readily available signs of this chemical reaction that was about to occur, and yet it did occur.

When you have as many variables, as many coatings that are used in the various plants across the country, it seems more likely that we're going to have these kind of surprises than less likely.

I mean Dr. Wallis and others asked questions about are these tests that are being performed bounding, limiting, conservative, whatever. Given the number of variables and the coatings, the temperatures, the air as a -- all these things, it just seems that this event shows that there's a pretty high likelihood or an unreasonably high likelihood that we haven't covered all the bases, and while we can do all this testing and show the things in the lab won't produce flow blockage and stuff, in reality I don't know.

I hope -- first of all, I hope we never have a loss of coolant accident where we have to test this thing, but if we do, will what we see be what Point Beach saw when they tried to weld the lid on, or will it be what predated that, where we had basically all the big answers -- questions answered, and we didn't have such a big surprise.

From what I've seen, to be fair, it's still a work in progress, and staff and the industry may cover all the bases at the end, but it seems like right now we haven't tested all the configurations, all the coatings, all the factors that could lead to this kind of chemical reaction that produces copious amounts of precipitate which could clearly challenge both the in-vessel and the containment sump screens themselves.

So that's basically -- I'll leave the DVD. The full thing is actually in the PDR, so you can see I didn't doctor or anything like that to the photographs, but we think that this issue is relevant to the GSI-191 issue, and we're hoping to see some integration of all these testing results to give some confidence that a surprise that may be down the road is relatively small, it's not as big as this one.

So --

DR. KRESS: Did anybody collect the debris and try to identify what it actually was chemically?

MR. LOCHBAUM: The -- when we looked -- and to be fair, we were in the same boat. When this event occurred, we looked at it for what other dry casks might be affected. We didn't, until the last few weeks did the light go in my head, well, this also has beyond dry cask issues.

When the data was collected, it was how many casks used that epoxy coating, how many of the ones that are already loaded could have had this white precipitant loaded that could affect heat transfer in a sealed cask. It wasn't drawing the bigger questions from that.

So --

MR. GEIGER: Well, this one says zinc-based coating, which would be more reactive, presumably, than most epoxy coatings. There's plenty of zinc-based coatings around.

CHAIRMAN BANERJEE: And it was acidic.

MR. WALLIS: Acidic. I think we talked about zinc earlier, and as long as you've got the buffer there, but like before it's mixed with the buffer, you can get some reactions up in the containment.

MR. GEIGER: Well, sodium hydroxide is generally in the spray.

MR. WALLIS: Yes, but before that.

MR. LOCHBAUM: In the containment spray, not in the spray out of the broken pipe.

CHAIRMAN BANERJEE: I think it would be interesting to at least know what that investigation showed, you know.

MR. LOCHBAUM: We looked at it, to answer Dr. Kress's question, from the dry cask event, and we actually have a -- again, one of the NRC Public Document Rooms for various reasons, and we couldn't find it in there. Because this event occurred in 1996, there's not many documents on it in ADAMS, but if you go back to the old microfilm, again, most of the questions were what other dry casks may have been affected and so on.

So I don't -- there's not -- there may be some other data that's not in the public document --

CHAIRMAN BANERJEE: So the investigation alluded to there, you couldn't find the results of that investigation?

MR. LOCHBAUM: Other than identifying who else might have been using similar materials. And for the event, that was the right questions asked, but I think there's bigger questions.

CHAIRMAN BANERJEE: Sure, they wanted to make sure it didn't happen again.

MR. LOCHBAUM: Right. And also this occurred in May of 1996. It actually predates GSI-191 by a few months -- not many months, but a few months.

So with that, I appreciate your indulgence.

CHAIRMAN BANERJEE: Thank you very much.

MR. LOCHBAUM: In putting me on the schedule, and --

CHAIRMAN BANERJEE: Thank you for your comments and please, you know --

MR. LOCHBAUM: That's your copy. I'll leave that here. Thank you.

CHAIRMAN BANERJEE: Okay. In that case, I think what we do now is we'll close the meeting, and I'll ask the appropriate people to ensure that whoever should not be in the room is not in the room, because

I don't know who should or should not be.

(Whereupon, at 2:59 p.m., the subcommittee went into closed session, and rejoined the open session at 3:40 p.m., where the following proceedings were had:)

CHAIRMAN BANERJEE: All right, we're going to go back in session. Back in session. And now we're going to hear from NRR staff with regard to activities related to this WCAP.

MR. SMITH: Yes.

CHAIRMAN BANERJEE: Or the WCAP to come.

MR. SMITH: WCAP to come.

It's Steve Smith again, and Bill Curdiak is going to help me out with some of the work that Research did, some of the analytical models on fuel blockage.

A lot of this you guys already talked about, so I'm not -- I'm just going to try and go briefly through the presentation and not dwell on areas that have already been discussed, so basically we're going to talk about -- next slide -- fuel blockage testing and considerations. I think this has been discussed pretty well.

We'll talk about some industry testing, and then we're going to talk about the analytical models that Research has worked on.

Basically the fuel inlet designs that we are working with -- and here's from Westinghouse and AREVA. The Westinghouse designs are relatively similar to each other. There are some differences. The AREVA designs have some differences between them. We haven't seen any testing done on the AREVA designs yet, so we're really not sure, you know, what the results will be once we get testing on that.

We have seen testing on the Westinghouse designs.

MR. WALLIS: Do you know what the fine mesh is like?

MR. SMITH: It's a fine mesh screen, basically.

MR. WALLIS: Well, how fine is it?

MR. SMITH: It makes me a little more nervous than the other -- than the other designs.

MR. WALLIS: You can't tell the Westinghouse guys what it looks like; right?

MR. SMITH: They know. They know what it looks like. They sent us the information. I mean the PWR --

(Laughter.)

MR. SMITH: The PWR Owners Group, not

Westinghouse.

(Laughter.)

MR. SMITH: They can only tell each other certain things. I'm not sure --

MR. WALLIS: Maybe AREVA will start sending you Westinghouse information.

(Laughter.)

MR. SMITH: We can get it.

(Laughter.)

CHAIRMAN BANERJEE: Going back to that previous slide, roughly what proportion of the fuel that you're talking about belongs in these categories?

MR. SMITH: I don't know. I have been told that the fine mesh is not even a full core. There's only some fuel assemblies and a core that has the fine mesh on it. So that is a consideration.

MR. DINGLER: This is Mo.

The fine mesh, there's two plants and two considering it. There's about 38 with Westinghouse fuel and about two-thirds, one-third split with the fuel. Westinghouse has two-thirds, AREVA is about a third, approximately, give or take in there.

CHAIRMAN BANERJEE: As these plants go to a higher and higher performance fuel for various reasons, do you expect they will have more complex sort of structures? What's done today somehow has to bound what will happen later; right?

MR. DINGLER: What we're finding is the initiative the CEOs have taken with NPO to have no leakage by 2010 is counterreactive to what we're doing in GSI-191.

CHAIRMAN BANERJEE: They want to open up the fuel more?

MR. DINGLER: No, they want to close the fuel more for normal leakage, which is fighting against us in GSI-191.

CHAIRMAN BANERJEE: But that's what I was meaning, yes.

MR. DINGLER: We're seeing that, and we're going -- having some talks with the CEOs that, you know --

MR. WALLIS: Well, this is sort of a different problem.

CHAIRMAN BANERJEE: Okay, let's go ahead.

MR. SMITH: Okay, the various fuel inlet designs and testing we've seen, Diablo Canyon performed significant testing on the Westinghouse alternate P-grid, and we have a lot of data that is actually in a public trip report that we put out, so we can share that data.

They also did some testing with reloads for -- with the P-grid versus the alternate P-grid, and it looks like the P-grid is actually a more limiting -- it's going to capture -- create a higher DP.

Now their testing was not like the Westinghouse test that you saw with the four foot assembly. It was only one -- it was only the bottom nozzle with the grid on top of it and then one intermediate strap on top of it, and we'll have a picture of that to show you.

CHAIRMAN BANERJEE: And they kept going until basically they've taken out all the --

MR. SMITH: Right. And they keep recirculating, so it's probably a more limiting test that gathered all the debris in one small area, and we'll show you some pictures of that.

And based on the testing that we have seen, both at -- that Diablo did and the Westinghouse testing, it looks like we are not going to get a thin bed across the bottom of the fuel inlet. The debris is going to spread out and get caught on all the straps going up the fuel inlet.

CHAIRMAN BANERJEE: Did they use the sort of high -- relatively what appeared to be high flow rates for what the Owners Group showed up to now, or --

MR. SMITH: They used both cold leg and hot leg flow rates. They did about half of each. They did some at 5 gpm and theirs wasn't quite as high. I think it was like 41 gpm was their hot leg break, and their cold leg was a 5 gpm flow rate. So they did some. And their head losses -- we'll go into it, but they were quite a bit lower. I mean they're usually measuring inches of head loss. So -- but they had a lower fibrous debris load also.

CHAIRMAN BANERJEE: They're a no-fiber plant?

MR. SMITH: Yes. Yes.

MR. WALLIS: Okay, this thin bed, it's never been clear to me what a thin bed is. Its thinness is not the key.

MR. SMITH: No, it's not.

MR. WALLIS: The key is that somehow the particles fill up the holes in the fibers and give you something which blocks the flow much more effectively than if it's randomly distributed, or is some other fraction of distribution.

MR. SMITH: It's the ratio --

MR. WALLIS: Oh, it's the ratio.

MR. SMITH: And also how it -- how the bed builds, you know, how the bed builds.

MR. WALLIS: And it can be at the bottom or the top or throughout or anywhere, as long as you get this critical mix of things.

MR. SMITH: Right. It seems to be less likely than if you already have a lot of fiber there that you're going to get that because the particulate tends to migrate through.

MR. WALLIS: Right.

MR. SMITH: But if you have a small amount of fiber with a lot --

MR. WALLIS: With a lot of particulates.

MR. SMITH: Yes, it seems to be more likely to have that happen.

MR. WALLIS: But it could be a thin layer in a thicker bed, too. I mean there are ways in which you can make a thin bed sort of on top of a thick bed. It's not a magical thing about just, you know, a certain thickness that --

MR. SMITH: I guess it's possible, but I think it's less likely. It's less likely.

MR. WALLIS: Until we really know what it is and how to predict it, be careful about talking about --

MR. SMITH: The thin bed is really hard to define, I agree with that.

MR. WALLIS: All right.

MR. SMITH: There's been a lot of discussions.

CHAIRMAN BANERJEE: Well, it's a qualitative description.

MR. SMITH: Yes.

CHAIRMAN BANERJEE: Where you get a rather high pressure loss, even though the bed is very thick.

MR. WALLIS: I would call it a saturated layer or something, something that sort of fills the pores in the layer and makes it much more effective as a blockage element than --

MR. SMITH: If we had started calling it that about five years ago, it probably would have made our job a lot easier trying to discuss with industry exactly what it is. Because when you say thin bed, you know, we say there's -- people think that there's a minimum amount of fiber, that if you have less than that, you won't get a high head loss, but we haven't seen that to be the case.

CHAIRMAN BANERJEE: Okay, let's move on.

MR. SMITH: Okay. I think we already talked about a lot of the bullets on this slide. We talked about how they do the fibers bypass testing.

The testing to date that has been done for the fuel -- one thing I don't know if that was brought up -- they assumed that there was no -- the particulate and the chemicals do not get filtered out, so they put the flow of chemical and particulate load scaled down to the single bundle into the test, and then the fiber is -- does assume whatever would bypass the screen.

So the fibrous load is reduced from what gets created during the event. However, the chemicals and the particulate loading does not get reduced.

CHAIRMAN BANERJEE: How did they establish the fiber loading based on their tests, based on bypass?

MR. SMITH: Yes, the Diablo Canyon fiber loading was established based on bypass testing that they did with their strainer.

CHAIRMAN BANERJEE: So I guess then we go back to that old question of -- how much goes through as a function of time. So they used a cumulative amount and stuck it in there.

MR. SMITH: And how much goes through is a function of time and the rate, I think, is a function of time, because as time goes on, less and less goes through, because the debris bed gets more and more efficient at filtering things out as the -- as time goes on.

CHAIRMAN BANERJEE: So in the testing that was done for Diablo Canyon, it was a once-through screen that they were using? They were not recirculating the flow in the screen?

MR. SMITH: It was continuously recirculating, so anything that got through the fuel assembly went back through the loop and came back to the bottom.

CHAIRMAN BANERJEE: No, I'm talking about when they established their bypass.

MR. SMITH: When they established their bypass --

CHAIRMAN BANERJEE: It was a once-through?

MR. SMITH: No, it was recirculating.

CHAIRMAN BANERJEE: Oh, it was recirculating?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: And then they might have got a very high bypass in the beginning, but it eventually got taken out?

MR. SMITH: In general, the bypass is much higher right at the beginning, because there's no fiber on the strainer.

CHAIRMAN BANERJEE: This is what is still troubling us. I guess it is troubling me; I don't know if it's troubling the rest of the committee. That if, let's say, you -- what you were calling the cumulative bypass was truly just a once through the screen and that's all that got through, and we were having a constant generation here, then of course that's a conservative number.

But if what gets through the sump screen and not the core is recirculated back, then what bypasses an hour later will be much less than what bypasses right at the beginning?

MR. GEIGER: But if it's added to the first one, you get the total.

CHAIRMAN BANERJEE: I'm just trying to understand what this cumulative means. Is it that you're taking out samples of the liquid being bypassed all the time?

MR. SMITH: You're getting an amount of fiber per a volume of liquid, and then --

CHAIRMAN BANERJEE: As a function of time?

MR. SMITH: As -- yes, because you take samples all the while the test is going on.

The other thing that makes the testing,

the bypass testing more probably conservative is that they do not generally put particulate in during the bypass testing. So that allows more fiber to pass through the strainer, because a bed with particulate in it is a much better filter.

CHAIRMAN BANERJEE: But that's exactly opposite to what Mo was saying. He was saying he's seen tests with fiber only which passes less fiber than fiber and particulates, and we couldn't understand why that was. And there was a theory being put forward by Mike here, who -- something, some interaction occurring.

MR. SMITH: I think that in general that probably wouldn't happen, but I guess it's possible that it happened -- I don't know. I don't know what test Mo was looking at when he saw that.

CHAIRMAN BANERJEE: But he said that. You heard him say it.

MR. SMITH: In general -- in general -- I must not have been paying good enough attention.

MR. GEIGER: Your anecdotal evidence says it goes the other way.

MR. SMITH: In general --

CHAIRMAN BANERJEE: Which makes no sense.

MR. SMITH: -- the bed is a much better

filter once it gets some particulate in it.

CHAIRMAN BANERJEE: So let me understand how this cumulative bypass is established, once and for all.

So as soon as this test stops and all this stuff stops coming through, what you start to do is you start to capture grab samples or isokinetic samples?

MR. SMITH: Yes.

CHAIRMAN BANERJEE: So you actually get the fiber loading coming through the bed as a function of time, but now that flow is recirculated back to the bed, so the bed starts to build up more and more fiber.

In reality, it may not because that -- the core is also a filter. You see what I mean? So all that stuff might not come back to the bed.

MR. SMITH: That's true.

CHAIRMAN BANERJEE: A portion of it gets caught in the core. So when you say it's a conservative number, is it really conservative or not?

MR. SMITH: I think overall it probably is. We discussed on the cold leg break some -- a lot of the debris would come back, and the amount of fiber that is bypassing the strainer is generally quite small. I mean percentagewise of what is upstream of the strainer, it's usually a couple percent --

CHAIRMAN BANERJEE: Once-through takes care of that.

MR. SMITH: -- goes through.

MR. WALLIS: It's not even that much.

CHAIRMAN BANERJEE: Right at the beginning. Even right at the beginning.

MR. SMITH: Some plants have assumed 5 percent. One plant I actually saw testing that said 9 percent went through, which I thought was really high. I don't know how that was determined, but it may have been a very conservative test that was done. But most of them are much lower.

MR. WALLIS: Nine percent of 35 pickup trucks is something like three and a half pickup trucks.

(Laughter.)

CHAIRMAN BANERJEE: So, okay, I'm still -- because the core is not in series with the screen when you recirculate that, with the cold leg break you're saying maybe three-quarters or two-thirds comes back. So your first approximation, what you're saying is that it's okay.

And does the bypass vary strongly with

time? Or is it fairly constant?

MR. SMITH: It's very strongly time. It's much more at the beginning.

CHAIRMAN BANERJEE: So then my question is sort of important.

MR. WALLIS: I'm very puzzled by all these qualitative statements we keep hearing. I like this 5 percent, 9 percent. I mean it doesn't seem to be consistent with other things we're hearing, and so tell me --

CHAIRMAN BANERJEE: You have data; right?

MR. WALLIS: -- some facts here that we --

CHAIRMAN BANERJEE: Do you have data on how this varies with time? Do you have some sample data?

MR. ROLAND: Could we -- could I suggest to help with this discussion that we could provide the committee a description of precisely how we determine this particular factor? Could we do that, rather than -- because I -- it's not clear that we're talking about the same terms. There's a whole set of language that is unique to this specific matter. Could we -- I would ask the staff, if you would indulge us, Chairman, to prepare something for the committee's use precisely to describe exactly what this phenomenon is.

Could we do that? And maybe that might add some clarity to it.

CHAIRMAN BANERJEE: Excellent.

MR. WALLIS: Well, just some kind of a diagram --

MR. ROLAND: Like a diagram, exactly.

MR. WALLIS: -- to help pick up --

MR. ROLAND: Yes, we need --

MR. WALLIS: This tiny little bit that goes to the core --

MR. ROLAND: Yes, Dr. Wallis. We need to provide some clarity here.

MR. WALLIS: I'm very confused by this slide. What does the last bullet mean? It means that everything that comes to -- that the strainer might as well not be there?

MR. SMITH: For particulate and chemical debris, yes.

CHAIRMAN BANERJEE: That's quite clear, it said that.

MR. SMITH: It's just the fibers.

MR. WALLIS: There's no filtering at all of particulates?

MR. SMITH: That's the assumption.

MR. WALLIS: In reality there is.

MR. SMITH: Yes, in reality there would be some. There would be some filtering.

CHAIRMAN BANERJEE: Well, the real issue is I think if you do what Bill suggested, it will clarify a lot of things. And the things that I would like to see clarified is how you are making these measurements, how they have been made, how they are varying with time, and what you really mean by cumulative, as just integrating these over a period of time.

Anyway, once we have that, then we'll have a much better understanding of the situation.

MR. SMITH: Okay.

MR. WALLIS: It's very strange, really, because in order to get the NPSH calculation conservative, you put all the chemicals in the strainer, and then in order to get this conservative, you put all the chemicals in the core.

MR. SMITH: Right.

MR. WALLIS: How do they get caught in the strainer? They must --

MR. SMITH: There is -- there are a number of conservatisms associated with this whole process, and it's just because of the unknowns. That's why we put the conservatisms in.

CHAIRMAN BANERJEE: Well, let's move on to the next slide, please.

MR. SMITH: Okay. This one I think we can just go past because we've discussed it all.

We had some early testing of the guardian grid that was done by a plant, and actually talking about testing that's been done to date. The staff isn't really taking that testing because there wasn't really good data, so we're not going to consider that testing.

We have Diablo Canyon testing that was done, and I have more details coming up on that.

The PWR Owners Group did some generic testing using a three-inch cylinder and we're not sure how that really applies, and now they've moved on to a more -- to a more prototypical test loop, and you saw what they talked about earlier, so I don't need to say too much about that, probably.

On -- the Diablo Canyon testing was done on an alternate P-grid. It was performed at CDI up in New Jersey. The staff was up there and witnessed a lot of the testing. The debris was prototypical for the plant, and they varied the debris load to see what would give them the highest head losses.

In some cases they doubled some of the

debris loads, like they doubled their fiber load on one test, they doubled their CaiSil load on some tests, they put extra chemicals in on some tests.

They had a bottom nozzle with the protective grid on top of it and then one intermediate grid strap slightly above that, and they tested, as we have discussed, both hot and cold leg flows, and their head losses came out within the allowable limits.

CHAIRMAN BANERJEE: And they had a centrifugal pump?

MR. SMITH: They had a centrifugal pump. They had a flow control on it also that maintained flow constant.

CHAIRMAN BANERJEE: Did the pump chop up any of this stuff, do you know?

MR. SMITH: I guess the pump could have chopped some of it up. The debris went through the pump.

CHAIRMAN BANERJEE: Right. Right. But the fiber lengths, did they change or anything like that?

MR. SMITH: I don't know if the fiber lengths changed after they went through the pump. They used actual debris that they put through their strainer, they put this upstream of a strainer, put it through the strainer, and collected it after it came out, and they actually used that debris, so they used real prototypical bypass fiber for their test rather than putting it in a blender and measuring it to make sure. They actually used a real bypass fiber.

CHAIRMAN BANERJEE: Okay.

MR. SMITH: This is just a schematic. The debris is all added into the plant here. It gets -- like we said, it gets pumped through a flow meter and flow control device. They have a little flow diverter here to make sure nothing settles out in the bottom, and then it goes up through the test article.

Anything that bypasses would go back around and go through the pump again.

In addition, they have some agitation in this tank here, so that nothing would settle out.

MR. WALLIS: It doesn't look like the picture.

MR. SMITH: Well, this is just like a cartoon depiction.

MR. WALLIS: It just looks as if the two grids are on top of each other in the sketch, and they seem to be separated in the picture.

MR. SMITH: Oh, in the picture, you're right, the grids are very close together. You cannot

-- in this picture here, you cannot see the bottom nozzle. It's behind that piece of aluminum.

MR. WALLIS: It's behind there. Okay.

MR. SMITH: It's behind the piece of aluminum.

MR. WALLIS: Okay.

MR. SMITH: And that's all you see, is the P-grid or protective grid, and then a little piece of like simulated fuel rods and then intermediate strap that you see here. That's why that looks a little bit funny.

MR. WALLIS: Okay.

MR. SMITH: And then the next picture shows basically a clean pretest, which this was passed around, so I think you guys have seen this up close and personal.

And this is just another -- this is a view of it from the top.

Yes, keep going.

This is -- after testing, this shows how some of the holes in --

MR. WALLIS: So what's -- excuse me. What was handed around was the bottom nozzle.

MR. SMITH: The bottom nozzle and --

MR. WALLIS: But the P-grid was never

handed around.

MR. SMITH: You're right, the P-grid was not handed around.

MR. WALLIS: I don't know what it looks like.

MR. SMITH: It looks like about half of the strap that you saw, flat on one side, and it's flipped upside down and put on -- the flat side is put against the --

MR. WALLIS: Well, that's the key thing, isn't it? That's the thing that captures the stuff?

MR. SMITH: That's what is supposed to catch the stuff.

MR. WALLIS: That's the one that wasn't handed out.

MR. SMITH: I guess that must be proprietary.

But what the testing did show, in response to that comment about what it's supposed to catch the stuff, it is supposed to catch the stuff, but what we saw in the testing that had the multiple grid straps is that the debris actually spreads out throughout the assembly. So the P-grid is not actually that great at catching the type of debris that we're putting in there.

And this just shows how some of the debris collected in the bottom nozzle, and then the next picture is probably a little bit -- this shows a side view of some of the debris.

MR. WALLIS: It doesn't look very uniform.

MR. SMITH: No, it's not. I think that it wouldn't -- I think that it would get more uniform if a lot more fiber was put in. I think that would create uniformity of --

MR. WALLIS: Well, doesn't this flow diverter set up some vortices in the middle chamber before all this stuff you're showing us here?

MR. SMITH: I think -- it probably does. It probably does set up some vortices. I don't know how that would compare to the real plant. I don't know.

MR. LANDRY: This is Ralph Landry from the staff.

No, the flow diverter is there to prevent vortices and to prevent any kind of channeling of flow and directing the flow. The flow diverter is a cone on top of the pipe that comes up --

MR. WALLIS: The flow goes up along the bottom and around like this?

MR. LANDRY: The flow comes up, hits the

flow diverter, and goes around and then comes up, so that you develop a uniform field of flow coming up into the test article rather than jetting straight up at the test article.

MR. WALLIS: How does it make the uniform flow if it's directing it along the bottom of the --

MR. SMITH: We observed -- I'll tell you, at the 5 gpm flow rate -- at the 40 gpm flow rate, I imagine you probably are going to get some turbulence up there, but at the 5 gpm flow rate, we were up and observed, and it appears that the debris comes in and flows up quite -- you know -- evenly and there's not a lot of flowing around. At the 40 gpm flow rate, I imagine there probably is some --

MR. WALLIS: So the fact that some of the holes get blocked and others do not is a kind of statistical thing? They stop, it keeps growing, and then they just get blocked and some of them don't?

MR. SMITH: Well, I think what actually happens is this: Some of the -- they may all get blocked, but the debris gets pushed through some of them and up further into the assembly.

And then the next picture, I think, will show you -- this shows how the debris is actually collected. That is the bottom of the P-grid. This is the bottom of the P-grid, so debris that came through these nozzles collected on the bottom of this P-grid, and it's pretty -- it's just kind of like funky, I guess; I don't know.

MR. WALLIS: The white stuff that we see on the bottom there is what fell off the P-grid onto the -- whatever the other thing is, the cold leg or something?

MR. SMITH: Yes. It was like sandwiched in between there so when you pull the two apart --

MR. WALLIS: So when you open it up, it's misleading because some of it's on one and some of it's on the other.

MR. SMITH: Those pieces are like sandwiched together, so you --

MR. WALLIS: It looks as if it was pretty well uniformly covered, and then some of it stuck to the other surface when you opened it up.

MR. SMITH: That's right.

CHAIRMAN BANERJEE: In proportion to what the Owners Group showed us, was this more fiber or less fiber than they had?

MR. SMITH: This is less fiber. Their design basis loading per fuel assembly was about 13 grams, whereas the Owners Group was testing with 53 in the test that we saw. So this is a low fiber plant.

The one difference is that I think that we collected probably more debris in a smaller area on this test, whereas the 53 grams was spread out between several grid straps.

MR. WALLIS: It looks as if the P-grid grabbed enough fibers to start packing them up into the bottom nozzle.

MR. SMITH: Yes.

Diablo also did a test which I didn't put on there, but they did a test where they actually duct-taped off the bottom nozzle so that it was totally blocked, so that you only had flow bypassing around, coming through the larger holes, these larger holes, it would come up and out these larger holes and bypass, and they -- at the 5 gpm flow rate, it was a relative -- there was enough bypass that they had a relative head loss, but they couldn't get up to the full 40 gpm flow rate with the test rig there because I think they had like a 5 psi limit and they didn't want to exceed that and break the rig. I'm not sure what the limit was, but there was a limit that they couldn't exceed so they stopped just below it.

MR. WALLIS: Well, at 5 psi, it assures that it will always be less 13.

MR. LANDRY: The limit was 120 inches of water.

MR. SMITH: One hundred twenty inches of water. Okay.

MR. LANDRY: They hit 119 at 36 gpm.

MR. WALLIS: What's 110 inches in psi?

MEMBER ABDUL-KHALIK: About four.

MR. LANDRY: That's just under a third of an atmosphere.

(Laughter.)

MR. LANDRY: Thirty-four feet of water per atmosphere, that's 10 feet of water, so it's just under a third of an atmosphere.

MR. WALLIS: It's tiny compared with what you're interested in.

CHAIRMAN BANERJEE: No, it's sort of -- an atmosphere is 5 psi.

MR. WALLIS: This magical 13.9 psi.

CHAIRMAN BANERJEE: They're not interested in the 13.9. That's still under --

MR. WALLIS: They're showing it's less than that.

CHAIRMAN BANERJEE: Let's go on.

MR. SMITH: The next slide shows debris types, and with the limited amount of fiber that we see here, it appeared that the things that would really drive head loss, if the CaiSil was increased or if these chemical precipitants were increased, those would tend to drive the head loss up. So it wasn't really such a -- dirt and silicon carbide did not drive the head loss as much as the CaiSil and chemicals seemed to drive it a lot more, which is pretty typical of what we've seen with other like vertical loop testing. They seem to be a lot -- drive head loss more than just other particulates.

Okay. And then the PWR Owners Group testing, I don't know that we really need to talk over this a whole lot because I think they already presented it, you know, a lot more than this to you.

MR. WALLIS: This picture that shows the bottom nozzle and P-grid, slide 15.

MR. SMITH: Uh-huh.

MR. WALLIS: That is only the P-grid that is shown there? It looks awfully thick.

MR. SMITH: Well, the P-grid is what is facing you. The simulated fuel is still there and it's still holding --

MR. WALLIS: So it's not just the P-grid, it's the P-grid plus the fuel plus the spacers?

MR. SMITH: Plus the spacers, that's

right.

MR. WALLIS: Aah, that's -- okay.

MR. SMITH: I'm sorry. The title was a little misleading.

MR. WALLIS: It looks as if there's a lot of debris on the fuel between the P-grid and the spacer, filling up the whole thing on the top.

MR. SMITH: Yes, that may have occurred because of the --

MR. WALLIS: It's an edge effect, is it, or what is it?

MR. SMITH: I don't know. I'd be guessing.

CHAIRMAN BANERJEE: Well, in general, the distribution looks like it's more around the edges. If you looked at two or three slides back --

MR. LANDRY: When we were there, when they took those -- this whole rig apart, the distribution of material in the bottom of the P-grid was very uniform all the way across the P-grid. And when they took the top grid, the intermediate spacer grid off, there was a film on the bottom of that grid also, but it was significantly thinner than the film material on the P-grid. But it too was a uniform grid covering. So the material, as Steve has said, was filtering out as you went up grid to grid, but of course there are only two grids there.

MR. WALLIS: Well, what we see here is a big white sort of sandwich there between the two. Is that an illusion of some sort? Between the P-grid and the spacers --

MR. LANDRY: No, those are rods.

MR. SMITH: Those are fuel, those are simulated fuel rods.

CHAIRMAN BANERJEE: They are white, you see.

MR. WALLIS: But it fills the whole space.

MEMBER ABDUL-KHALIK: There is junk between them.

MR. SMITH: Well, there's some. There's some open area between and there's some --

MR. WALLIS: No, no, if you go up top, you look at the sandwich.

MR. SMITH: This?

MR. WALLIS: That strip there. It's pure white.

MR. SMITH: I'll show you a picture of the clean one and you can see what --

MR. HARRISON: You can see it here from the side.

MR. LANDRY: The amount that was captured between the rods themselves was very, very little.

MR. WALLIS: That's an illusion then.

MR. LANDRY: Right. This is just from looking at a messy piece of equipment that's been disassembled. As it was taken apart, we were there to watch, and we saw that there was very little material captured rod to rod. Virtually everything was captured by the grid itself. And when those Delron rods were pulled out, material did not come out with them. It stayed in the grid.

MR. WALLIS: It looks like enough to make a thin bed.

MR. LANDRY: We measured -- we took a piece off and measured it. It was about an eighth of an inch on the P-grid.

MR. WALLIS: So are we getting back to what the chairman asked for last time, which was studies of a uniformly blocked core?

CHAIRMAN BANERJEE: A thin bed.

MR. WALLIS: We seem to be getting back to that, don't we?

CHAIRMAN BANERJEE: Well, 1/8th inch obviously is not enough to cause you real problems, but --

MR. SMITH: I think that that question about a uniformly blocked core is a perfect lead-in to Bill's discussion of the models that Research did.

MR. WALLIS: We've come a long way from saying there was no effect to saying this, it seems to me. What it means, we have to figure out.

CHAIRMAN BANERJEE: Well, the amount of fiber that you used here was -- give me a rough idea. Was it about a quarter of what the Owners Group was testing, or --

MR. SMITH: Thirteen grams versus 53, so approximately a quarter.

CHAIRMAN BANERJEE: Okay. And typically even though you saw it fairly uniformly distributed, it was less than an eighth of an inch thick?

MR. SMITH: On the P-grid, yes.

CHAIRMAN BANERJEE: And, I don't know, maybe we should ask the Owners Group. Did they do an analysis sort of when they disassembled the stuff? Did you guys see it sort of fairly uniformly distributed like this, a certain thickness of fiber or what did it look like?

MR. ANDREYCHEK: When we disassembled the rods, we didn't do a, quote, analysis. It was observed to be relatively uniformly distributed by pressure drop across the grid spaces. And that's using the pressure drop measurement to indicate collection of debris, and it was a relatively uniform pressure drop across the -- give or take a tenth or two of a psi -- across the -- each of the grid straps in the test bundle.

CHAIRMAN BANERJEE: How did you know it was relatively uniform? I mean --

MR. ANDREYCHEK: We actually had pressure drop measurements. That's --

CHAIRMAN BANERJEE: I know you had that, but --

MR. ANDREYCHEK: I'm saying by pressure drop --

CHAIRMAN BANERJEE: I'm saying the observation at that -- well, as Professor Wallis was saying, if you had some channels which were not very blocked, most of the flow would go through them, and by the pressure drop measurement, you wouldn't know it's uniformly distributed or nonuniformly distributed.

MR. ANDREYCHEK: That's true.

CHAIRMAN BANERJEE: So the issue here is when you observed it postexperiment, it looks relatively uniformly distributed. Did you do some observations postexperiment?

MR. ANDREYCHEK: Yes, and there was debris at each elevation. We didn't focus to see whether or not it was uniformly distributed, but there is debris at each of the elevations, and it was spaced throughout the bundle.

CHAIRMAN BANERJEE: Are you able to observe whether, when you disassembled the bundle, whether it's uniformly distributed, or does it totally disturb the distribution when you disassemble it?

MR. DINGLER: When we pulled it out, it wasn't as, let's say -- I hate the word, use quotes, compacted like Diablo, so it came loose a little easier than that when we pulled them out. So it was a little tougher for us to see it because it wasn't -- as you see it here, when we pulled it apart, some was stuck on the top, and some -- my understanding is we didn't see that.

CHAIRMAN BANERJEE: You didn't. Okay.

MR. WALLIS: Well, since this looks like a pretty uniform distribution, I would expect you would get good comparison between the pressure drop in terms of the flow rate and the same constituents and so on. Were the tests done at ANL and PNNL in the vertical loop, which is very similar? There really ought to be a comparison made for the same constituents and the same method of introduction, same area. Was the pressure drop the same or close? Was it orders of magnitude different or what? I've read about this from the vertical loop test. It looks very, very similar.

MR. SMITH: The vertical -- it would be difficult to get the proportion of debris on this strainer, on the vertical loop strainer, the same as --

MR. WALLIS: Why?

MR. SMITH: Because we don't know exactly how thick or where this debris bed exactly was, and there's bypass flow around this, around parts of this. It's a lot more complicated than a simple vertical loop would -- you know, that's completely blocked off.

MR. WALLIS: And so bypass flow --

CHAIRMAN BANERJEE: I think Bill is going to answer the modeling questions. So why don't we --

MR. SMITH: Bill will answer the modeling. I think Paul maybe wants to jump in.

MR. WALLIS: You want to make the comparison because there's always then going to be the suspicion that there weren't enough tests here to pick up some of the phenomena which you observed in the vertical loop test.

MR. SMITH: I think it would be really difficult to compare the two, but we can look at it.

MR. WALLIS: I think you should.

MR. KLEIN: With respect to the Diablo-specific test, I think they did on the order of 18 tests or so, so there is quite a bit of data there in their plant-specific debris, but the difficulty with benchmarking that to the earlier ANL stuff is that you had calcium silicate and other insulation materials that weren't in the ANL test loop, so it makes comparison between the two more difficult.

MR. WALLIS: So what use then -- aren't these old tests supposed to shed light on what happens? Now they're no good because they somehow contain different materials or something?

MR. KLEIN: I think that --

MR. WALLIS: I thought that we learned a lot from the ANL tests.

MR. KLEIN: We did learn a lot.

MR. WALLIS: Now you're saying that because they can't be compared with these, we should ignore them?

MR. KLEIN: No, I'm not suggesting that. I think the ANL tests informed us -- they provided a lot of information with respect to chemical effects.

I think we have to be somewhat careful in comparing ANL tests with fiber and WCAP surrogate with a test that has fiber and calcium silicate and latent debris and WCAP surrogate.

MR. WALLIS: ANL got these interesting tests where you go along with the pressure drop and the flow; right? Then they do something, and whoop, the pressure drop is 20 times as big. That never happens here; right?

MR. KLEIN: I think what -- I think what you're starting to see in some of the evidence, it's accumulating in the assembling tests, is that fiber seems to be the controlling factor, it seemed like with -- say you look at the first three Owners Group tests as a whole, and it seems like there's plenty of particulate and chemical particulate in those tests. If you didn't see a sensitivity in a greater amount of particulate with test two compared to test one, I think as you added more fiber and created a bed somewhere that was a better filtering bed, you're starting to see some increase in head loss now with chemical precipitate where you didn't see that in test one.

MR. WALLIS: So you ought to be able to

get something like the ANL tests and then show that it's so atypical.

MEMBER SHACK: Well, I think the thing that you're thinking of in the ANL test is where we did tests where the initiation of the precipitation occurred during the test as we were changing concentrations.

Here they are adding the precipitate externally. This is like our Westinghouse surrogate test where we get exactly the same thing they get, you know, we add a little bit of surrogate, and --

MR. WALLIS: So the surrogate doesn't duplicate what happens when you got --

MEMBER SHACK: Well, it -- what Paul tried to say was that, you know, when we look at equivalent amount of aluminum removed, the surrogate is more conservative than any other way we've found to induce the precipitate. Whether we induced the precipitate by adding chemical amounts of aluminum, whether we add the aluminum by corroding aluminum plates in place --

MR. WALLIS: That's amounts of aluminum, but how about -- it can be conservative for delta P.

MEMBER SHACK: When I say it's conservative, the delta P that you get for the equivalent amount of aluminum for one ppm of aluminum is higher from the WCAP surrogate than anything else we have ever tested.

MR. WALLIS: Well, they should be able to duplicate your tests, so you go along and add a little bit more aluminum and --

MR. KLEIN: Well, you have a more complex geometry here in that you have perhaps multiple beds at different elevations that are accumulating fiber, so it is somewhat different than flat plate and the vertical loop.

MR. WALLIS: The dominant bed is this one we see here, is the dominant bed, which is the one on the -- at the P-grid.

MR. LEHNING: This is John.

I just wanted to add to some of the other points already made. And one of the things is that it wasn't throwing out that ANL data. I think like was said, that was used to say this WCAP precipitate is conservative by using those tests and running those values, and that's what's being used in these tests.

I think in addition to some of the different types of debris being used, the debris is different sizes. This is the bypassed size of fiber versus the amount that would collect on the strainer. The geometry used to collect the fiber, and the flow patterns would be different as well, too.

So given all those differences, you wouldn't be able to quantitatively say that the same amount of debris on this type of set-up here in this fuel assembly would be the same as you would get in this vertical loop.

I mean you could use insights, and that's the way we're using that ANL. We're not ignoring that data.

MR. WALLIS: The vertical loop did show that there was a critical condition where you suddenly got a very high pressure drop, and although this was not thoroughly explained, it happened. There was some sort of combination of circumstances where it happened.

I would expect, therefore, it would happen here with the right combination of circumstances.

MR. LEHNING: What was being tested in those ANL loops, I think was said already, at the onset of precipitation and things like that. So you decrease the temperature or -- I'm not exactly sure which test we're talking about -- and then it spiked.

And here -- and that test was used to basically say that WCAP precipitate had -- would have the similar type of impact as was seen in those tests, and that's what we're using here.

I mean if you had everything the same, you could go back and say if we set up like an ANL loop and then added in WCAP precipitate for a similar quantity in that set-up that you should get to the same end point, but you may not get this big jump. But this is a different set-up with a different type of debris, different sizes of debris, different strainer to collect it on, and so one wouldn't necessarily be able to get to that same end point.

MR. WALLIS: Of course, when they do the full test matrix, they may get something like what ANL got with the spike.

MR. KLEIN: They may as they get to higher fiber loads.

MR. GEIGER: If I may add my two cents, since I observed this. Erv Geiger.

What I observed and nobody has mentioned yet is that in observing these tests, there were eddy currents and counterflows and everything going every which way, which when the flow came up through that bottom nozzle assembly and it hit that P-grid, it could go underneath sideways and break up the debris. So there were many flow paths, and I think there was enough turbulence to -- as soon as the pressure drop got too high just to break up some of that, to break through.

CHAIRMAN BANERJEE: Did you see that at the lower flow rates as well, the 5 gpm, or even at the --

MR. GEIGER: Even at the 5 gpm, yes. And as it loaded up, you could see on the sides of the wall, and actually in the corners, you'd have flow coming up and going down and going through and going every which way. So it was -- it was a fascinating experiment to watch and, you know, I was trying to figure out a way to explain exactly what was going on. But you could see the surrogate, the chemical surrogate material as it like migrated in different areas, and you could actually see where the current was all -- going every which way. So it wasn't like, you know, in the ANL test you have a nice uniform flow coming up or going down through that matrix, right? I mean it was fairly uniform. For this thing, it was just churning every which way.

MEMBER SHACK: As uniform as we could make it, yes.

CHAIRMAN BANERJEE: Well, the particles mixed the flow, so it would probably make for a uniform debris loading, which is what you observed.

MR. GEIGER: And the bypass around the sides made a big difference, because you could get bypass through slides and it would go back in through the matrix, and attempt to break all of that up. That was my observation.

CHAIRMAN BANERJEE: Can we let Bill --

MR. SMITH: Yes, we've been promising you Bill. He's ready.

MR. KROTIUK: Actually I did this assessment to look at the uniform distribution at the inlet of the core, and I used a TRACE calculation, but I also did an independent hand calculation on an Excel spreadsheet.

CHAIRMAN BANERJEE: Excellent. Exactly what we wanted.

MR. KROTIUK: Right. But I thought, you know, it would be interesting to compare the two. So this slide I'm just describing the models. It has a fairly detailed core model for TRACE, and in both calculations I assumed that the recirc started at 120 seconds, so that's really when you got instant -- I assumed there was an instantaneous debris bed formed at that point in time.

Okay. The hand calculation was basically just an approach where I was trying to balance, similar to what Dr. Wallis was saying. It's based on trying to balance the pressure drops and energy going into the core, such that you could calculate the rate on a flow rate and get an appropriate flow rate.

Two-phase pressure drops were included in there. I had a simple homogenous Martinelli-Nelson type correlation.

CHAIRMAN BANERJEE: Did you take subcooling into account?

MR. KROTIUK: Yes, subcooling was taken into account, so there was a part of the bottom of the core that was actually subcooled, and we actually calculated where that location was.

CHAIRMAN BANERJEE: Well, since you kept quiet during the discussion with the Owners Group, what was your average void fraction?

MR. KROTIUK: It was a function of flow rates.

CHAIRMAN BANERJEE: What was the maximum?

MR. KROTIUK: Let me just take a look. Okay, it was a function of flow rate and a function of the bed thickness that was assumed, and it --

CHAIRMAN BANERJEE: That's your personal spreadsheet; right? It's not --

MR. KROTIUK: Yes, it's not here. This

report is available. I just --

CHAIRMAN BANERJEE: Anyway, tell us the numbers.

MR. WALLIS: Did you have chemical effects, Bill?

MR. KROTIUK: No. Okay, let me just -- before I do that, let me just say what my assumptions were, okay, just so that, you know --

What I did is that I did the calculation for an unblocked core and then 1.2 inch, 2.4, and 4 inches of Nukon/CaiSil. The pressure drop that I assumed -- that I should say calculated for the debris bed was based on the PNL testing.

CHAIRMAN BANERJEE: This was not 6224 or anything?

MR. KROTIUK: No, it was not 62-- well, no, it was not 6224. Based on the PNL test data and then using the model that I had developed for NUREGS 1862, where I assumed the saturated, as you were saying, the saturated portion of the debris bed, I then used that calculation to extrapolate up to the larger thicknesses and also to extrapolate up to a higher operating temperature, because the tests at PNNL were run at a lower temperature.

CHAIRMAN BANERJEE: Without chemical

effects?

MR. KROTIUK: Without chemical effects, right.

So in order -- I put the -- what I ended up doing, since when you're doing these calculations for a pressure drop across the debris bed, you'll essentially have a pressure drop that's somewhat linearily dependent upon velocity as opposed to a V-squared.

And so --

CHAIRMAN BANERJEE: Because it's in that region?

MR. KROTIUK: It's in that region, right. Yes.

CHAIRMAN BANERJEE: It's not --

MR. WALLIS: The PNNL data, was this the -- did you then -- and you said you had nonuniform bed?

MR. KROTIUK: Nonuniform bed.

MR. WALLIS: And you had the worst case?

MR. KROTIUK: I don't know if I had the worst case or not. I can't answer that. I'd have to go look at the data again, but I chose what I thought was a good case to look at.

MR. WALLIS: So you have a sort of a saturated bed?

MR. KROTIUK: I have a saturated bed.

MR. WALLIS: So you had a thin bed effect, so --

MR. KROTIUK: Right. What is called a thin bed, which I have called in previous -- and you picked up on it, I call it a saturated bed.

MR. WALLIS: And the proportions of Nukon/CaiSil were based on what?

MR. KROTIUK: The proportions of Nukon/CaiSil were based on the test that was done at PNNL, and then I extrapolated up to give the appropriate thickness.

MR. WALLIS: How does that compare with the Owners Group proportion? Or they didn't use CaiSil, did they?

MR. SMITH: They haven't used CaiSil yet. That's in the plants.

MR. KROTIUK: I can't compare that. I don't know the comparison.

CHAIRMAN BANERJEE: Go on. I think it's interesting.

MR. KROTIUK: Okay.

CHAIRMAN BANERJEE: So we know what you did.

MR. KROTIUK: And then for the hand

calculation, what I did is that I just did steady state calculations at 1200 seconds, which is timer recirc, and then at 2000 seconds. The tracer on it went out longer than that.

Now I've sort of lost my track. You have to ask me something.

MR. SMITH: Was that the void fraction?

MR. KROTIUK: The void fraction, right, yes.

CHAIRMAN BANERJEE: You can go on and tell me as you go on.

MR. KROTIUK: The void fraction -- ah, geez, I didn't print it out here. I have the exit void fraction.

CHAIRMAN BANERJEE: Tell me the exit void fraction.

MR. KROTIUK: The exit void fraction for these cases varied pretty high. It was almost 100 percent.

CHAIRMAN BANERJEE: So it was just basically all steam?

MR. KROTIUK: Basically, yes. But --

CHAIRMAN BANERJEE: But essentially boiloff?

MR. KROTIUK: Yes, but I didn't uncover

the core. I'll go over that. There was one case where --

CHAIRMAN BANERJEE: That is reassuring.

MR. KROTIUK: Yes.

(Laughter.)

MR. WALLIS: This value is uncompressed, is it, or --

MR. KROTIUK: That's sort of a nominal bed thickness, right.

MR. WALLIS: With the pressure drop, it gets thinner?

MR. KROTIUK: Right. It gets thinner. I looked at it -- you know, this came up with a nominal number to use. But it does vary as a function of various things, velocity and whatever.

Let's look at the -- first the results here. There's a TRACE calculation. And -- oh, one other thing I wanted to say, in order to be able to incorporate this correlation to -- for the pressure drop across the debris bed, since it's really directly proportional to velocity, I did include into TRACE a modification to include a loss coefficient for the debris bed that was a function of the bed thickness, and was --

CHAIRMAN BANERJEE: Based on the

correlation?

MR. KROTIUK: Based on the correlation, right. So it was bed thickness and approach velocities.

So then in essence what happens is the pressure drop was dependent upon velocity. It comes out to be 1.1 power. Close to 1.

CHAIRMAN BANERJEE: I think you're filling the peak clad temperatures, but clearly you have things like the collapsed liquid level.

MR. KROTIUK: Yes, I have collapse liquid level. I just didn't include all that information. I have written a report, and that report is available. I can give you the numbers so that you can take a look at it.

CHAIRMAN BANERJEE: And the report has all this stuff in it?

MR. KROTIUK: The report has all that stuff in it, yes. Okay.

MR. WALLIS: How do your fiber quantities compare with the 53 grams per assembly in the --

MR. KROTIUK: Yes, I was -- you know, when you went to lunch, I actually was doing that calculation to try to see, and I couldn't come up with a good comparison right now because everything I did was in kilograms per square meter.

MR. WALLIS: But you know the material --

MR. KROTIUK: Yes, I know the total amount of material and in fact entered it --

MR. WALLIS: But you calculated it?

MR. KROTIUK: Yes, I just haven't taken it that far.

CHAIRMAN BANERJEE: Didn't you know that we'd be asking you questions like that?

MR. KROTIUK: Yes. In fact, I have a back-up slide with it. But I -- it's in the report and I could actually --

CHAIRMAN BANERJEE: Is it exactly what we wanted?

MR. KROTIUK: Yes. I just haven't taken the step --

CHAIRMAN BANERJEE: All right.

MR. KROTIUK: -- to come up, because I didn't really know --

MEMBER SHACK: Well, it may be hard to do the one-to-one comparison because yours are based on a much longer and unchopped fiber length, where their fiber length distribution --

MR. KROTIUK: Was finer.

MEMBER SHACK: -- was finer, and so your

--

MR. KROTIUK: That's that.

MEMBER SHACK: -- model really is a little different than their model.

MR. KROTIUK: So I used the data that I had, and that was available data.

Okay. Back to TRACE results.

This table here with the TRACE calculation shows the peak clad temperature that was calculated, and actually for the TRACE -- it's a transient calculation.

For the unblocked, for this case, the -- you could see that we were down and look at degrees Fahrenheit, you know, 280 degrees Fahrenheit. And somewhere between 2.4 and 4.8 inches thickness of the bed, the temperature started to increase and there was a peak clad temperature -- I have 4.8 inches that was almost 200 -- I'm sorry, 960 degrees Fahrenheit.

CHAIRMAN BANERJEE: Well, these peak clad temperatures and things depend a lot on the heat transfer models and stuff like that.

MR. KROTIUK: Right.

CHAIRMAN BANERJEE: That's the collapsed liquid levels, which are more.

MR. KROTIUK: Yes. And again, to report,

I do have the collapsed liquid levels. And then again as a comparison I compared these results to the hand calculation. Obviously in a hand calculation I did not calculate a peak clad temperature because it was just heat addition and boiloff.

But what I was able to do was to compare the -- I would just say the collapsed level of the liquid in the core, and then we related that back to some of the experiments that we've run, the RBHT and the data experiments, and come up with an assessment of when you would get a -- you know, an uncovery of the top of the core based on the void fraction measurement, void fraction calculation, and the data -- the test results, and just doing a correlation.

CHAIRMAN BANERJEE: When you set this up, you didn't tell us, was this for a hot leg break or a cold leg break?

MR. KROTIUK: I'm sorry. Yes, it was for a cold leg break.

CHAIRMAN BANERJEE: Okay.

MR. KROTIUK: Sorry.

CHAIRMAN BANERJEE: So you took into account the bypass flow out of the cold leg?

MR. KROTIUK: That's correct. Yes. Yes, it took into account the bypass flow out of the cold leg, yes.

CHAIRMAN BANERJEE: And -- yes, I think this is the more restrictive case. Okay. Go ahead.

MR. KROTIUK: But the interesting thing is that the hand calculation in terms of the collapse level and the point at which you start getting the core uncovery -- because for that last case, the TRACE was showing you were starting to get the core uncovery for that 4.8 inch thick bed, and there was an agreement, basically agreement within I'd say 10 to 20 percent between the hand calculation and the --

CHAIRMAN BANERJEE: I would think your hand calculation of this is good because the whole thing is dominated by the pressure drop.

MR. KROTIUK: That's right. It's balance of the pressure drop and balance of heat.

CHAIRMAN BANERJEE: So this was the question we asked you the last meeting, or asked somebody.

MR. KROTIUK: Asked somebody, right.

MEMBER ABDUL-KHALIK: How does the core flow rate change as you move along in this thickness?

MR. KROTIUK: In what way? I mean it was a fraction of what? I don't quite understand.

MEMBER ABDUL-KHALIK: As the thickness of this layer changes.

MR. KROTIUK: Oh, okay. Got you.

MEMBER ABDUL-KHALIK: How did the core flow rate change?

MR. KROTIUK: Okay. For instance, I'll talk about the calculations at 1200 seconds, which is just set recirc. For the unblocked core, it was like about 115 kilograms per second. For the 1.2 inch, it was like 78; 2.4 was 61; and 4.8 was 45.

CHAIRMAN BANERJEE: It's fairly linear because you're in the part of that sort of equation which is in the laminar region, so this is delta P --

MR. KROTIUK: That's right. That's correct.

MR. WALLIS: So there's no sudden effect; it's just a steady increase?

MR. KROTIUK: No. It's a steady increase, yes. To the flow rate.

CHAIRMAN BANERJEE: That's because it's such a low flow rate.

MR. KROTIUK: Yes. The flow rate is completely dominated by gravitational effects, you know, and the balance with the pressure drop.

CHAIRMAN BANERJEE: And you took into account the voiding in the core, of course, automatically?

MR. KROTIUK: Yes, we took into account the voiding in the core, so the bottom of the core had all subcooled liquid, and then there was a two-phase region calculated at a place where you had to transition from a subcooled liquid to starting the voiding. I made some approximation, obviously, since this is a hand calculation regarding the distribution of the void in the --

MR. WALLIS: You just used the homogenous model?

MR. KROTIUK: Homogenous model, right. Homogenous model, right.

MR. WALLIS: So you have a theory which lets you predict this?

MR. KROTIUK: That's correct.

MR. WALLIS: I haven't seen anything like that from anybody else today. All this data is coming and we're going to do something with it. We think we're going to be conservative. We're going to have enough to demonstrate we're conservative.

MR. KROTIUK: I guess the question is --

MR. WALLIS: But you have a theory that says this is the way that the core blockage evolves with time, and this is the maximum temperature we get, and so on.

CHAIRMAN BANERJEE: Well, the theory assumes a bed. I mean the whole difficulty is predicting what happens to the bed.

MR. WALLIS: The strategy of the utility seems to be to take some limiting case and show that that's -- they'll never get there. It's not to actually make a prediction of the way in which the temperature varies throughout the transient. Is that right? He's predicting the way the temperature varies throughout the transient. I don't think that what I've seen today is leading to something you can put into a code to predict the way things vary throughout a transient. Is that right?

MEMBER ABDUL-KHALIK: He assumes that the bed forms instantaneously.

CHAIRMAN BANERJEE: The difficulty is with the bed.

MR. WALLIS: He talks about the worst case.

CHAIRMAN BANERJEE: I don't know if it's the worst case. But it's a case, you know, and he's done more or less what we asked for at the last meeting.

MR. WALLIS: He's closest to a realistic

evaluation.

CHAIRMAN BANERJEE: I don't know about that.

(Laughter.)

CHAIRMAN BANERJEE: So what you're really saying, what is the pressure loss across the bed at your 4.8 inches?

MR. KROTIUK: The pressure loss across the bed is around 4 psi.

CHAIRMAN BANERJEE: And the pressure loss is roughly linear at this velocity?

MR. KROTIUK: Yes, looking at it, it's pretty linear, right.

CHAIRMAN BANERJEE: To be expected. Yes.

MR. KROTIUK: It's pretty linear, yes.

CHAIRMAN BANERJEE: Okay. I think he has answered the question.

MEMBER ABDUL-KHALIK: So how does that square with what they said earlier, that the maximum available delta P is -- for a cold leg break is only 2-1/2 psi?

MR. KROTIUK: When I did this calculation with the unblocked case, my available pressure drop at that higher flow rate was 7.8 psi.

MR. WALLIS: He's got a higher void

fraction in the core, probably.

CHAIRMAN BANERJEE: But in the unblocked case you don't have a higher void fraction.

MR. KROTIUK: No, that's right, that's right, you wouldn't. You'd have a lower void fraction.

CHAIRMAN BANERJEE: There must be -- we need to look at it in detail of how you did it, and clearly we need to look at the driving heads available and things like that.

MR. KROTIUK: Right.

MR. WALLIS: Well, I think that the staff has to decide, are they going to ask the utilities to do this kind of a calculation where they actually predict in a realistic way the way the temperature evolves, or are they going to settle for an overarching conservative estimate of some kind.

CHAIRMAN BANERJEE: I guess it's really up to the utilities, whichever way they want to do it.

MR. WALLIS: No, I think the staff has some way of saying what they want, too, don't they?

CHAIRMAN BANERJEE: They can certainly give some guidance, probably. But let's go back to this calculation to ensure that we understand it, because I think it's a very useful calculation.

What -- the difference seems to be a matter of 15 feet of water, roughly, or maybe 10 feet of water. So let's try to understand this better in terms of driving head.

MR. KROTIUK: Uh-huh.

CHAIRMAN BANERJEE: Their argument for 1.2 psi seemed to be correct at the time they gave it. Your argument -- with their whatever void fraction they had, which we thought --

MR. KROTIUK: Yes, I think it was a 50 percent. I know I'm not 50 percent.

CHAIRMAN BANERJEE: Now let's say you have a case which is close to that, so how is it that you have so much higher driving head? That's really the --

MR. KROTIUK: Well, the driving head that I defined was simply the gravitational head from basically the level of the cold leg down to the bottom of the core. And so that's just a roh gh.

CHAIRMAN BANERJEE: But that assumed that the core was completely voided.

MR. KROTIUK: No, the core is partially voided.

CHAIRMAN BANERJEE: Partially voided.

MR. KROTIUK: Right.

CHAIRMAN BANERJEE: So when you say the driving head, you haven't subtracted out the static head in the core? Is that what you're meaning? So it's just from the top of the -- the bottom of your hot leg or cold leg or whatever it is.

MR. KROTIUK: Right, right, right.

CHAIRMAN BANERJEE: To the bottom of the core. That's what you're calling driving head.

MR. KROTIUK: That's what I'm calling it.

CHAIRMAN BANERJEE: There is a difference here, okay?

MR. KROTIUK: Okay.

CHAIRMAN BANERJEE: As long as I understood the difference. That's exactly right.

MR. KROTIUK: I didn't catch that.

CHAIRMAN BANERJEE: Okay. It's fine. Now we understand -- do you understand?

MEMBER ABDUL-KHALIK: No. That's his delta P across the bed is 4 psi, which is higher than the total available driving head that they've calculated.

MR. WALLIS: That's because they have a void fraction of 50 percent in the core.

CHAIRMAN BANERJEE: If it was 100 percent, which is what would happen --

MR. WALLIS: Then they get 7.6 or something, whatever it was.

MEMBER ABDUL-KHALIK: Well, 100 percent is the void fraction at the top of the core. He says it's a subcooled layer in the bottom of the core, he has some intermediate layer with lower void fraction. The 50 percent is an average void fraction for the whole core height. I don't know what the average void fraction.

MR. KROTIUK: Yes, I never calculated it.

MEMBER ABDUL-KHALIK: It may or may not be, you know, less than or greater than 50 percent. I don't know.

CHAIRMAN BANERJEE: So you've saying it's 7.8 psi at the bottom of the core. That's -- between the cold leg and -- that's just --

MR. KROTIUK: Okay, between the cold leg, from the -- from the cold leg to the bottom of the core.

MR. WALLIS: That's just a matter of height of water; right?

MR. KROTIUK: Right. And then that's also assuming the numbers -- you know, you have to look at the numbers that I assumed for height and, you know, dimensions and all that. So, you know, it's, you know, typical numbers that --

CHAIRMAN BANERJEE: Plus 15 feet of water?

MR. KROTIUK: Something of that nature, yes.

CHAIRMAN BANERJEE: Okay.

MR. WALLIS: Now there are uncertainties in your calculation?

MR. KROTIUK: True.

MR. WALLIS: And they're fairly big?

MR. KROTIUK: It's hard for me to quantify that.

MR. WALLIS: Yes, but if you put uncertainties in, then you could perhaps get overheating with a significantly thinner bed. I know there are fairly big uncertainties in these predictions.

MR. KROTIUK: Uh-huh.

MR. WALLIS: So if you looked at sort of the 95th percentile or something, you might well find it to be conservative, but you'd have to have a much smaller amount of debris.

One uncertainty is chemical effects. Which are not in there. So if you put in chemical effects, it might be that --

CHAIRMAN BANERJEE: Well, whatever gives

you 4.2 psi. That's the answer we're looking for. And so we've got the answer, really. If you've got 4.2 psi or pressure loss, you've answered the question we asked.

MR. WALLIS: You've given the Owners Group more pressure drop. You've given them 4.2 now.

MR. ANDREYCHEK: We appreciate that.

(Laughter.)

MR. WALLIS: What do we do with this?

CHAIRMAN BANERJEE: If they get 4.2 psi pressure loss --

MR. WALLIS: What do we do now, having heard this?

MR. KROTIUK: I think we need to take a look at this.

CHAIRMAN BANERJEE: I think this is a pretty good bounding -- this is exactly what we are looking for.

MR. WALLIS: But it's CaiSil. It's different stuff.

CHAIRMAN BANERJEE: It doesn't matter. It's the 4.2 pressure loss, which is really the important factor. How we arrive at that doesn't matter.

MR. WALLIS: Well, it does matter how

thick the bed has to be.

CHAIRMAN BANERJEE: It doesn't matter because the 4.2 could come from a tin bed with chemicals or -- we don't know how it's going to happen.

MR. WALLIS: Well, he's just done two-phase flow then. I mean he's just --

CHAIRMAN BANERJEE: Well, at least he's done the two-phase flow right. So that's fine.

MR. WALLIS: What he's saying is that you can get thicknesses which are not unreasonble, perhaps, which might lead to overheating.

CHAIRMAN BANERJEE: Well, that's a --

MR. WALLIS: The message about the debris is important, isn't it? Not just how you do the two-phase flow in the core.

DR. KRESS: Well, we don't know that it's 4.2 because we went all the way up from 2.4 to 4.8. It might be somewhere in between.

CHAIRMAN BANERJEE: It's somewhere in between.

DR. KRESS: In between those.

CHAIRMAN BANERJEE: Yes. But what you are really saying is that if you do a little bit better calculation with TRACE, which is giving you something better than the homogenous model, it's still -- your first approximation is close to the homogenous model. So if I sat down and I had to do this by hand, now I know the homogenous model works reasonably well. Even I could do it.

MR. WALLIS: But to use TRACE or to use your hand calculation, you have to have a theory of how to predict delta P. You have a set of equations which --

MR. KROTIUK: Right.

MR. WALLIS: -- which predicts delta P.

MR. KROTIUK: Correct.

MR. WALLIS: All right. These guys have tests.

MR. KROTIUK: Oh, okay.

CHAIRMAN BANERJEE: Well, they can use the tests.

MR. WALLIS: I don't see the connection. Is the staff going -- you can't use TRACE unless you have an equation, presumably, or something to predict how the pressure drop varies.

CHAIRMAN BANERJEE: If they measure a pressure drop, somewhere between 2.4 and 4.2 psi, we know there's a chance of uncovery. It's as simple as that.

DR. KRESS: You could have put in delta P as the independent variable.

CHAIRMAN BANERJEE: He just put it in.

MR. WALLIS: See, if you had a big enough test matrix, you might be able to do that.

DR. KRESS: No, he can just put it in as an independent variable. And you'd come up with an answer for delta P --

MR. WALLIS: How do you get that delta P? For what conditions do you get that delta P?

DR. KRESS: Oh, that's a key question, yes.

MR. WALLIS: He's got a theory to tell you.

DR. KRESS: Yes, just for some sort of debris, but not --

CHAIRMAN BANERJEE: Well, he's given us two pieces of information which are valuable: what the pressure loss can be in a uniform bed, of course; and the other -- I guess the only theory part of it is that it varies linearly, the bed thickness. The delta P --

MR. KROTIUK: Excuse me. To clarify the question in my own mind -- I'm sorry.

MEMBER ABDUL-KHALIK: But that delta P

that you calculate is calculated using an empirical correlation that you put in --

MR. KROTIUK: In the debris bed, right. It's using an empirical correlation that's based on test data.

DR. KRESS: Okay. Yeah, but you've fooled around with that by having it compressed with the flow. You changed the parameters with the flow rate, didn't you?

MR. KROTIUK: No, that's a function of the calculational method to calculate -- to, you know, you're using an equation called the Ergon equation, and this is basically a modification of the Ergon equation that I developed in NUREG 1862, and it's a iterative process to come up with the saturated thickness of CaiSil, say, in the fiber bed. So it's an iterative process.

But then to use it in the hand calculation in TRACE, I came up with a curve because I didn't want to include that into the -- all the calculations. I came up with a curve fit to approximate it.

MR. WALLIS: So you have done a prediction based on PNNL experiments of the particular stuff they used.

MR. KROTIUK: That's correct.

MR. WALLIS: How are you going to make a prediction, if any, for the real case in a plot?

MR. LANDRY: If I may. This is Ralph Landry again.

CHAIRMAN BANERJEE: Yes.

MR. LANDRY: I think we're losing perspective of what the goal was in this calculation. It's the old adage, when you're up to your neck in alligators, it's difficult to remember that the goal was to drain the swamp.

In March when we came in, we had a calculation that was done with TRACE that assumed a 95 percent blockage of the core inlet. There was a 5 percent area slot that the flow came into the bottom of the core.

The core -- the flow was redistributed throughout the core and kept the core cool. And the question was, that's fine, but how do you know that that's a realistic flow through the core, and how do you relate that to a blockage of the entire core, or distributed blockage?

We went to Research and said how can we do this? Can we go in and take a 5 percent flow area in every cell coming into the core, and Bill said, I've got a better idea, let me devise a porous membrane across the bottom of the core and we'll have then a restricted flow through the entire bottom of the core, and see how much restriction we can take across the entire bottom of the core and still have adequate cooling.

That was the goal.

CHAIRMAN BANERJEE: And you've done it.

MR. LANDRY: The goal was to see could we have some representation of a porous membrane, a thin bed, whatever you want to call it, across the bottom of the entire core of the TRACE model. Could you get enough flow, or how thick and how much resistance do you have to have in this membrane to get to the point that you can't keep the core cool? That was the goal. Not to develop a theory or doing a calculation.

Bill had to go back and find a way to get something that represented a porosity or a resistance, and that's when he went to the PNNL data. He had to come up with a way to represent the porosity distributed across the bottom of the core, so he could restrict the flow to see. Then as he elevated --

MR. WALLIS: Well, that's trivial. That's trivial. All you need to know is what's the resistance to bring the flow down to the point where you get --

MR. LANDRY: But, Graham, that was the purpose of those --

CHAIRMAN BANERJEE: That was the question.

MR. LANDRY: -- analyses.

MR. WALLIS: Well, that's true, but you don't need any model of --

CHAIRMAN BANERJEE: That's what he did, he just used the homogenous model.

MR. LANDRY: And now you are talking about an entirely different problem. The goal was to measure or to do a calculation that said we could keep the core cool with a certain amount of restriction. That's been done.

MR. WALLIS: I'm very puzzled by what you said. Maybe I misheard you, but I understand that with an unblocked core you get 115 kilograms a second. With a blocked core that overheats, you get 45 kilograms per second. That doesn't sound to me like 94 percent blockage. Ninety-four percent blockage is a much bigger effect than he's got here. I can't reconcile the two pieces of evidence.

CHAIRMAN BANERJEE: You are talking about the previous case calculations?

MR. WALLIS: The previous thing, which said you can block 94 percent or 98 or something, whatever it was --

MR. LANDRY: It was 95 percent.

MR. WALLIS: -- and that will cool the core.

MR. LANDRY: But, Graham, we weren't -- we're not trying to get at that now. The purpose here wasn't to reconcile the calculation that was done previously. The purpose was to determine is there a restriction on the inlet to the core that you could sort of relate to a porous membrane, and then get to the point where you can't adequately cool the core. That was our goal.

MR. WALLIS: His restriction that doesn't adequately cool the core reduces the flow rate through the core by a factor of less than three. It seems to me that 94 percent blockage is going to have a bigger effect than that, so I cannot reconcile --

CHAIRMAN BANERJEE: No, it doesn't necessarily because what you're having is -- this is why the 95 percent was very confusing. It's not the same as putting a uniform thing with a pressure loss because a lot of stuff can be going through that little hole, which is what was worrying us.

MR. WALLIS: So it's not really --

CHAIRMAN BANERJEE: You can get a lot of

flow.

MR. WALLIS: It's just putting the same flow rate through the little hole?

CHAIRMAN BANERJEE: Well, it's not proportional to the flow area, remember.

MR. KROTIUK: Yes, I think you have to remember that the pressure drop through the debris bed could be different than the pressure drop through that 5 percent little hole.

CHAIRMAN BANERJEE: The 5 percent hole has no resistance. Everything goes through it.

MR. WALLIS: At the critical condition where the core overheats, the pressure drop through the hole or through the bed should be the same.

CHAIRMAN BANERJEE: So if you made a -- so let's the orifice equation, okay, and if you look at it, this hole might give you enough flow to -- more than enough to cool the core.

MR. WALLIS: But we know we've got to get the balance between the pressure drop through the core and the pressure -- when the core is overheating, the pressure drop through the core is a fixed number, pretty well; right? Now the pressure drop through the downcomer is a fixed number. So all we need to know is the pressure drop we can get across a hole or a bed.

CHAIRMAN BANERJEE: In his case, he's saying it's somewhere between 2.4 and 4.2 psi. The pressure drop through a 5 percent opening may not --

MR. WALLIS: PSI?

CHAIRMAN BANERJEE: It may be less than that. It may be much less than 2.4 psi. That's all I'm saying.

MR. WALLIS: And give you the -- it doesn't make sense.

CHAIRMAN BANERJEE: I'll talk to you about it later.

MR. WALLIS: You'll talk to me later. Okay.

CHAIRMAN BANERJEE: Yes. Okay. I think you've done exactly what we wanted, and the issue of how this is used as a model is a separate issue. You've answered the question we had.

So I think that is enough for that. Now do you have some other things you want to talk?

MR. SMITH: Basically Bill was our grand finale, and he did a great job.

(Laughter.)

MR. SMITH: But the conclusions are that, as we know, that there's testing underway now for both the Westinghouse and the CE and the AREVA fuels, and the testing is going to determine acceptable debris loading for the various fuel designs.

And I think the other conclusion that I have, after today, I think you guys have brought up some good points that we need to consider while we're reviewing this data and, you know, I think we're going to work with Research on what the allowable potential head loss could be. I think that's a very important piece of the puzzle.

MR. HARRISON: And providing this information to the committee as well.

CHAIRMAN BANERJEE: So now we need to spend a little time discussing -- if you like, you can stay up -- what we do for the full committee meeting, and so in this case we usually ask each of the subcommittee members, first of all, to sort of summarize their views on the whole day, and give you some feedback.

Now how much time do we have at the full committee meeting?

MR. SMITH: I believe two hours.

(Discussion off the record.)

CHAIRMAN BANERJEE: So what we need to do now is to discuss our views and maybe it will help you, the staff, I mean, to prepare for the full committee meeting, and what the subcommittee feels might be important.

So why don't we start with Tom.

DR. KRESS: This is for what? What we're going to present to the full committee?

CHAIRMAN BANERJEE: Yes, the full committee has to write a letter, so just to set the stage. We will be writing a letter in our October meeting, and this letter really needs to summarize the three subcommittee meetings in some way.

Now, of course, because we've had three subcommittee meetings, but we don't necessarily need to dwell on what has happened before, but really give the staff's resolution of the PSI-191 as of the time of the full committee meeting. The history is important, but it's not all, you know, that germane.

We need to be able to give a sort of a status report and, if possible, to give some review of the staff's plan to close the issue, and what the full committee feels about it.

I think that's really the important part, the whole thing.

So taking that into account, what I'd like to do is to get some feedback from the subcommittee over the next 15 minutes to half an hour, and then have some interaction with the staff on that before we close the meeting. So that's the purpose.

DR. KRESS: I certainly would have a big part of this be the current tests that are ongoing because what I see as the strategy is to get enough empirical data for specific plant types and specific filters so that you can use that empirical data to put limits on the amount of debris you can have.

Now so this is a start on that process, and I think that needs to be the main part of the meeting, actually.

The -- I would like to see them give some indication of how many more tests they think are going to be needed to more fully put this thing to bed. I don't think we got a good feel for that today.

But I think with the -- I would also present the stuff on the settling out tests that were run because I think those -- getting back to the settling out before you go through the screen. I think the committee will have some questions about those, particularly the Skelly effects, so I think that ought to be presented. But it doesn't take too long for that.

This TRACE calculation, that's of

interest, and it can be very short, so it could be fitted in, and it has some useful information, I thought.

So that's basically my feeling of what you need.

CHAIRMAN BANERJEE: Okay. Let's go to the other end and we'll come back, since Bill has vanished.

Graham.

MR. WALLIS: Well, as always, progress has been made. What we heard from the Owners Group tells me that there are a lot more tests coming, that they are rewriting the NUREG, and it may change quite a bit from what we saw before. So I cannot tell how complete the final methods will be and whether they will be adequate. I need to see more evidence. So I've learned that they're doing things. They've got a plan. I'm not sure that they know until they start doing more tests how messy the results are going to be. Because it may turn, as we have learned from other tests, you know, when you do two tests and everything looks fine, you do four tests and you find you've got something you can't explain, and so on.

So I'm waiting to see, really. I'm glad, very glad they're doing these tests, you know, because realistic geometries and hopefully fairly realistic, conservatively realistic, if that means anything, debris. But I really have to wait and see.

The staff is, I think, well aware of all the issues. They've been with us long enough, they've seen enough things that they are aware of the issues.

What I still don't know is how they are going to review these submittals, which are going to come in all kinds of forms and all kinds of rationale. There isn't really a standard way to compute these things, which everyone agrees on.

So until we see how the staff actually confronts something which claims to be showing adequate assurance, I don't really know that the problem has been resolved.

So I am still a bit mystified about just how the staff is going to evaluate what is a very difficult problem with all kinds of aspects.

I think they understand what's involved, but they have some evidence, they have some ways of getting a handle on these things. But I don't really know how they're going to put it all together.

CHAIRMAN BANERJEE: What do you think, do you have any thoughts on what they should present at the full committee meeting?

MR. WALLIS: Well, I think you have to say that there's been progress.

CHAIRMAN BANERJEE: Well, I mean they have to present, the staff have to present.

MR. WALLIS: For the staff to present?

CHAIRMAN BANERJEE: I can't presume what the full committee will write at the end of --

MR. WALLIS: I think it would be good if the staff could very clearly say that when we met with you last time, we knew this. Since then we've made this progress. And this is where we need to go.

Can you do that in half an hour?

CHAIRMAN BANERJEE: Two hours.

MR. WALLIS: And do you know where you need to go until you see the details? Do you know enough about the form of these submittals to know where you need to go before you can really truly evaluate them?

CHAIRMAN BANERJEE: Well, there's always going to be surprises, so they have to have a plan at any given time which they can revise, obviously.

MR. WALLIS: I think what they should present to the committee is this is where we were when we met you last, this is the progress we've made, and this is what we need to do. And I think just perhaps a review area or discussion quickly would help, saying these items are where we have concerns.

CHAIRMAN BANERJEE: So I think some part of it can be what you're saying, that this is the progress we've made. It would be nice if the progress we've made is punctuated with some data.

MR. WALLIS: Absolutely. Not just words.

CHAIRMAN BANERJEE: Yes. You sort of get a negative reaction, you know. You know the committee.

MR. WALLIS: We now know that if you can be assured you won't get more than full psi pressure drop across this thing, everything will be fine.

CHAIRMAN BANERJEE: Right. Whatever it is, you know, it needs -- well, maybe 2.4 is safer. Whatever. The more data in reporting where we are today, the warmer the reception obviously will be.

But also what Graham is saying about the plan to close the issue out, I think that's very valuable, but you can only base it on your best knowledge today. I mean what else can you do? And if some surprise occurs, well, one will deal with it.

MR. ROLAND: When you say data --

CHAIRMAN BANERJEE: The status.

MR. ROLAND: Meaning where we stand for

the specific plant?

CHAIRMAN BANERJEE: No, I think it's always nice to have some indicative data, you know, of things, like, for example, the stuff you showed us today on some of the data you got on downstream effects. It doesn't have to take long, but briefly if one could show some data, it's always nice. The committee -- the committee, I know -- likes this feeling of activity that there's actually something happening and it's just all words.

MR. ROLAND: Well, obviously you know there's lots happening.

CHAIRMAN BANERJEE: Yes.

MR. ROLAND: The problem I'm having in thinking about the data, as the committee no doubt has discovered well before this meeting, this is highly plant specific. So what is acceptable at one particular plant may or may not be acceptable at another one.

So what we'll try to -- you know, what we'll try to maybe -- and we've been asked, actually, by our management over and over again, Bill, tell me what the closure path is, and they have asked us for charts -- can you bin the plants. And they have asked us many times to try to put bounds on this other than the answer I just gave you, which it depends. It depends on each individual plant.

And really we have not been successful, but I -- one of the reasons we showed you the pictures and the film today was because we think that is representative of data, that licensees are in fact collecting data, but on those specific -- it all depended on that specific plant and the data for that plant.

So what we can give is anecdotes. You know, okay, examples and data attached to those examples. That we can provide.

CHAIRMAN BANERJEE: Well, I think --

MR. WALLIS: Some criteria which are not plant specific. You need to have a prediction of pressure drop across the screen. Are you going to have -- you're going to have to say we will accept data taken in a flume where someone with a bucket pours stuff in and pours it in in a way which we believe to be conservative. You have to have a statement that says we're going to accept that kind of result and use it.

CHAIRMAN BANERJEE: Well, there is guidance; right?

MR. WALLIS: Otherwise, you will be

questioning that forever.

MR. ROLAND: That's exactly the problem we have faced. And one of the reasons we have chosen this holistic review that the commission told us to do is because of the incredible site-specific nature of all these evaluations.

We have done this holistic review, and because it changes at every plant, we make this judgment. And that's the way we have chosen to do it.

MR. WALLIS: I don't think the site-specific problem is as big as the extrapolation from the tests to any site. That's the real question. If you know how to do that, you can evaluate the site specific.

CHAIRMAN BANERJEE: Well, I think it is to some extent site specific. In the situations where you mix up everything and do a rather conservative prototypical test, you're probably getting pretty good conservative bounding estimates there.

So my sense of it is that you'll have different approaches for different plants and different types of things, but you are trying to do -- you are trying to make tests as prototypical as possible, and in some cases it's easier because, you know, you can mix everything up and make it happen.

And that's certainly something worth showing, at least the successes there.

And it is worth saying also that in some way it's more difficult to handle situations where you have to appeal to a lot of dropout or changes in insulation or whatever.

I think that would be fine. I mean you're telling it like it is, and I think just tell us like it is, but not taking too long over it. I'm just saying anecdotally, you know.

MR. ROLAND: Yes, sir.

CHAIRMAN BANERJEE: It will take longer and longer, anyway.

But I don't want to preclude, so I'm just dealing with Graham's comment because Otto will have another set, and I'm sure Mike will have another set, so --

MR. ROLAND: I understand.

CHAIRMAN BANERJEE: -- let's wait till we get through it.

MR. ROLAND: Okay.

CHAIRMAN BANERJEE: Otto, carry on.

MEMBER MAYNARD: Well, first of all, I'm glad to see additional testing being done, and I know that we're kind of in the early stages of it, part way through it, so I think it's a good opportunity, and I'm glad we got a chance to review that, and provide some off-the-cuff comments, kind of, first impressions and things, and I think that will help both the staff and the licensees to maybe take a harder look at some of these areas and make sure some of these things are being cured.

So I'm encouraged by that. I think that there's probably going to be a need for more justification for some of the observations and results, and I think maybe more than what they might have anticipated. I think I'd be careful of just assuming that something is obvious or it's just -- you know, well, that's just what we observed. I think it's going to have to also include the whys and, you know, why is -- some simple thing, you know, why is a four-foot tall one good enough as opposed to a full-length 12-foot long one. You know, if you see a pressure drop when something is added rather than a pressure increase, why?

And I think that's going to help both the future of the licensees and also the staff in reviewing other plants' applicability to the WCAP. I think it's going to be important to understand what the limitations of the testing were, why, how much does it really encompass, and I think that will make the rest of the process much better.

Because the WCAP is not the end. I mean that provides one set of data, but then the applicants or licensees have to come in and justify why they fall into that, and the staff has to review and have some type of acceptance criteria and guidance as to what they're going to accept, showing that it's consistent with that.

So I think there is still a lot of work, but I am encouraged. I think in general it's on a path to get in that direction. I think there's still a lot of little details to be worked out, but I do see that as a better path than trying to justify it with the existing data as to that everything is okay.

I agree with Tom on the settling. I think, you know, a little bit more needs to be done there.

First of all, I believe that's what being done is probably conservative. I'm not sure I have a high degree of confidence in CFD results for this situation, and there may need to be some more explanation or something more done to kind of justify that.

Like I said, I'm not saying I don't think

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CHAIRMAN BANERJEE: I don't want to enter into a long argument at the full committee on CFD calculations when we have bigger fish to fry.

MEMBER MAYNARD: As far as -- and I think that ultimately there's never going to be a program put in place that addresses every detail of this issue in a way that guarantees every aspect is totally conservative. I think it's going to end up being in the overall big picture of things, everything that's been done, overconservatisms here, maybe it's not as conservative here, but it's going to result in a judgment of reasonable assurance for the existing licensees.

I don't think that necessarily has to be the end or the definitive end of looks at this thing. We've got new plants coming down the line, new designs and stuff, and I think that, you know, this -- I know everybody would like to see this thing put to bed, but I'm not sure it's totally going to get to -- I think that for the existing plants and for the existing conditions, I think it's going to just result in, you know, at some point a decision of reasonable assurance is going to come out of this.

As far as for the meeting, you know, the three things that I would say, I do think the staff's review process for this, I think their process is important, and the real brief deal at the beginning where they have talked about the process, you know, the consistence of membership, the people doing the reviews, to show some consistency as to what's reviewed at one plant versus another.

I don't know you necessarily have to have the guidance documents here, but, you know, to demonstrate that there are guidance documents for which one of these review areas so that there is a process and a method for reviewing the licensees' submittals.

I think the Owners Group tests and plans needs to be a part of the discussion there, where that's going, and that personally I know we've gotten quite a discussion, but I thought the staff's TRACE results were exactly what we had asked for.

CHAIRMAN BANERJEE: Exactly.

MEMBER MAYNARD: And, you know, there was one set that was for, okay, if you assume the entire thing other than 95 percent is blocked and there's one opening there, they did that last time. This time they have answered the question, well, what if it's a uniformly distributed bed, you know, how thick a bed can you withstand or take care of, and I think they did that. So I thought that was good.

So those are the three things that I would suggest.

CHAIRMAN BANERJEE: Okay. Mike?

MEMBER RYAN: Thanks.

I guess my comments are very similar to what Otto and others have said, in that I would like to hear and understand a little bit more about why things are conservative or bounding. We used those terms a lot today, and I think it would be very helpful if I understand a little bit more detail of why you've made that decision or judgment that something is bounding and conservative.

And it would also be helpful to ask the opposite question: When wouldn't it be conservative? What would be the circumstances, conditions or features to a problem that would take you out of that conservatism, so people could get an understanding of the range of where that reality might be.

Again, I appreciate, as Otto mentioned, there's a wide range of conditions and systems and so forth in plants that can cause that to be quite a variable, but, you know, it's very helpful, I think, to try and offer some insights as to that, particularly for members of the full committee that worry about such things as uncertainty analysis and PRAs and so forth.

So I think that would be very helpful.

Again, as much as you can deal with the range of materials that are involved in various plants and how they behave physically in the flow system. You know, do they build up as a thin film or a thick layer, and are there voids in some of the physics of all that accumulation and flowthrough of accumulations would be helpful to me just to see a little bit more detail.

Again, it may exist already and I'm not as conversant with some of the history on this issue as I might be. But that, I think, would help the full committee to understand that a little bit more.

CHAIRMAN BANERJEE: Okay. Thanks.

Said.

MEMBER ABDUL-KHALIK: I think most of the comments I was going to make have already been made. But in my mind, sort of the biggest question is the prototypicality of experiments. How does one use the results of an experiment to extrapolate to actual plant conditions in all the experiments that we have seen today?

And perhaps that process is what this review committee goes through, and if that is the case, I'd like to understand this process.

The second question -- first of all, I liked very much the calculation that was presented by Bill towards the end because that's very much what we asked for at the last meeting. And it sort of answered a lot of the questions, but it also brought some additional questions.

I mean, you know, we were told by the Owners Group that criteria will be developed based on these delta P limits for maximum loadings, and that puts a lot of weight to whatever values for these delta Ps that you will come up with, and if there is an obvious discrepancy between your hand calculation and what the calculation that was presented by Bill says as far as the delta P in the bed --

MR. ANDREYCHEK: We're going to figure it out. One was 18 feet and one was 16, so we've just got to figure out where to get the 18.

MEMBER ABDUL-KHALIK: Well, I think it's important -- he was doing a calculation for a cold leg break and he came up with a delta P of four point something psi which tells me that the total available pressure drop is higher than the 4 psi, and you're saying that the available delta P is 2.5 psi. I think it would be important to clarify that discrepancy, given the fact that, hey, this is going to be the basis for whatever criteria you're going to develop.

And the third thing is, you know, if you're going to develop these criteria, how do you combine these three limits? I'd like to see a better understanding for how a combination of the three different types of loadings can be extracted from limits on individual material loadings.

Thank you.

CHAIRMAN BANERJEE: Thanks.

So I think you've got a pretty good idea of what we'd like to hear, and of course I would tend to believe the TRACE calculations, so I wouldn't belabor that point too much. You know, so I'd go with that and not waste too much time with other stuff.

But certainly that is even very briefly worth presenting, I think, to the committee, so that's been echoed by several people who just reaffirmed that.

I do feel that you've given us status reports before of how you've moved forward to try and close this, and you have even addressed the full committee before. So this is the second time you're addressing the full committee. The last time we didn't write a letter.

But I think it's still worthwhile just reminding them very briefly of the status of the activities that have taken place, that so many reactors have done stream changes, so many people have done and removed insulations; you know, the sort of the usual things that you've been telling us. People have done things with their buffer.

I don't think you need to dwell long on this.

MR. ROLAND: But it sounds like what we said today, but add some numbers.

CHAIRMAN BANERJEE: Add some numbers.

MR. ROLAND: Okay.

CHAIRMAN BANERJEE: Yes. And do it very briefly so we understand very quickly where we are at, and my sense of it is that several people have been asking about the testing that is being done, the prototypicality of those tests; something to address that and maybe show a little bit of data, if you can, on the pressure loss testing and how chemical effects are being taken into account. You know, whatever it is to reassure the committee that this is an area which is under control, and clearly, to me, there is no simple answer to this, and you have to handle it in some holistic way, which is what the commission's direction originally was, and I think in our letter, one of our formal letters, which I was reading, we endorsed that, by the way.

MR. ROLAND: Right.

CHAIRMAN BANERJEE: So it's very much in line with what you said. But I do think that you must address with these pressure loss tests, with the screens, the prototypicality of the tests, how you're addressing that, and the sort of applicability to the full scale systems. I mean you can do it briefly.

So I see sort of a part of this presentation dealing with the issue of what happens through these screens, and hopefully we are well advanced, because now we've got these screens in place and we're really testing to ensure that these screens are adequate, we don't get too high pressure losses, and if necessary, whatever actions have to be taken to take care of the situation will be taken care of.

The second issue seems to be the downstream effects. And there I think let's assume that you can deal with the pressure loss across the screens. There are some new series of tests and so on that are being planned by the industry.

And so I would think that it would be good to present what the plan is, to the extent that it's available, and the rationale for that plan based on the best available knowledge today, whatever that is. I mean if you find surprises, obviously we'll have to revise that plan.

But based on what we know today, this is the plan, this is why this is the plan, you know, this is what we know about the sort of loadings that we are getting from the bypass, and we are going to survey this range of conditions, this sort of stuff.

I think it would make a fairly good story, you know. What we've seen is you've got data on bypass from several plants now. We haven't seen the whole data set -- hopefully the subcommittee will see the whole data set. You've got size distributions for particles, you've got a pretty good idea of, you know, the loadings from different plants.

I feel much better about this than -- personally than I did when this thing first came through. Okay? So we've advanced a long way. So I think that story needs to be told with the plan.

And then any other issues that you feel you'd like to inform the committee about with regard to closure. If there is any issue as to why we should keep all these plants operating while they are still trying to meet the requirements. And if you are going to discuss some other aspects like what you'll do to assure that they will meet your requirements that you're setting forth in an expeditious manner, that might be something to say. I would say it. Okay?

So I think, with that, what we're really looking for is for the committee to write a letter endorsing your plan to close the issue. I mean it can be as short as that.

MR. ROLAND: Thank you for this help.

(Laughter.)

CHAIRMAN BANERJEE: I hope that's said --

MR. ROLAND: No, no, seriously. I think we know what you're looking for. You know, one of the things we did in this presentation, we really didn't get through a lot of history about -- you know, to bring some of the other members up to speed that haven't been with this issue all along. So we kind of just launched right into it without a lot of background about, you know, what is a sump and all that kind of background. And I'm thinking that we take that same approach, or probably a little more information, about just maybe five minutes about background about, you know, put it in context, how long the issue has been out there, what we've been doing. So I'm thinking we ought to add a little more context upfront to our presentation than we did there. It can't be long.

CHAIRMAN BANERJEE: No. You won't have any time.

MR. ROLAND: It's got to be five minutes of, you know, of history. So I think we need to do something like that also that we didn't do here. And if any members needed that, I apologize. But because of the time constraints here, we made that -- that was a conscious decision on our part.

My sense is -- and that, you know, maybe we can go back and kind of look at the distribution of data we're getting, and maybe we can give you a sense of kind of the range we're looking at as opposed to, you know, specifically what we have found at a particular plant. And I haven't asked our staff yet if that's even doable, but that's something we can think about. You know --

CHAIRMAN BANERJEE: Whatever you do, there'll be questions regarding the prototypicality of these tests.

MR. ROLAND: Right.

CHAIRMAN BANERJEE: And the applicability to the plants. So I think that's the issue that really needs to get addressed.

MR. ROLAND: And I'd just like to ask all the -- the rest of the GSI-191 staff here if there's any questions that they have about their understanding of what they believe the committee is looking for, for the full committee.

Well, they're either -- this is not a bashful bunch, so I guess they don't have any other questions.

What I propose --

CHAIRMAN BANERJEE: Or they're asleep by now.

MR. ROLAND: I don't think they're asleep.

What I propose is we would kind of try to map out what our approach is, and I'll talk to Ed and through Ed through you to kind of come up with a generic approach of how we intend to do that.

Would that be okay?

CHAIRMAN BANERJEE: That works.

MR. ROLAND: Okay. And I'd like to also just think both the GSI-191 staff, the Owners Group, and the committee itself for continuing to plug away at this issue because, you know, in my mind this is the design basis safety issue. If you wanted to come up with something as complex as possible to test how a regulator would deal with, my estimation is you would do this. This is the system you'd come up with.

We would love to have 2200 degrees, 17 percent oxidation, or some similar line in the sand that we could all agree is acceptable or not. It would make our job easier. And, in fact, that's not what we have, and we have virtually the complete opposite.

But it is through experience in these reviews that we have been kind of gaining that insight, and I think you heard during this meeting that we kind of are approaching a limit on our understanding of testing, but while it's still not perfect, what we have is a far better idea of what makes a good test today than we did even six months ago.

So I would just like to agree with the committee that we are making progress, albeit sometimes for the staff and us, it doesn't feel that way. And it definitely doesn't feel that way for my management when they talk to me about this.

CHAIRMAN BANERJEE: We understand.

Well, I think there are no other comments, I'd like to --

MR. WALLIS: Well, I have a comment.

CHAIRMAN BANERJEE: Yes.

MR. WALLIS: When we meet again --

CHAIRMAN BANERJEE: Yes.

MR. WALLIS: -- I hope we're very close to the end, and I hope we'll have documents to review ahead of time so that we can be sure that we are sure that you're near the end. Today everything was all "we didn't have time to look for paperwork." Maybe what we read will be very, very short, but we don't know yet.

So, please, next time --

MR. ROLAND: Yes, sir, I got it, Doctor.

MR. WALLIS: -- be closer to the end and have documents ahead of time.

MR. ROLAND: Okay.

CHAIRMAN BANERJEE: Well, I was just going to thank all of you for taking your time. It's been a very productive meeting, I think, and I'd like to thank the Owners Group, the staff, and my fellow subcommittee members for making it out here.

And with that, I'm going to adjourn the meeting.

(Whereupon, at 5:33 p.m., the subcommittee was adjourned.)

WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid"

PWR Owners Group

September 23, 2008

Agenda

- Background
- Debris Collection at Core Inlet
- Fuel Assembly Testing
- Boric Acid & GSI-191

Background

- GL 2004-02 issued to identify and request utilities to address the effect of debris from the sump on Long-Term Core Cooling (LTCC)
- Utility responses to GL must include:
  - Basis for concluding that adequate ECCS flow is available for LTCC in spite of increased resistance to flow downstream of the screens (i.e. downstream effects)
  - Description of modifications, if needed, to provide for adequate ECCS flow
- Industry guidance for fuel effects
  - WCAP-16793-NP

Background - WCAP-16793-NP Basis

- Provide an evaluation of long-term core cooling for the PWR design in the presence of debris ingested from the sump following a LOCA that provides reasonable assurance that decay heat is removed
- Demonstrate that there is reasonable assurance long-term core cooling requirements of 10 CFR 50.46 are satisfied with debris and chemical products in the recirculating coolant delivered from the containment sump to the core
- Use available tools and information
- Draw from and address
  - The design of the PWR from all US vendors,
  - The design of the open-lattice fuel from all US vendors,
  - The design and tested performance of replacement containment sump screens from all US vendors, and, tested performance of materials inside containment
- Applicable to the fleet of PWRs, regardless of the design (B&W, CE, or Westinghouse)

Background - Sump Screen

- Replacement sump screen openings are on the order of 1/16" to 1/8"
- Some debris that arrives at the sump screen may be smaller than the openings and penetrate the screen
- Any debris that passes through the sump screen can then be transported to the RCS, which could reach the core
- Debris is not ingested until after ECCS suction source is realigned to containment sump

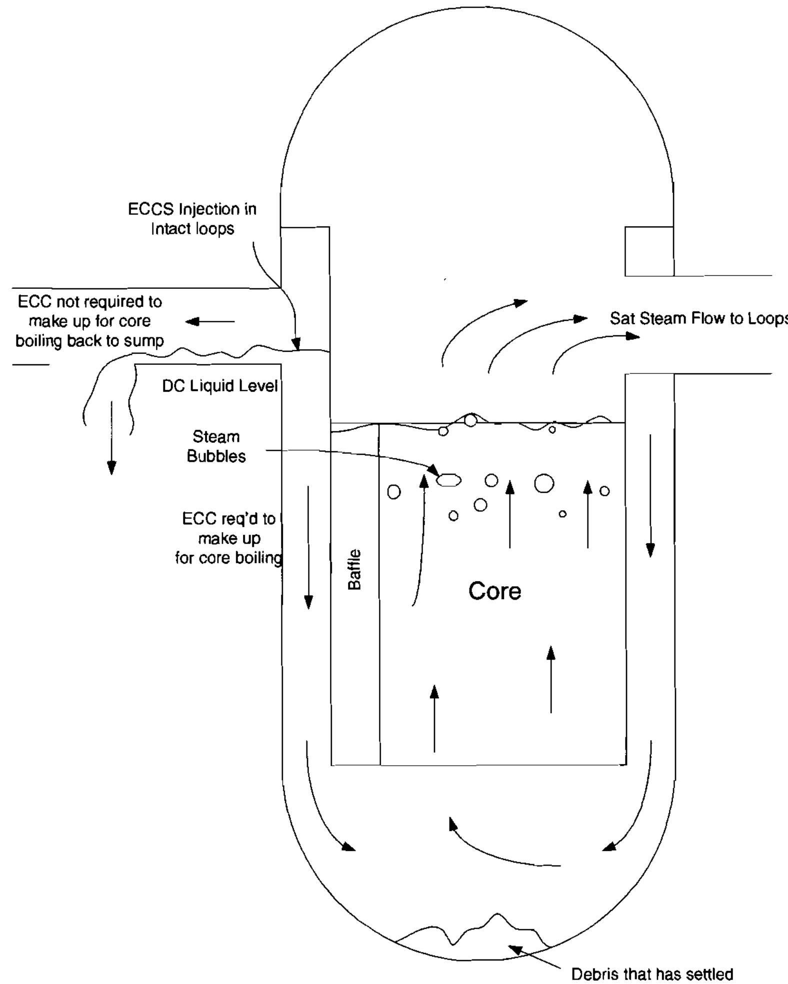
Background - Core Conditions

- At the time of sump switchover (20-60 minutes after large break LOCA)
  - Core is fully recovered (i.e. covered with a 2 phase mixture)
  - Core mixture level above the top of the core
  - Actual vessel level, core flow rate, and debris transport are dependent on break location

Background – Break

Cold Leg Breaks

- Downcomer (DC) is full to at least the bottom of the cold leg
- Core level is established by the manometric balance between the DC liquid level and the core level and RCS pressure through the loops (or reactor vessel vent valves for B&W plants)

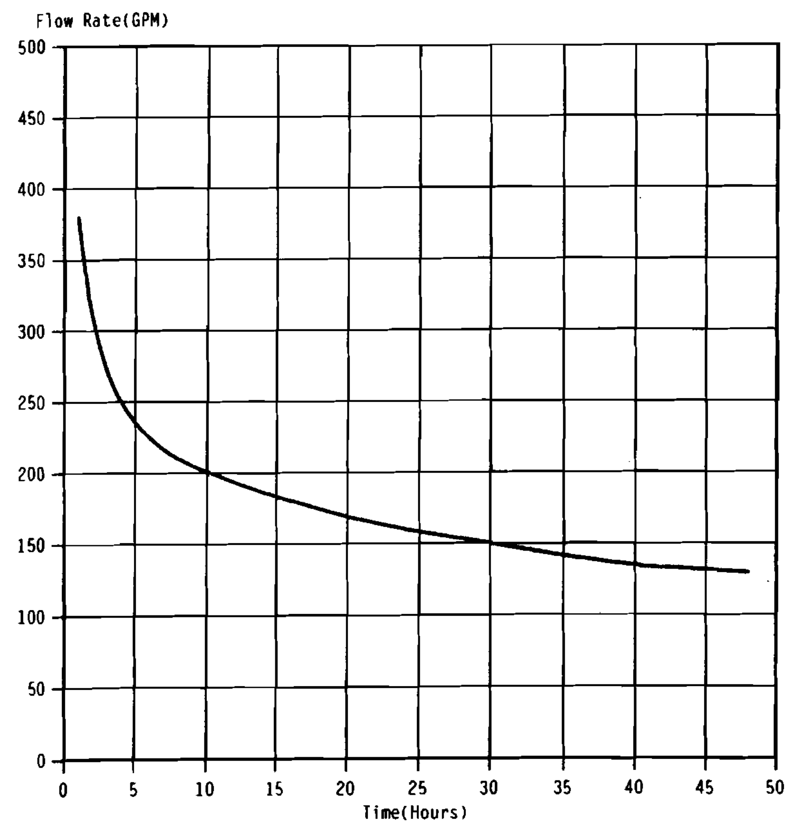


Background - Break

Cold Leg Breaks (cont.)

- ECCS flow enters the intact cold legs and upper downcomer at flow rates on the order of
  - 1000-3000 gpm for min ECCS
  - 6000-8000 gpm for max ECCS
- ECCS flow to the core is only what is required to make up for liquid lost due to boiling in the core.
  - At time of sump switchover, core boiloff rate is ~350 gpm for a Westinghouse 4-Loop plant
- Excess flow goes around the top of the downcomer to the break
- Once back in the containment sump, debris is again filtered by sump screen before returning to the RCS

Flow Rate to Match Boil-off versus Time for a Westinghouse 4-Loop PWR



Background - Break

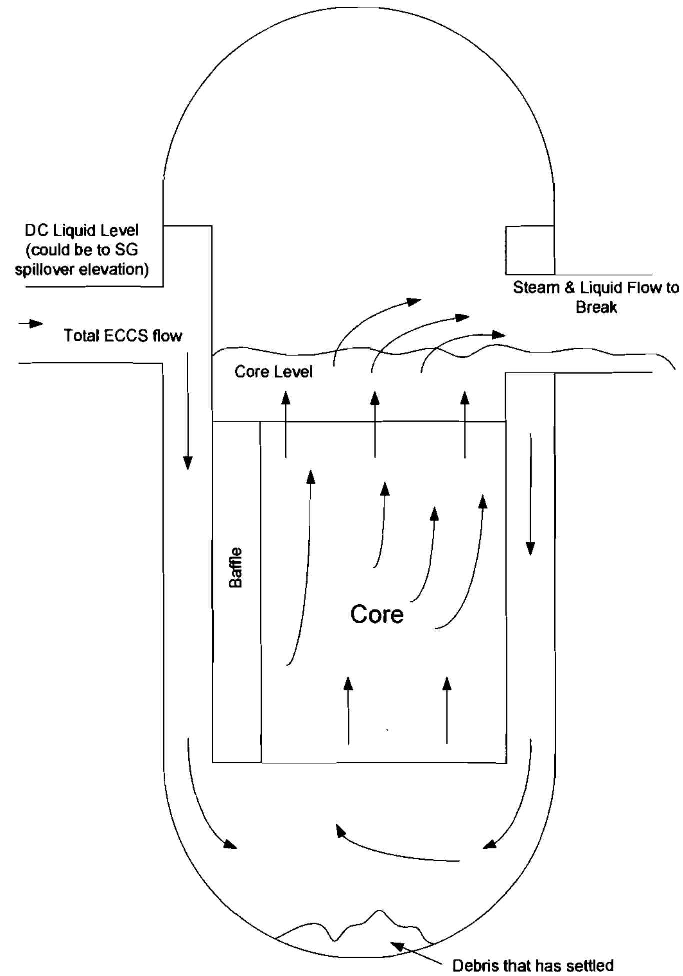
Cold Leg Breaks (cont.)

- Most debris will flow to the break with the dominant flow field
  - For maximum ECCS, most of the ECCS fluid and debris exits from the break and returns to the sump
    - Flow to break = (total ECCS) – (boil-off rate) = 6000 – 350 = 5650 gpm
    - Percentage of ECCS fluid & debris that returns to the sump = (flow to break) / (total ECCS) = 5650 / 6000 ~ 94%
  - For minimum ECCS, ~2/3 of ECCS fluid and debris exits from break and returns to the containment sump
    - Flow to break = (total ECCS) – (boil-off rate) = 1000 – 350 = 650 gpm
    - Percentage of ECCS fluid & debris that returns to the sump = (flow to break) / (total ECCS) = 650 / 1000 ~ 65%

Background - Break

Hot Leg Breaks

- ECCS must pass through the core to exit the break
- Core flow rate is equal to the ECCS flow rate
- All debris will progress to the RV lower plenum



Background - Break

- Once the debris reaches the RV lower plenum
  - It may settle in the lower plenum, or,
  - It may transport to the core
- Three areas of possible concern for transport to the core include
  - Debris adherence to fuel cladding surface
  - Resistance to Flow at the Core Inlet
  - Resistance to Flow at Spacer Grids
- This presentation examines all three items

Collecting Fibrous Debris on Cladding

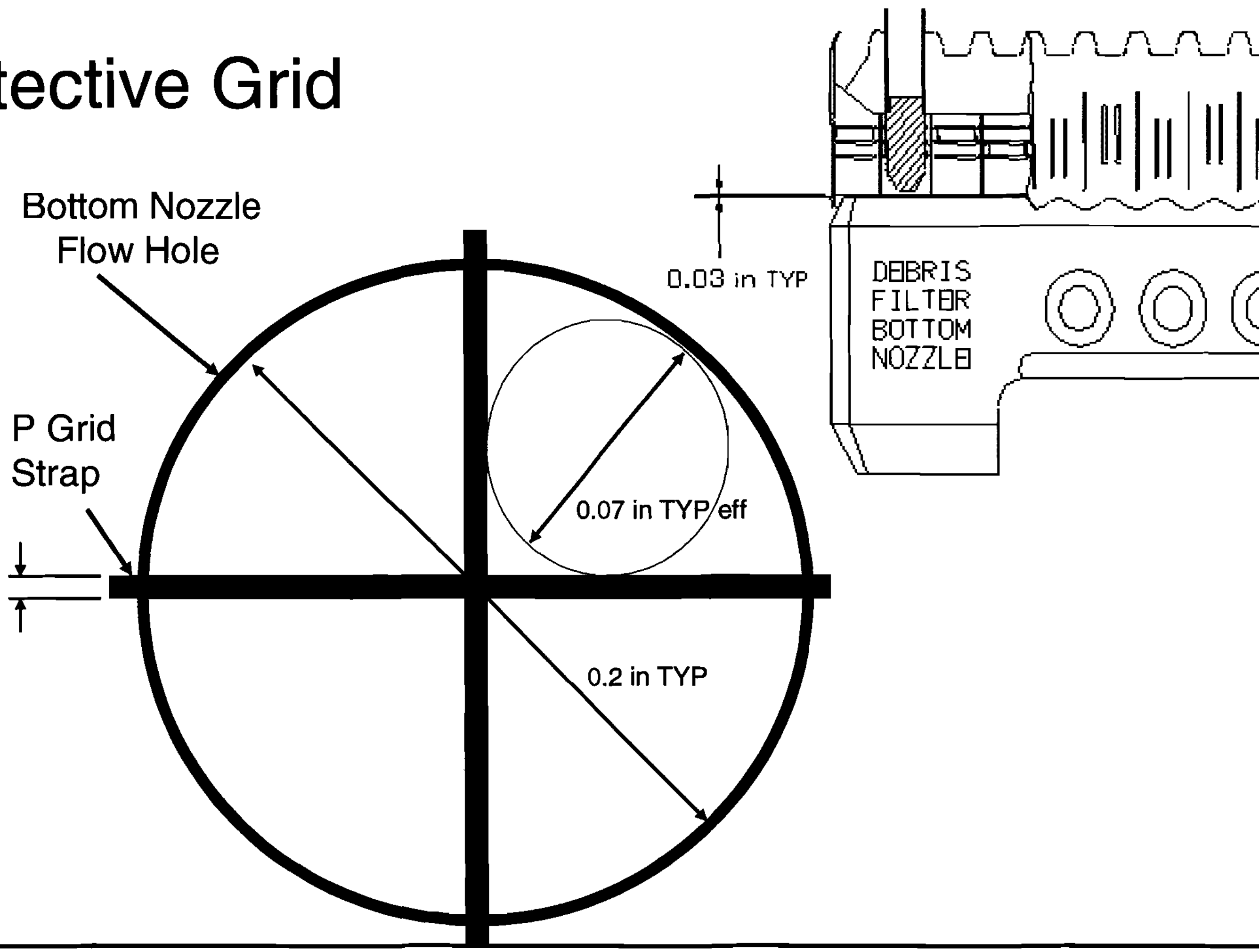
- Fibrous debris, should it enter the core region, will not tightly adhere to the surface of fuel cladding
  - NUKON OFC-1 Report
    - Submersion of a rod heated to 2200°F in a fiber slurry
    - Nucleate boiling of a heated rod in a slurry
    - Film boiling of a heated rod in a slurry
    - NRC reviewed and accepted the NUKON OFC-1 Report

Background - Fuel Assembly

- Fuel assembly inlet debris filters are included in the bottom of fuel assemblies
  - Designed to help reduce fuel assembly fretting problems during normal operation and reduce normal operation fuel failures
  - Fuel failures are high impact issues that affect normal plant operation and the cost of operations
- The Westinghouse P-grid design will be presented as an example to show the size of the openings

Background - Fuel Assembly

Protective Grid



Flow Resistance Due to Debris at Core Inlet

Types of debris that might reach the RCS:

- Fiber
- Particulates
- Chemical precipitates

Flow Resistance Due to Debris at Core Inlet

- For a postulated debris build up at the core inlet:
  - To determine if sufficient flow will reach the core to remove core decay heat through a potential debris bed at the core inlet
  - It must be demonstrated that the head available to drive flow into the core is greater than the head loss across the debris bed at the core inlet

$$\Delta P_{available} > \Delta P_{debris}$$

Available Head at Core Inlet

- The available driving head is based on the manometric balance between the downcomer and core
- $\Delta P_{available} = \Delta P_{dz} - \Delta P_{flow}$

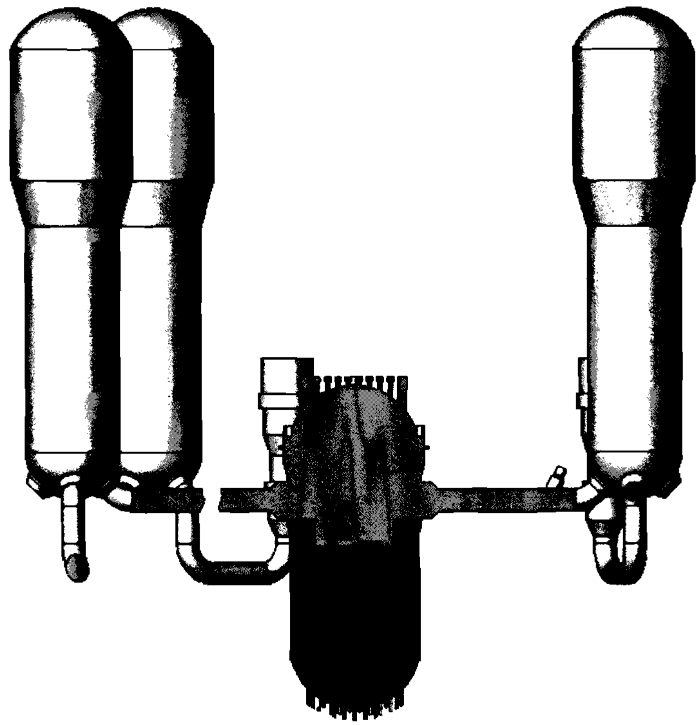
  Where:

  $\Delta P_{available}$ = total available driving head at the core inlet

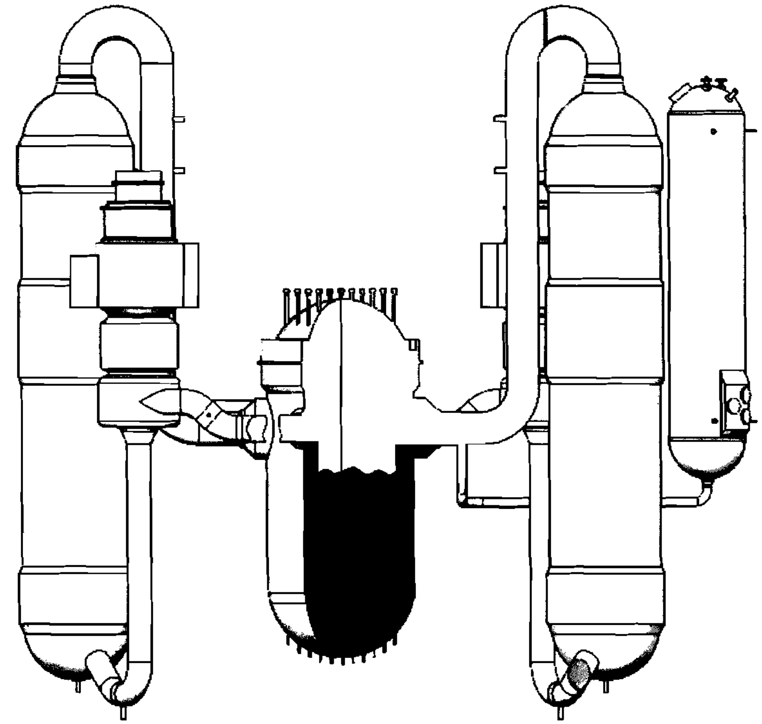
  ΔP_{dz} = pressure difference available to drive flow through the core due to liquid level difference between the downcomer and core

  ΔP_{flow} = pressure drop due to flow losses in the RCS (hot leg, steam generator, and cold leg to break)

Available Head at Core Inlet



RSG (W/CE design)



OTSG (B&W design)

Schematics demonstrate relative elevations of core and steam generators

Available Head at Core Inlet

- Elevations listed are typical of a W 4-loop plant design
- All elevations are with respect to the bottom of the core

Location	Variable	Elevation (ft)
Bottom of core (location of possible blockage)	$Z_{core\ inlet}$	0.0
Top of active fuel	Z_{TAF}	12.0
Bottom of hot leg	Z_{HL}	16.06
Bottom of cold leg	Z_{CL}	16.16
Spillover elevation of shortest SG tube	Z_{SG}	49.5

Available Head at Core Inlet

- Cold Leg Break
  - Liquid density, $\rho = 60\ lbm/ft^3$
  - Core is saturated with voiding
  - The core mixture level is taken at the top of the core.
  - Calculate core collapsed liquid level using an average void fraction, α, in the core:

    $\alpha = 0.50$
  - As the transient progresses
    - Voiding will decrease
    - So will core boil-off rate, which will decrease flow losses
  - Using 50% with high flow losses offsets less voiding with lower flow losses

Available Head at Core Inlet

- Cold Leg Break (cont.)
  - Pressure difference available to drive flow through the core due to liquid level difference between the downcomer and core is:
    - $\Delta P_{dz} = [Z_{CL} - (1 - \alpha)(Z_{TAF} - Z_{core\ inlet})](\rho)$
    - $\Delta P_{dz} = [16.16 - (1 - 0.5)(12 - 0)](60/144) = 4.2$ psi
  - The pressure drop due to flow losses through the reactor coolant system, based on the boil-off rate, is:
    - $\Delta P_{flow} \sim 1.7$ psi
  - Total available driving head is:
    - $\Delta P_{available} = 4.2 - 1.7 = 2.5$ psi

Available Head at Core Inlet

- Hot Leg Break
  - Liquid density, $\rho = 60\ lbm/ft^3$
  - For conservatism, core mixture level is taken at the bottom of the hot leg with no voiding
  - Pressure difference available to drive flow through the core due to liquid level difference between the downcomer and core is:
    - $\Delta P_{dz} = (Z_{SG} - Z_{HL})(\rho)$
    - $\Delta P_{dz} = (49.5 - 16.06)(60/144) = 13.9$ psi
  - With the break in the hot leg, flow losses from the core to the break are:
    - $\Delta P_{flow} \sim 0$ psi
  - Total available driving head is:
    - $\Delta P_{available} = 13.9 - 0 = 13.9$ psi

Available Head at Core Inlet

- The available driving head at the core inlet is then:
  - Cold leg break: $\Delta P_{available} \sim 2.5$ psi
  - Hot leg break: $\Delta P_{available} \sim 14$ psi
- The head loss through a debris bed must be less than these values to provide reasonable assurance that the flow required to remove core decay heat will continue to reach the core.

Pressure Drop from Debris

- The head loss through a possible debris buildup at the core inlet is a function of the amount and type of debris that reaches the reactor coolant system:

$$\Delta P_{debris} = f(\text{debris type, debris amount})$$

- Multiple combinations of debris can reach the RCS.
  - The amount and combinations at any given time are related to the plant design and timing of the arrival of the various debris
  - The combination of types of materials in plants and the variability of arrival times suggest that a bounding or limiting representation is a prudent approach

Pressure Drop from Debris

- Particulates will generally be smaller than the fuel filter openings
- Consequently, a fiber bed must be present to collect the particulates at the core entrance
  - Otherwise, the particulates will simply pass through and no blockage will occur
- The following slides provide the basis for investigating the amounts of each type of debris

Fibrous Debris

- Testing of sump screens has shown small amount of fibrous debris may collect particulates and chemical precipitates to produce a large head loss
  - This bed has been called a "thin bed"
- Additionally, large fiber masses may collect large masses of particulates and chemical precipitates and generate a large head loss
  - This bed has been called a "thick bed"
- Therefore, fiber masses that must be investigated experimentally range from small to large

Particulates & Chemical Precipitates

- If sufficient amounts of particulates and chemical products are not available:
  - Voids in the fiber bed will not be filled,
  - Flow through the bed will continue
  - Core cooling is maintained
- Therefore, large volumes of particulates and chemical precipitates should also be investigated

Chemical Effects at the Core Inlet

For a postulated hot-leg break:

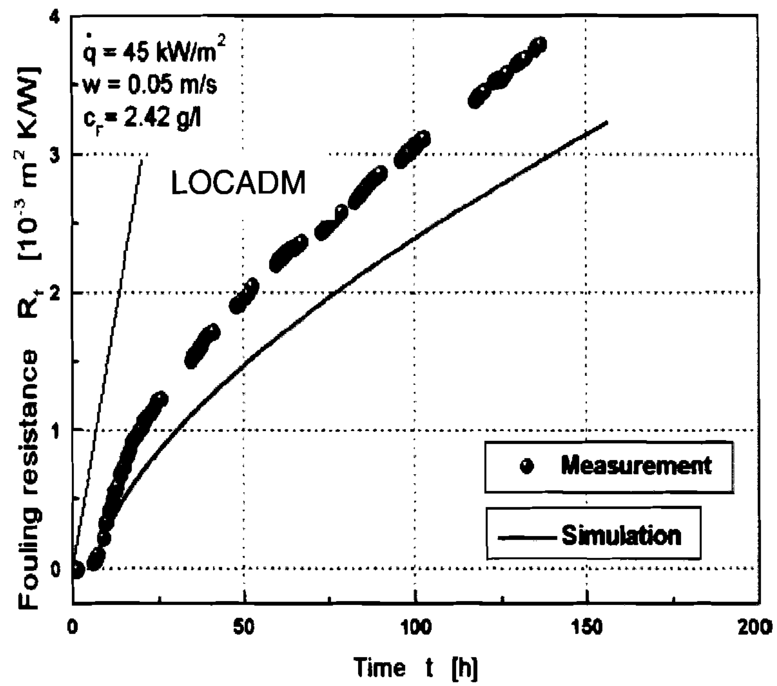
- Maximum flow into core results in maximum hydraulic drag on debris at core entrance
- Concentration of chemical products builds over time (demonstrated by ICET program)

Head Loss and Calcium Phosphate

- Calcium-based chemical product could form early in the accident and at elevated temperatures
- Head-loss testing at Argonne National Laboratory (ANL)
  - Test conditions:
    - NUKON fiber bed
    - Approach velocity of 0.1 ft/sec
  - Results indicate aluminum chemical products generate larger pressure drop at same concentration than calcium phosphate
- Demonstrates use of aluminum surrogates provide for a conservatively large or high head loss

LOCADM - Validation of Core "Boiler Scale" Model

- LOCADM is an automated (spreadsheet) calculation of post-LOCA material deposition
- Model conservatively assumes that <u>all</u> fiber and chemical products passed by the sump screen and transported to fuel surfaces by boiling will deposit
- Verification of the model performed by comparison of calculations to test data
- As shown in the comparison to the right, deposition is conservatively predicted



Fahmi Brahim, Wolfgang Augustin, Matthias Bohnet, "Numerical simulation of the fouling process" International Journal of Thermal Sciences 42 (2003) 323-334

Fuel Assembly Debris Capture Tests

- Head loss test protocol developed to support WCAP-16793-NP
- Testing will investigate:
  - Combinations of debris materials (fibrous, particulate and chemical)
  - Thin bed debris loading
- Output of test program is an acceptance criteria:
  - Maximum debris masses which, if passed through the reactor containment building sump screen, will result in an acceptable pressure drop at the core inlet
  - Plants demonstrate acceptable long term core cooling by showing that plant-specific sump screen bypass masses are bounded by the limits in the acceptance criteria

Key Features of Test Protocol

- Debris Preparation Identified
  - Fibrous debris – three size ranges
  - Particulate debris – silicone carbide 10mm $\pm$ 2 mm
  - Chemical surrogates – WCAP-16530-NP-A
- Test Method Identified
  - Sequence of debris addition (particulate first, then fiber and chemical surrogates last)
- Test Termination Criteria Identified
  - Maximum Pressure Drop: 13 psid
  - Achieving a Steady Pressure Drop:
    - Less than 1% change in pressure drop over the last 30 minute time interval, and,
    - Minimum of 10 flume turnovers after all the debris had been inserted into the test flume.
    - Criteria to allow terminate testing if Steady Pressure Drop not reached

Debris Characteristics - Fuel Assembly Test

Fiber Sizes		
Fiber Length	Target	Range
< 500 μm	77%	67% - 87%
500μm < 1000μm	18%	8% - 28%
≥ 1000μm	5%	0% - 15%

- Particulates: Silicon carbide:
  - 10~~mm~~ μm ± 2 ~~mm~~ μm
  - Small size provides for maximum lift and penetration into fiber bed

- Chemical Surrogate: Aluminum Oxy-hydroxide (AlOOH)
  - Shown by Argonne National Laboratory to produce the highest pressure drop among all of the chemical precipitates
  - Ensure AlOOH surrogate meets settling criteria of WCAP-16530-NP-A and its modification in the associated SER

Fuel Assembly Debris Capture Tests

- Initial tests plan to use:
  - Vendor bottom nozzle configurations
  - Hot-leg break flow rates
  - Fiberglass, particulate and chemical surrogate debris
- Output from initial tests:
  - Selection of a limiting fuel design for further tests
  - Correlation of pressure drop between the various bottom nozzles designs of a vendor
  - Intend to evaluate if adjustments to the plan are warranted as testing is performed

Fuel Assembly Debris Capture Tests

- Debris for testing with limiting nozzle design and hot-leg flow rates:
  - Fiberglass, particulate and chemical surrogate debris
  - Fiberglass, particulate, chemical surrogate debris and calcium silicate
  - Fiberglass, particulate, chemical surrogate debris and Min-K
  - Amount of debris
    - Will be set by sump screen bypass data provided by licensees
    - Generic number of bypass per 1000 ft^2 of screen area not used
- NRC Involvement:
  - Test Protocol has been shared with NRC
  - Comments received and addressed
  - NRC visited and observed a test

Summary of Fibrous Debris Dimensions from Replacement Screen Bypass Testing

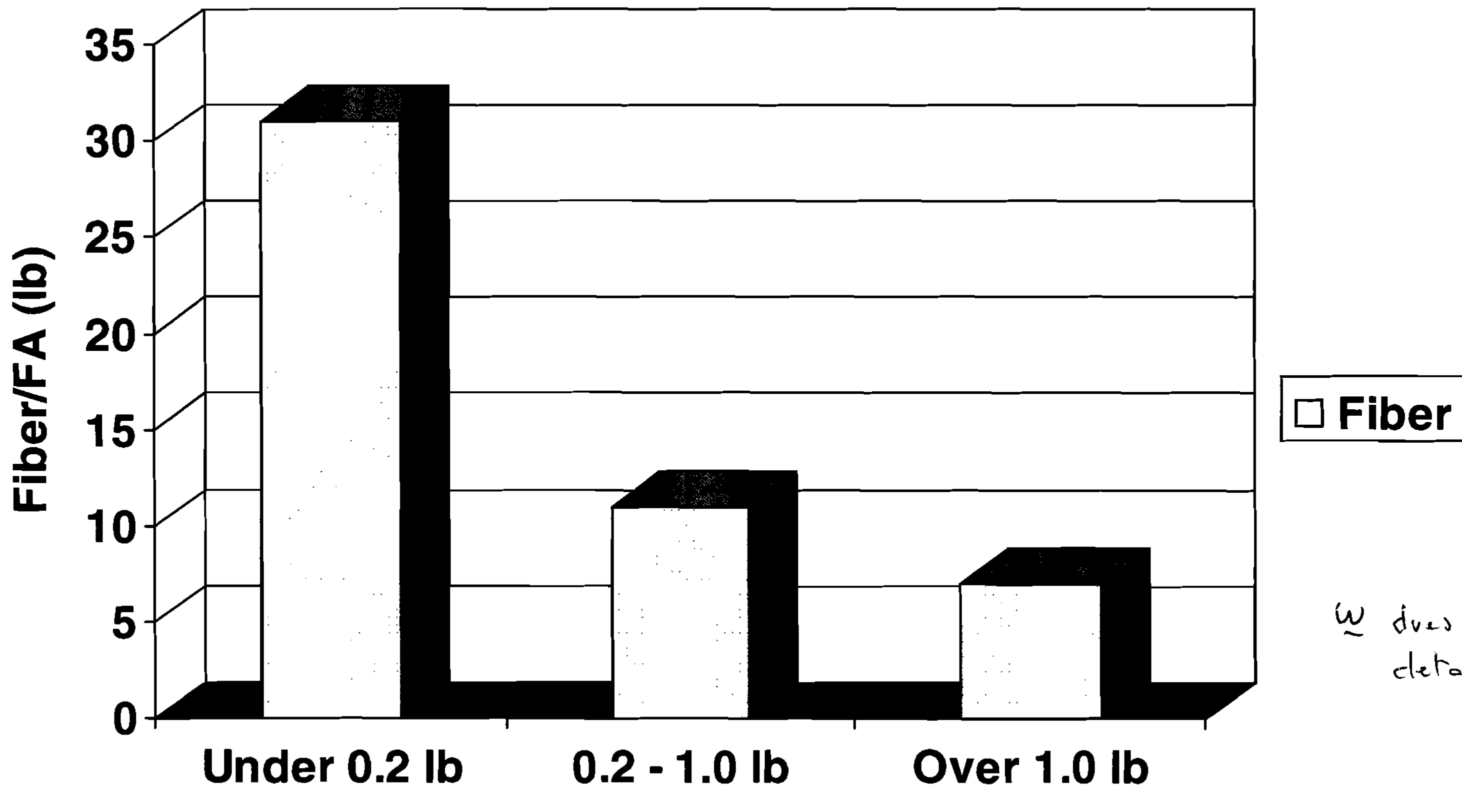
Plant Designation	Bypass Test Number	Distribution of Bypass Fiber Lengths				
		< 100 µm (0.0040 in)	< 300 µm (0.0118 in)	< 500 µm (0.0197 in)	< 1000 µm (0.0394 in)	> 1000 µm (0.0394 in)
A	1			63%	21%	16%
	2			66%	25%	9%
B	1			48.4%	39.3%	12.3%
C	1			63.1%	27.3%	9.6%
D	1	16%	78%			6%
	2	17%	75%			8%
	3	17%	75%			8%
	4	17%	75%			8%
	5	17%	75%			8%
E	1			50%	45%	5%
	2			89%	11%	0%
F	1			90%	10%	0%
	2			84%	14%	2.0%
	3			94.2%	4.7%	1.1%
	4			96%	4%	0%
F	1			80%	18.5%	1.5%
	2			95%	4.5%	0.5%

cumulative numbers

from plants

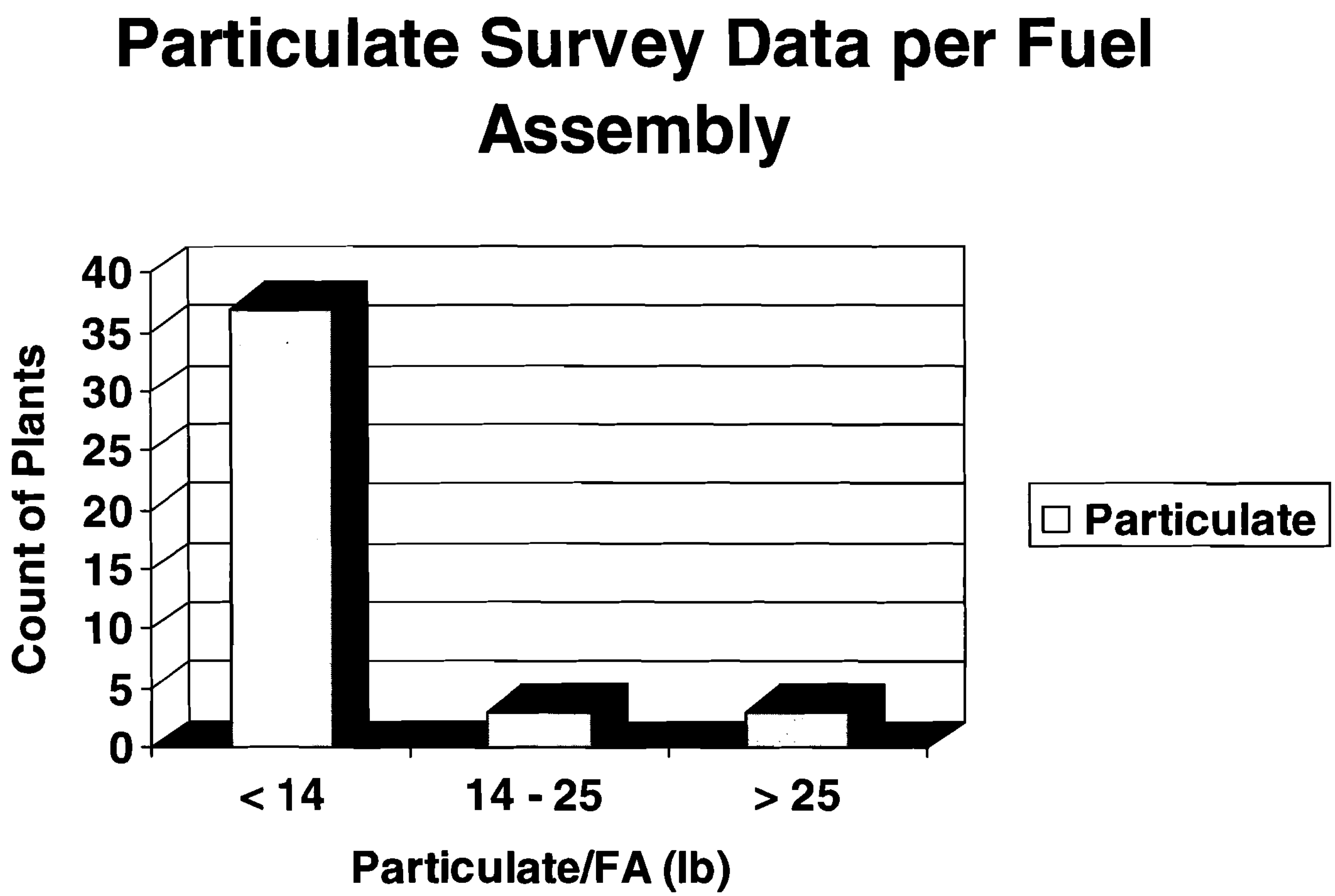
Fiber Survey Data

Survey Fiber Data per Fuel Assembly



W does not remember details

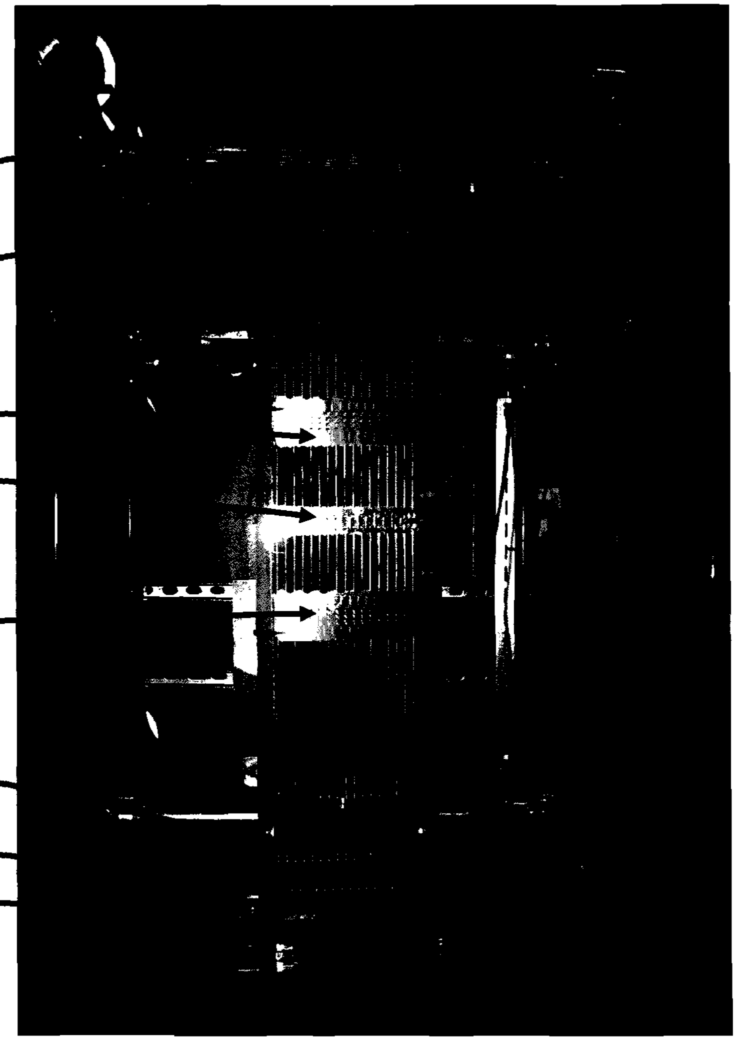
Particulate Survey Data



Test Rig – Westinghouse F/A

- Assembly Height: 4 ft

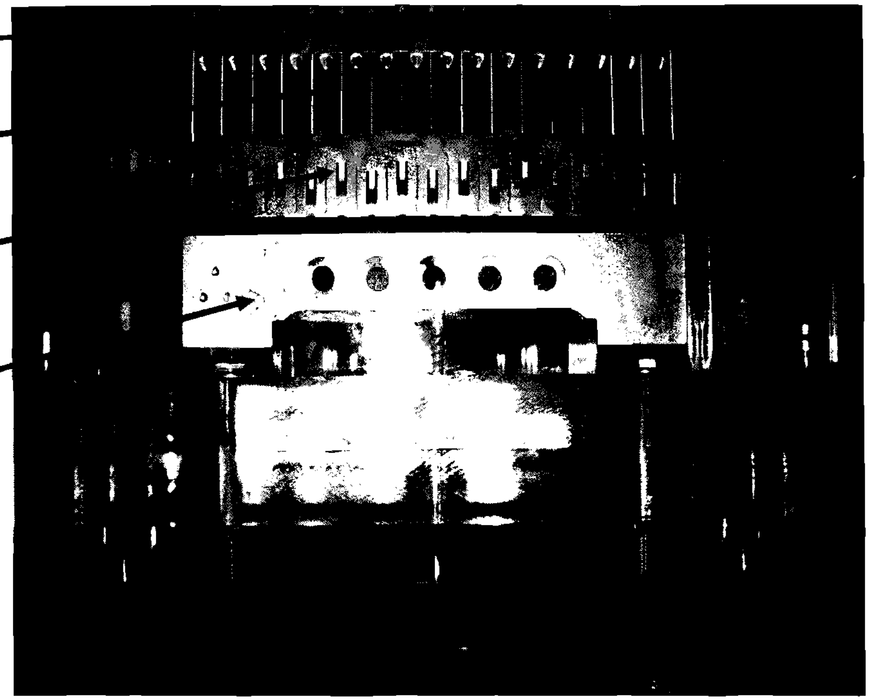
- Top Nozzle
- Inconel top grid
- Intermediate grid
- Intermediate Flow Mixing (IFM) grid
- Intermediate grid
- Inconel bottom grid
- Standard p-grid
- Debris Filtering Bottom Nozzle



Test Rig – Westinghouse F/A

Close-up view of:

- First Support Grid
- Fuel Rods
- Protective Grid
- Bottom Nozzle



Test Parameters

- Conditions for Low Particulate /Low Fiber
  - Scaled based on 193 assemblies in core
  - Hot-leg flow rates 8630 gpm
  - Total Particulate mass 580 lb_M
  - Total Fiber mass 22.5 lb_M
  - Total Chemical Precipitate mass 28 lb_M
- Conditions for High Particulate /Low Fiber
  - Scaled based on 193 assemblies in core
  - Hot-leg flow rates 8630 gpm
  - Total Particulate mass 2700 lb_M
  - Total Fiber mass 22.5 lb_M 0.1 lb 45g
  - Total Chemical Precipitate mass 28 lb_M

Summary of First Two Tests

Data still being evaluated.

- Test CIB02
  - Particulate: $3\ lb_M$
  - Fiber: 53 gm
  - Chemical: 66 gm
  - Flow rate: 44.7 gpm
- Sequence
  - Particulate addition
    - 1 addition of $3\ lb_M$
  - Fibrous addition
    - 8 additions of 5 gm of fiber
    - 1 addition of 13 gm of fiber
  - Chemical addition
    - 3 additions of 11 gm of chemical surrogate

- Test CIB03
  - Particulate: 14 lbM
  - Fiber: 53 gm
  - Chemical: 66 gm
  - Flow rate: 44.7 gpm
- Sequence
  - Particulate addition
    - 4 additions of $3\ lb_M$
    - 1 addition of $2\ lb_M$
  - Fibrous addition
    - 8 additions of 5 gm of fiber
    - 1 addition of 13 gm of fiber
  - Chemical addition
    - 3 additions of 11 gm of chemical surrogate

In both tests, pressure drop under 13 psid

Preliminary Test Observations

- "Thin bed" behavior not observed in tests to date
- Fiber:
  - Provides collection sites for debris
  - Is the driver for head loss
- Chemical precipitates:
  - Are another source of particulates
  - Initial results show chemical precipitates do not increase head loss
  - Rather, in some cases, some decrease in head loss observed after chemical addition
- Debris appears to be distributed at grids along the height of the bundle

Use of Core Inlet Head Loss Testing

- The test results will establish an acceptance criteria for debris in the RCS:
    - Total bypass fiber mass (lb_m)
    - Total bypass particulate mass (lb_m)
    - Total bypass chemical precipitate mass (lb_m)
- If a plant cannot meet these criteria, the following actions may be taken
    - Reduce debris load reaching RCS
        - Reduce debris generation
        - Reduce debris transport
    - Perform tests to demonstrate that the pressure drop through the plant-specific debris bed is less than the available driving head

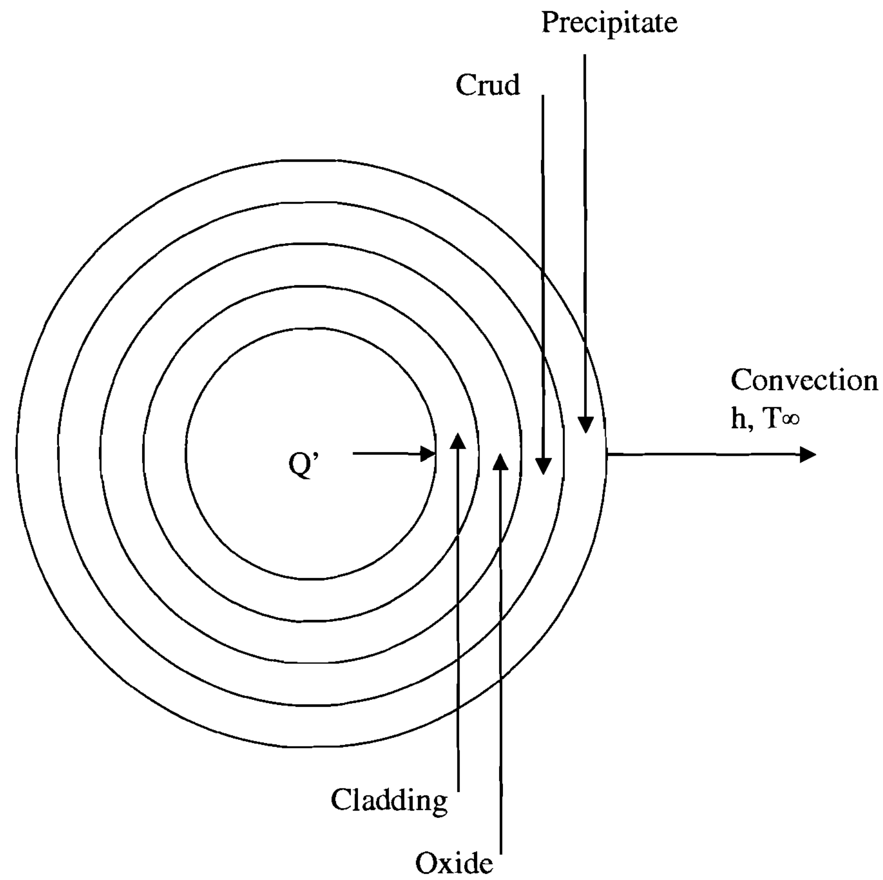
Effect of Debris Collection on Hot Spots

- Source of heat post-LOCA is from decay heat in the fuel rod
  - This source is limited to the fuel in the rod and decreases with time
  - "Hot spots" can arise only if the local flow is severely restricted
  - Local temperature increases would be mitigated by boil-off in the region
  - Heat will be dissipated:
    - Grids act as radiators
    - Axial conduction along the fuel rod
  - Sustaining quench and replacing boil-off maintains clad temperatures < 800°F
- Conservative calculations of clad temperatures demonstrate coolability of clad with deposition on clad surface and blockage at a grid:
  - High decay heat levels set by initiation of recirculation from sump
  - Between grids, chemical product and debris deposition less than 50 mils yields clad temperatures < 800°F
  - Assuming no flow through the grid yields clad temperatures < 800°F behind grids

1-D Clad Hot Spot Calculations

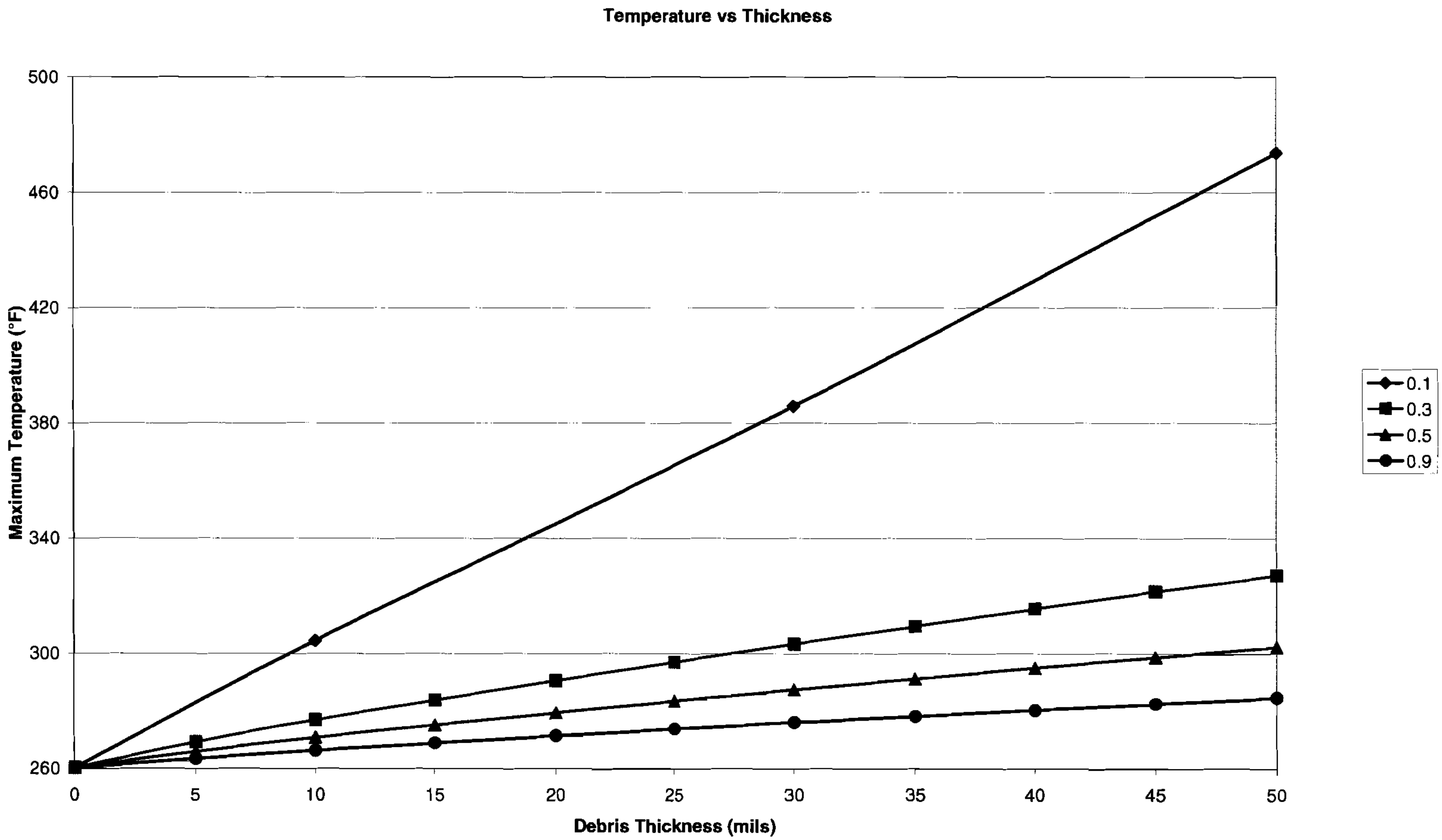
Clad/Oxide Interface Temperature vs. Chemical Precipitate Thickness				
Chemical Precipitate Thickness (mils)	$k_{precipitate}$ (BTU/hr-ft-°F)			
	0.1	**0.3**	**0.5**	**0.9**
0	273°F	273°F	273°F	273°F
10	336°F	293°F	285°F	279°F
20	396°F	313°F	296°F	286°F
30	453°F	331°F	308°F	291°F
40	508°F	350°F	318°F	297°F
50	560°F	367°F	328°F	302°F

Clad/Oxide Interface Temperature vs. Chemical Precipitate Thickness		
Chemical Precipitate Thickness (mils)	$k_{precipitate}$ = 0.1 BTU/hr-ft-°F	
	0.422" OD rod	**0.416" OD rod**
0	283.6°F	283.6°F
10	377.0°F	376.9°F
20	466.4°F	466.2°F
30	552.1°F	551.9°F
40	634.5°F	634.1°F
50	713.8°F	713.2°F



2-D Clad Hot Spot Calculations

Peak Temperatures were calculated under Grid Straps



Boric Acid Precipitation

- Following a LOCA, borated ECCS water is injected to RCS
- For a postulated **Hot Leg** break:
  - All of the cold side ECCS injection travels through the core to the break
  - No opportunity for boric acid or sodium borate to concentrate in the core
  - Therefore, these breaks are not a concern with respect to boric acid concentration
- For a postulated **Cold Leg** break:
  - Core flow is only that needed to make up for core boiling
  - Boric acid and sodium borate carry-over in steam is low; therefore they concentrate in core
- Current licensing basis calculations are in place to define the time to initiate an operator action to dilute the core

Boric Acid Precipitation and GSI-191

- To assure the licensing basis calculations will remain valid considering debris that reaches the RCS, plants meet the following conditions:
  - ½ of the RV lower plenum remains available for mixing
  - Existing Emergency Operating Procedures (EOPs) direct plant operators to initiate Hot-Leg Recirculation/Core Flushing Flow
- Based on what is currently known, once plant operators initiate Hot-Leg Recirculation/Core Flushing Flow via the EOPs:
  - Core fluid is diluted, and,
  - Mixing of the boric acid solution in the core is maintained
- The potential impact of debris on boric acid solution mixing is to be addressed in another PWR Owners Group program outside GSI-191 (Project Authorization PA-ASC-0264) define the issue & solve it

Boric Acid Precipitation and GSI-191

- Defense in depth is provided by considering the following conservative assumptions used in the licensing basis boric acid precipitation calculations:
  - No credit for sump buffering agents that will neutralize the boric acid and raise the solubility limit
  - No boron carry-over in entrained liquid around the loop
  - No boron carry-over in steam
  - Appendix K decay heat (1971 ANS + 20%) used
- Defense in depth is provided by considering the following conservative assumptions used in the GSI-191 debris transport calculations:
  - All debris (fiber, particulate, & chemical) are assumed to arrive at the core inlet at the time of sump switchover
  - Core decay heat decreases with time, reducing the velocities in the RV lower plenum

Summary

- WCAP-16793-NP and supporting work ~~has~~ may demonstrate~~d~~ reasonable assurance of LTCC
- Fuel assembly testing is currently being performed to establish debris limits for plants
- Plants that can demonstrate they satisfy those limits are done; no additional action needed
- Plants that do not satisfy the limits can take remedial actions:
  - Reduce debris generation
  - Reduce debris transport
  - Perform plant-specific fuel head loss testing

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Status and Closure Strategy for Generic Safety Issue (GSI) 191 Pressurized Water Reactor Sump Performance

Presented by:
Donnie Harrison
Office of Nuclear Reactor Regulation

Presented to:
Advisory Committee on Reactor Safeguards
Thermal-Hydraulics Subcommittee
September 23, 2008

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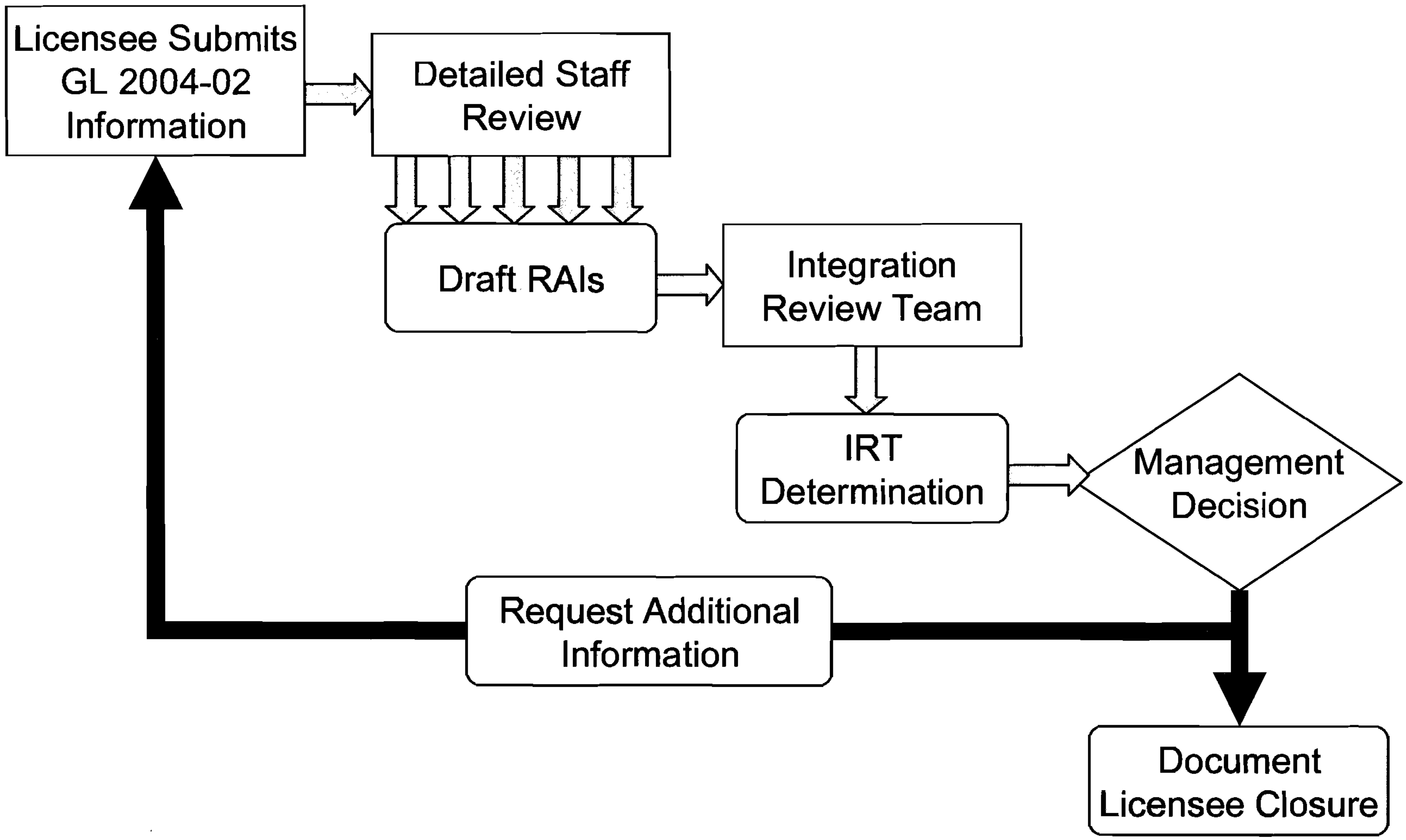
Today's Discussions

- Broad overview of current status and closure process for GL 2004-02
- Status on Technical Issues
  - Emergency Core Cooling System (ECCS) Sump Strainer Head Loss Testing
  - Chemical Effects
  - In-vessel Downstream Effects

Closure Process



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End Point for Reviews

- Each licensee will provide, as applicable:
  - Responses to RAIs on the licensee's GL supplemental submittals
  - Responses to open items identified in NRC staff audits
  - Final supplemental response after all testing and evaluations completed
  - Submittal addressing in-vessel downstream effects after WCAP-16793-NP issued

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Closure Activities

- The staff reviews supplemental information/RAI responses in accordance with the closure process
- The Regions inspect implementation of modifications and other commitments
- The staff will issue a closure letter to each licensee when sufficient information is provided to close the issue for that plant
- After all licensees have been issued closure letters, GL 2004-02 will be formally closed
- Some modifications will be made after planned issue closure
  - NRC will track all commitments to completion
- The staff expects to complete all technical review activities to support closure next year

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Current Status of GSI-191

- All licensees have installed significantly larger ECCS sump strainers
- Many licensees have done, or will do, other modifications, for example:
  - remove insulation
  - replace sump buffer
- Strainer testing activities have been completed for many licensees

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Current Status (Continued)

- Most licensees requested extensions beyond December 2007 to complete certain corrective actions
  - Integrated head loss testing, including chemical effects
  - Downstream effects analyses
  - Plant modifications
- All plants submitted supplemental responses to GL 2004-02 in February/March 2008
- The staff is nearing completion of the review of the licensee supplemental responses

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Current Review Results

- The staff has informed several licensees with "low-fiber" plants that the staff has few additional questions for those plants
- Most other plants have received, or will receive, RAIs
- "Placeholder" RAI for in-vessel downstream effects, since most plants relied on WCAP-16793-NP

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Conclusion

- The staff has a process for closure of GL 2004-02
- Significant modifications to prevent unacceptable strainer blockage
- Conservative test protocols and evaluations that will show satisfactory performance of strainers
- In-vessel downstream effects resolved as part of WCAP-16793 review

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ECCS Sump Strainer Head Loss Testing

Presented by:
Stephen Smith
Office of Nuclear Reactor Regulation

Presented to:
Advisory Committee on Reactor Safeguards
Thermal-Hydraulics Subcommittee
September 23, 2008

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Strainer Testing Overview

- Strainer testing is being conducted to ensure adequate NPSH margin for ECCS and CSS pumps under accident conditions
- To be discussed:
  - Current status of testing
  - Strainer vendors and test labs
  - Staff review of GL 2004-02 responses in the head loss area
  - Areas of concern regarding head loss testing
  - Review guidance for head loss testing and evaluation
  - Path forward

Head Loss Testing Current Status

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- Most strainer vendors/testers have now developed procedures that the staff agrees are capable of producing prototypical or conservative head loss results
  - Recently observed tests have had fewer issues identified than earlier tests
- Some vendors have not provided adequate assurance that their current protocols are prototypical or conservative
- Some plants are relying on testing that was conducted prior to the development of current vendor test protocols
- Staff has witnessed a number of head loss tests at each vendor
  - Lessons learned have been incorporated into staff review of licensee test activities and GL 2004-02 submittals

Head Loss Test Vendors

- Five main test vendors for U.S. PWRs
  - Alion Science and Technology
  - Atomic Energy of Canada, Limited (AECL)
  - Control Components, Incorporated (CCI) – Switzerland
  - General Electric – Hitachi (GEH)
  - Performance Contracting, Incorporated (PCI)
- Additional test vendors
  - Enercon Services / Wyle Laboratories
  - Westinghouse / Fauske and Associates

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GL 2004-02 Responses – Head Loss Testing

- Most GL 2004-02 supplemental responses reviewed to date have had RAIs proposed in the head loss testing area
  - Few RAIs typically proposed for licensees that tested recently using updated test procedures
  - Significant RAIs proposed for plants that performed testing that is not consistent with current staff guidance for head loss testing
    - Additional testing may be necessary for some plants to adequately address these RAIs

Head Loss Testing Key Technical Issues

- Debris Preparation
- Debris Introduction
- Thin Bed Test Protocol
- Test Flume Flow Patterns

Head Loss Testing Review Guidance

- Staff Issued Updated Head Loss Testing Review Guidance in March 2008
  - Incorporates recent lessons learned from industry head loss testing discussed previously
  - Publically available
  - Tests and evaluations conducted per this guidance should result in a conservative or prototypical result that may be used for plant strainer qualification

Path Forward

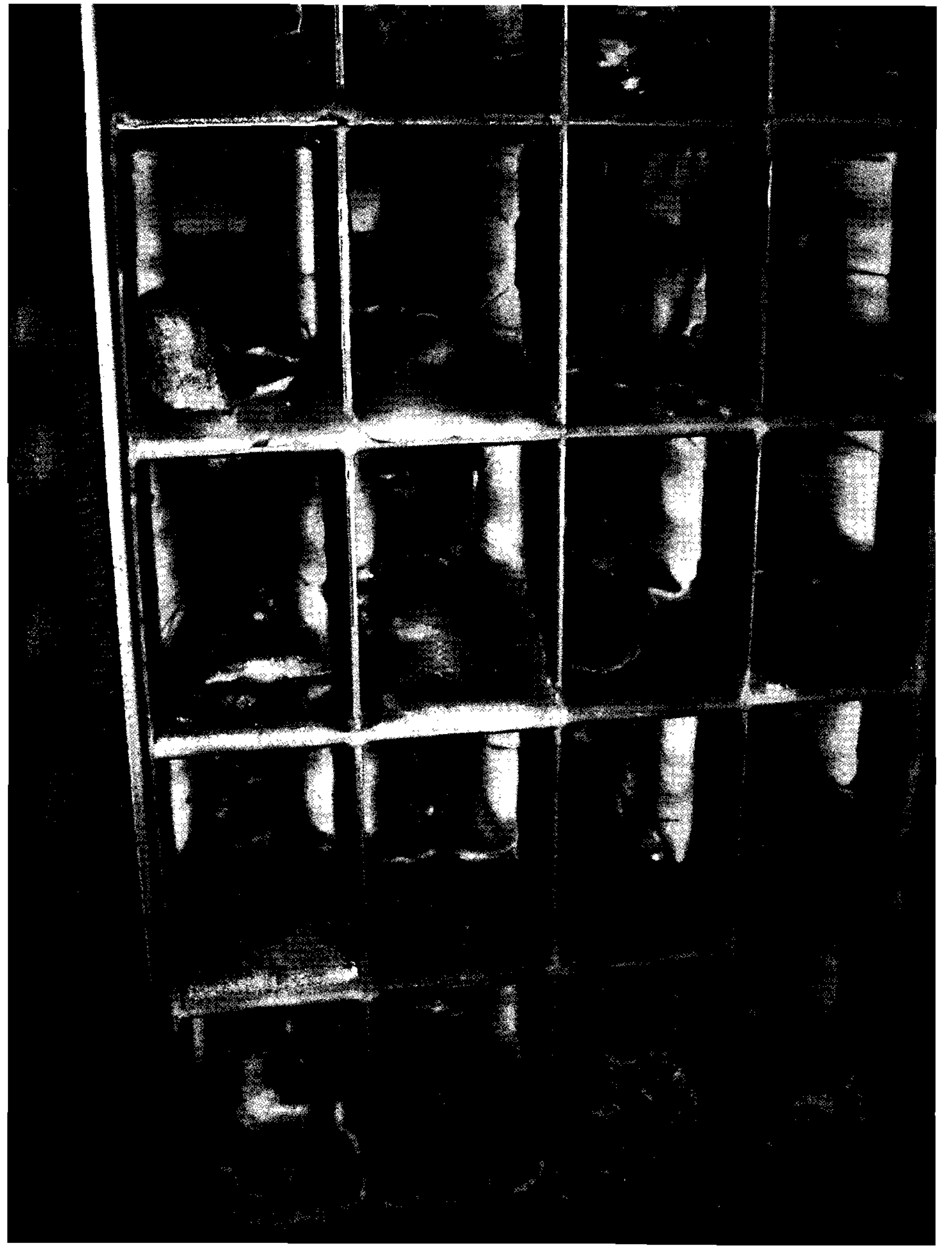
- Plants that have RAIs will have to provide acceptable responses, additional analyses, or retest to assure adequate strainer performance
- Some licensees that have had unacceptable test results using conservative protocols are "testing for success" by identifying and testing several contingency plans until success is achieved, e.g.:
  - Analytical changes to reduce calculated debris loading
  - Physically removing debris sources from containment
  - Installing debris interceptors or other plant modifications
  - Plant will be modified at upcoming outage to be consistent with successful test condition

At the Movies

- CCI Debris Introduction
  - Finer debris, more uniformly covering strainer will lead to higher head losses
- CCI Chemical Debris Addition
  - Shows flow pattern in test flume
  - Illustrates modeling of strainer in test flume
  - Chemical debris increases head loss and results in debris bed compaction

CCI Test Flume Overview

- Strainer testing at CCI
- Post-drain down
- Low fiber plant
- Some clean strainer area observed following test
  - Met acceptance criteria



post drain down

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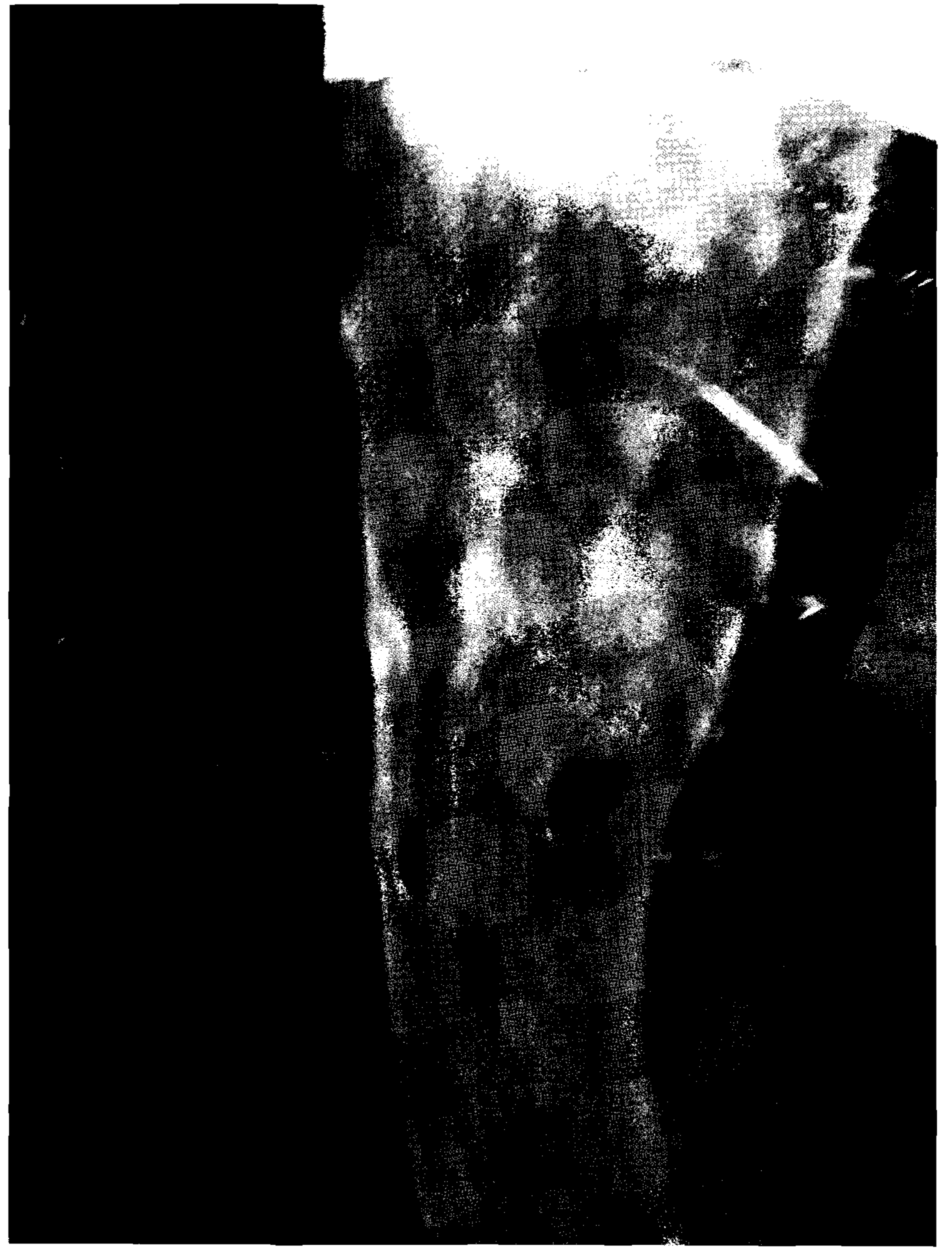
- Strainer at CCI prior to chemical addition
- Fiber covers face of strainer
- Relatively low head loss



- Strainer following chemical addition
- High concentration of chemical debris suspended in fluid indicates adequate transport
- Fiber collapses into pockets
- Head loss increases

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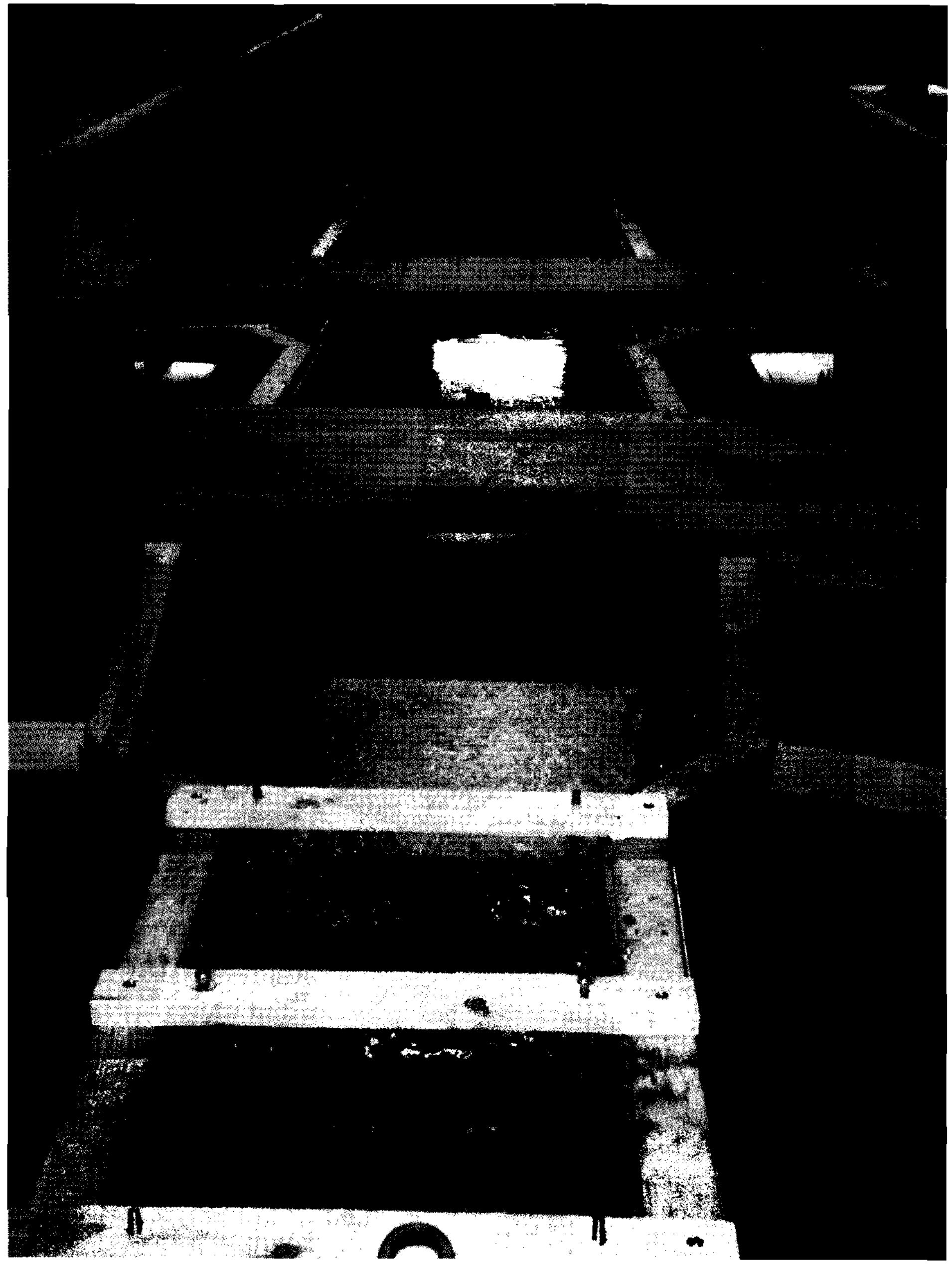
- PCI test flume overview
- Models flow near strainer
- Compared to CFD flows
- Test allows debris settlement
- Debris added 30 to 40 feet from strainer module

Correlation - measure velocities?



- Example of non-prototypical debris addition
- Excessive agglomeration due to high fibrous debris concentration
- Excessive settling of debris could occur
- Agglomerated debris less likely to uniformly cover strainer
- Vendor changed debris introduction, based on staff feedback

[redacted]

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Conclusions

- Strainer testing methods have improved
- Some licensees have demonstrated acceptable strainer performance as shown by prototypical or conservative tests
- Some licensees are working to reduce debris loads
  - Retesting with reduced debris loads is required
- Some licensees will attempt to stand on current test results by responding to staff RAIs
  - Staff will consider the additional information provided on a case by case basis

Chemical Effects Status

Paul Klein, Matt Yoder
Office of Nuclear Reactor Regulation

Chi Bum Bahn, Ken Kasza, Bill Shack, Ken Natesan
Argonne National Laboratory

ACRS Subcommittee on Thermal-Hydraulic Phenomena
September 23, 2008

Outline

- Chemical Effects Testing
  - Description of industry test approaches
  - NRC Staff assessment and technical issues
- Argonne National Laboratory (ANL) Testing to Support NRR
  - Vertical head loss loop testing
  - Bench testing
- Summary

Chemical Effects Testing Progression

- Initial chemical effects head loss testing performed in vertical head loss loops
- Industry test approach varies by strainer vendor:
  - Atomic Energy of Canada Limited (AECL)
  - Alion Science and Technology
  - Control Components Inc. (CCI)
  - General Electric Hitachi (GEH)
  - AREVA/Performance Contracting Inc. (PCI)

  - Single licensee tests at Fauske & Associates and Wyle Laboratory

Test Methods (1): WCAP Precipitate Addition

- Precipitate generated outside the test loop. Test objective is the transport of all debris, including precipitate, to the test strainer
  - Alion – Warrenville facility
  - CCI – some licensees
  - GEH – some licensees
  - Fauske – one licensee
- Technical Issues
  - Verification of acceptable precipitate settlement rates
  - Verification that plant specific debris and chemical precipitate transport to the test strainer occurs
- Staff Assessment – WCAP-16530 methodology is acceptable to the staff, safety evaluation report issued December 2007.

Test Methods (2): WCAP Precipitate with Settling

- Precipitate generated outside test loop. The test approach allows for representative settling of debris, including precipitate, upstream of the test strainer.
  - GEH – some licensees
  - AREVA/PCI
- Technical Issues
  - Representative/conservative flume flow characteristics
  - Precipitate settlement characteristics
- Staff Assessment – acceptable to the staff, provided flume flow characteristics are justified and a more restrictive precipitate settlement acceptance criterion is met

Test Methods (3): In-Situ Precipitate Formation

- Precipitate generated by addition of dissolved aluminum, calcium, and silicates to test flume containing borated, buffered water simulating plant-specific environment
  - CCI – some licensees

- Technical Issues
  - Argonne Laboratory testing ANL tests showed precipitate characteristics can be sensitive to local concentration effects during addition of chemicals
  - Precipitate transport to the strainer

- Staff Assessment – staff is evaluating on a licensee specific basis. Licensee to demonstrate adequacy of precipitate formation process

Test Methods (4): Long Term Chemical Addition

- Thirty day tests with simulated post-LOCA environment (e.g., borated, buffered water). Dissolved aluminum additions to the loop over time to match the plant specific chemistry
  - AECL
  - Wyle Laboratory
- Technical Issues
  - Transport of non-chemical debris to the strainer (Wyle)
  - Adequacy of the debris bed formed on the strainer
  - Technical basis for plant-specific chemical additions
- Staff Assessment – staff is reviewing on a licensee specific basis. Licensee to demonstrate why test conservatively evaluates chemical effects

Test Methods (5): Long Term Leaching Test

- Thirty day tests with chemistry developed by leaching from debris interaction with the simulated LOCA environment
  - Alion - VUEZ facility

- Technical Issues
  - Adequacy of the debris bed formed on the strainer
  - Validity of chemical effects factor developed from these tests

- Staff Assessment – based on questions, including non-chemical debris bed formation, the staff has concluded that an alternate approach is needed

ANL Technical Support to NRR

- Given the varied industry approach to chemical effects testing, NRR requested technical support from Argonne National Laboratory
  - Compare head losses from:
    (1) WCAP-16530 precipitate,
    (2) precipitate formed by corrosion of aluminum coupons,
    (3) precipitate from chemical additions

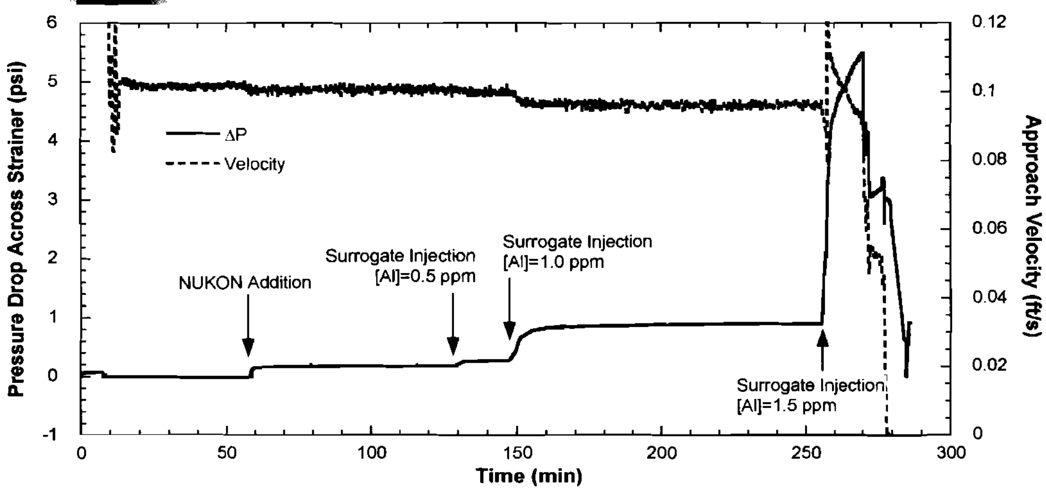
- Evaluate the long term solubility of aluminum in alkaline, borated solutions, including potential effects of thermal cycling

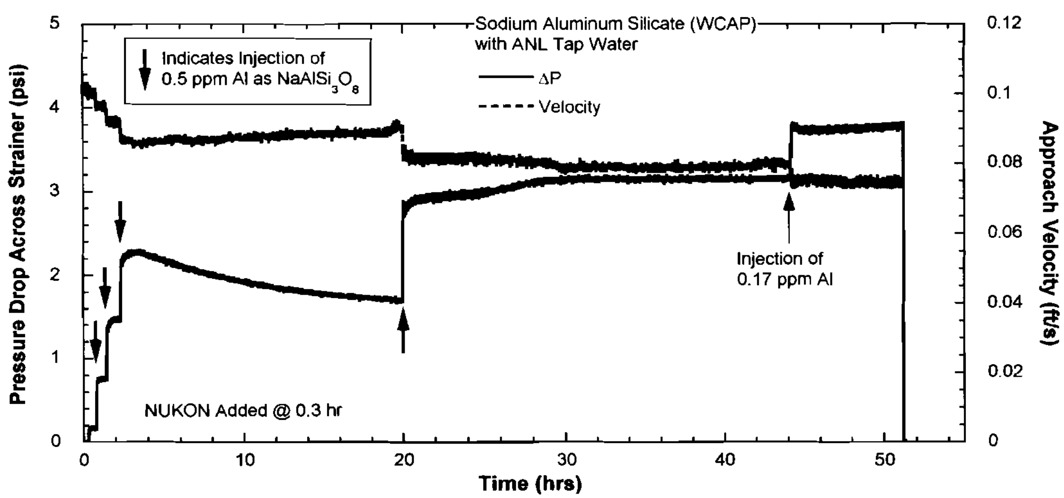
- Evaluate the stability of WCAP-16530 AlOOH precipitate as a function of pH

References

- ANL Technical Letter Reports covered in this presentation
  - C. B. Bahn, K. E. Kasza, W. J. Shack, and K. Natesan, *Technical Letter Report on Evaluation of Chemical Effects: Studies on Precipitates Used in Strainer Head Loss Testing,* ADAMS Accession No. ML080600180, U.S. Nuclear Regulatory Commission, Washington D.C., January 2008.
  - C. B. Bahn, K. E. Kasza, W. J. Shack, and K. Natesan, *Technical Letter Report on Evaluation of Long-term Aluminum Solubility in Borated Water Following a LOCA,* ADAMS Accession No. ML081550043, U.S. Nuclear Regulatory Commission, Washington D.C., February 2008.
  - C. B. Bahn, K. E. Kasza, W. J. Shack, and K. Natesan, *Technical Letter Report on Evaluation of Head Loss by Products of Aluminum Alloy Corrosion,* ADAMS Accession No. ML082330153, U.S. Nuclear Regulatory Commission, Washington D.C., August 2008.

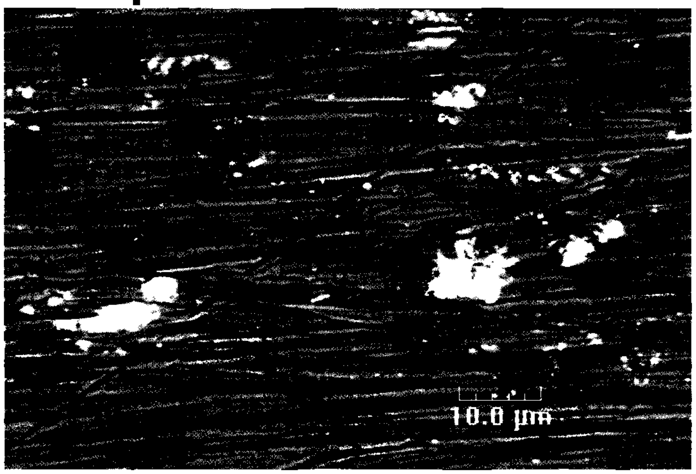
Head Loss Testing – WCAP Aluminum Oxyhydroxide (top) Sodium Aluminum Silicate (bottom)



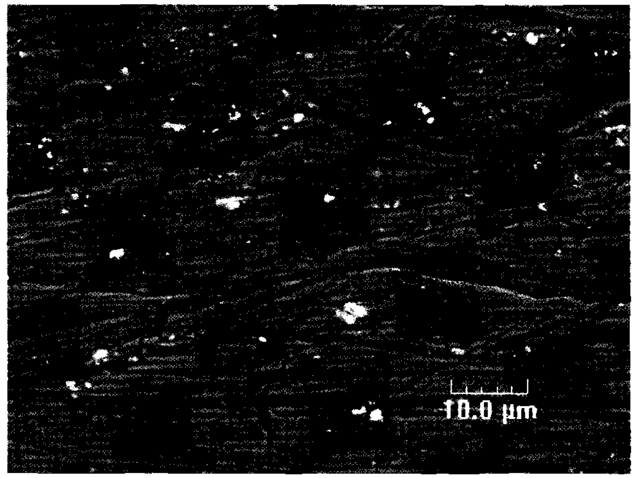


- The median particle size of WCAP SAS surrogate is ~3 times bigger than that of WCAP AlOOH.
- This surrogate is not as stable as WCAP AlOOH surrogate in high purity water.
- WCAP AlOOH and SAS surrogates caused significant head loss with the amount equivalent to 1.5 and 2 ppm Al, respectively.

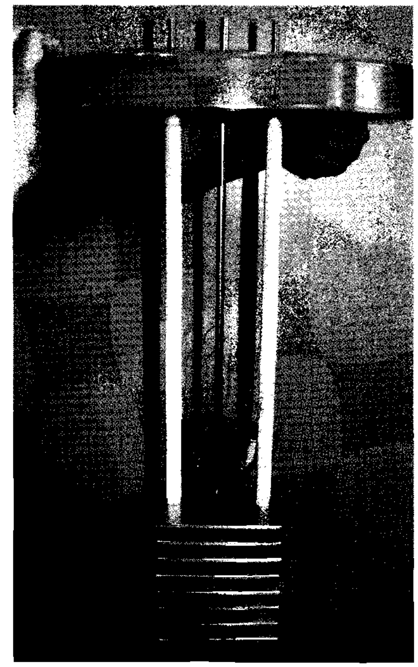
Head Loss Tests With Aluminum Coupons



Al 6061 BSE Image

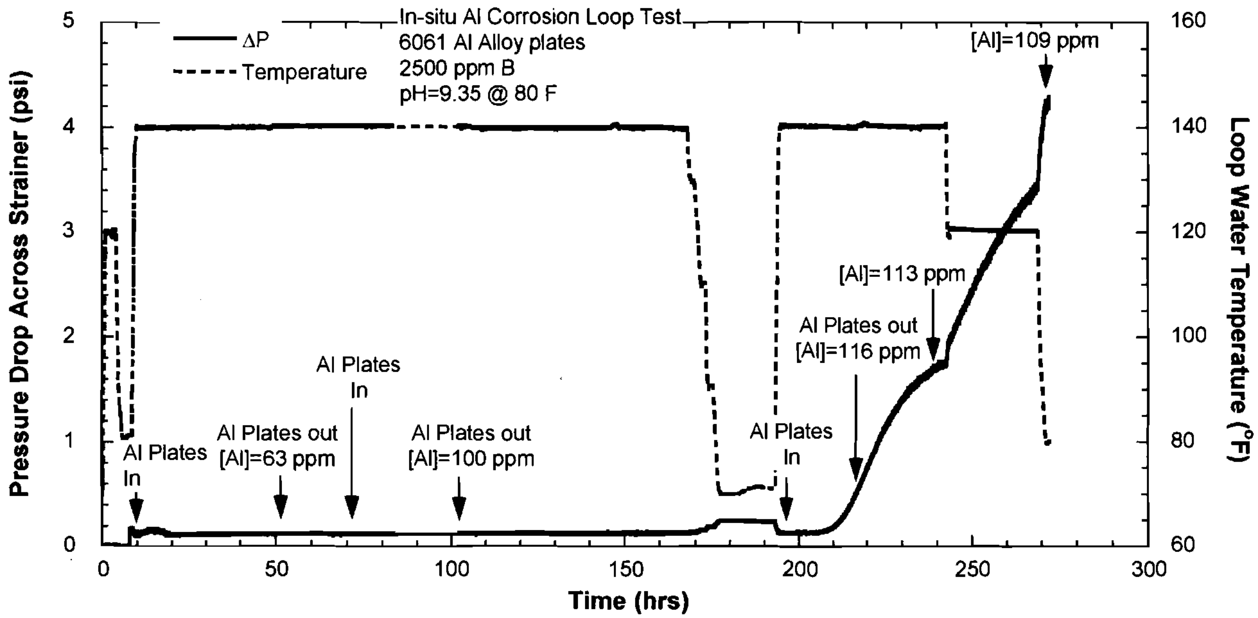


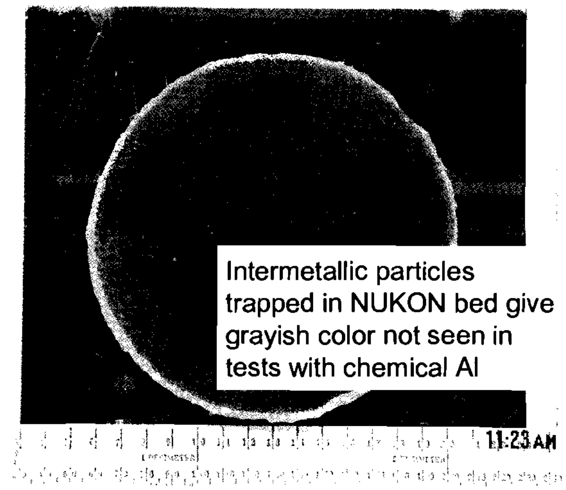
Al 1100 BSE Image



- Coupons suspended in test loop at 140°F and 9.3 pH
- Al alloy plates have intermetallic particles such as (FeAl), (FeSiAl), (FeCuAl)
- Alloy 6061 intermetallic particle size (max. ~10 µm) is larger than Alloy 1100(max. ~4 µm)

Head Loss Tests w/ Al Alloy 6061





Alloy 6061 Test Bed

- Intermetallic particles released by corrosion of the alloy matrix caused head loss at 140 F even though dissolved Al was below the solubility limit; additional head loss was experienced due to the formation of $Al(OH)_3$ when the temperature was decreased

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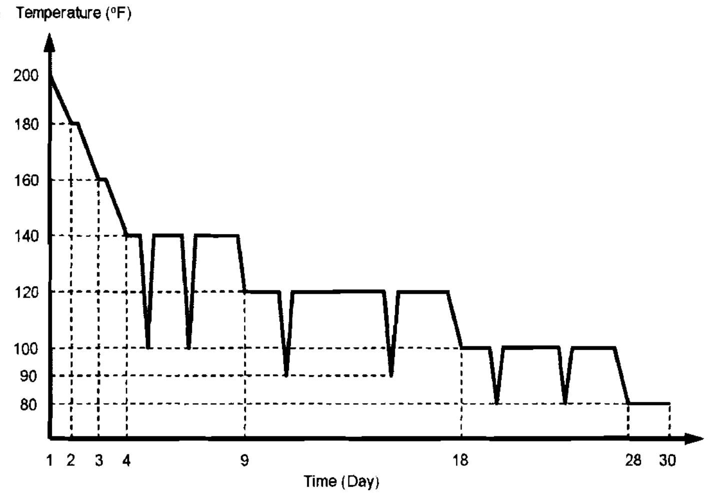
Vertical Loop Test Results

- Industry Test Precipitates Characteristics
  - Per unit mass of Al removed from the solution, the WCAP AlOOH surrogate appears to be more efficient in increasing head loss than the $Al(OH)_3$ formed by corrosion of Al.

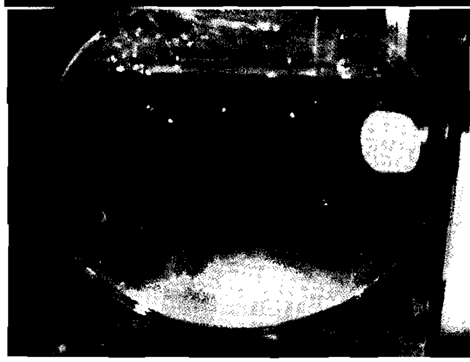
- Efficiency in increasing head loss for ANL test conditions:
  - WCAP AlOOH
  - WCAP Sodium Aluminum Silicate – "tap water"
  - In-situ formation $Al(OH)_3$, CCI approach
  - 6061 Aluminum, 1100 Aluminum
  - WCAP Sodium Aluminum Silicate – high purity water

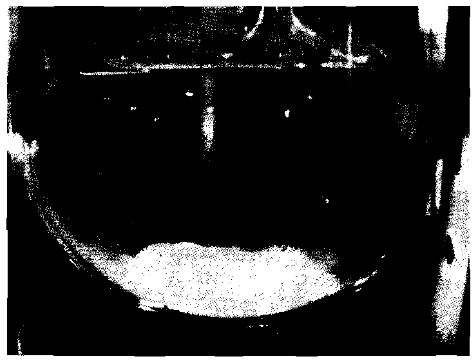
Aluminum Hydroxide Solubility

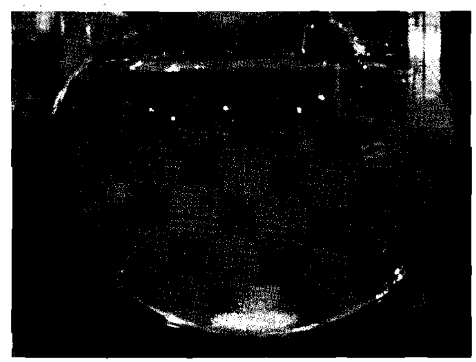


- Aluminum solubility in borated water was studied for a typical ECCS mission time.
- Temperature was varied with time to simulate long-term cooling with thermal cycling to simulate ECCS fluid temperature change passing through heat exchanger and reactor core
- 30-minute thermal cycles over temperature ranges of 140-80 F, 120-80 F, and 100-80 F did not cause aluminum hydroxide precipitation from a solution at pHs ranging 7.0-8.5 and total Al concentrations ranging 45-98 ppm

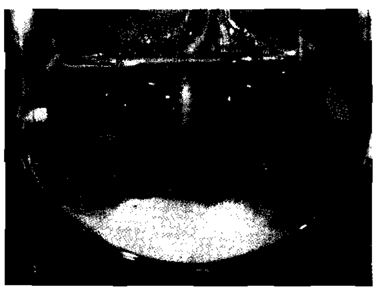
Long-Term Aluminum Hydroxide Precipitation Tests


(pH=7.0)


(pH=7.50)


(pH=8.0)

Test Solution pH @ 98 ppm Al


(98 ppm)

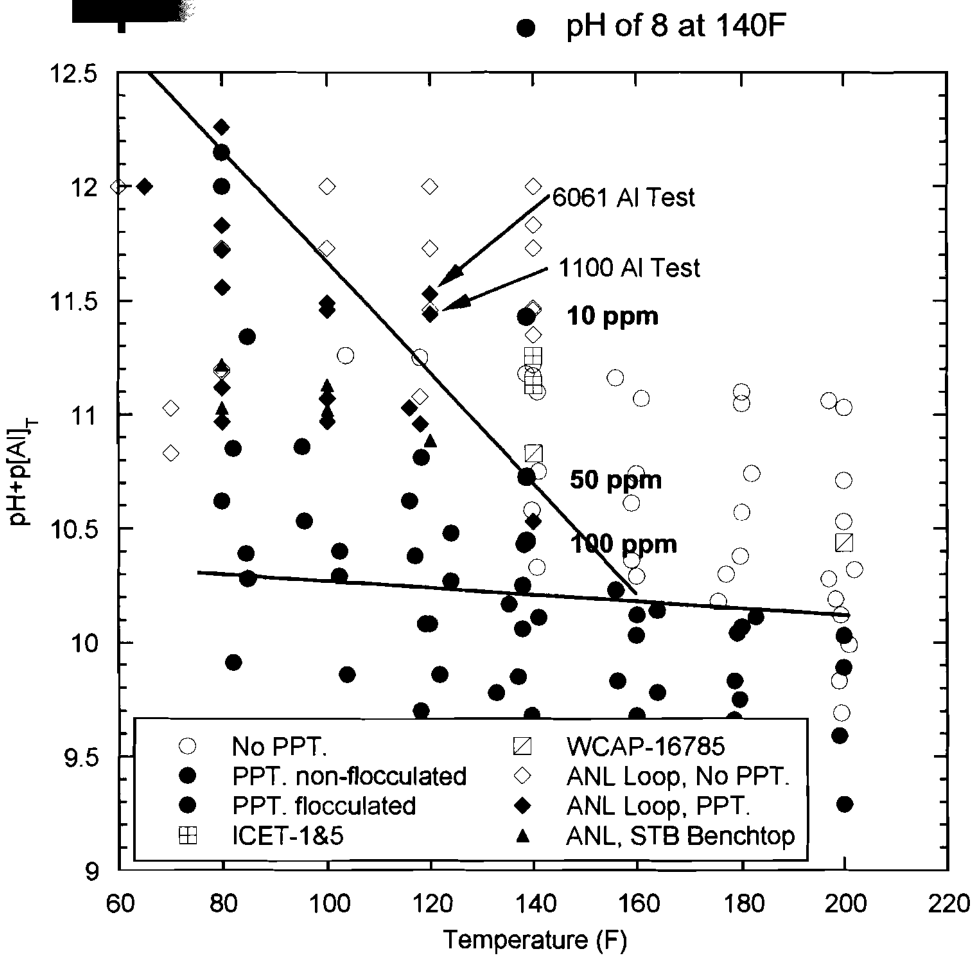

(70 ppm)


(55 ppm)


(40 ppm)

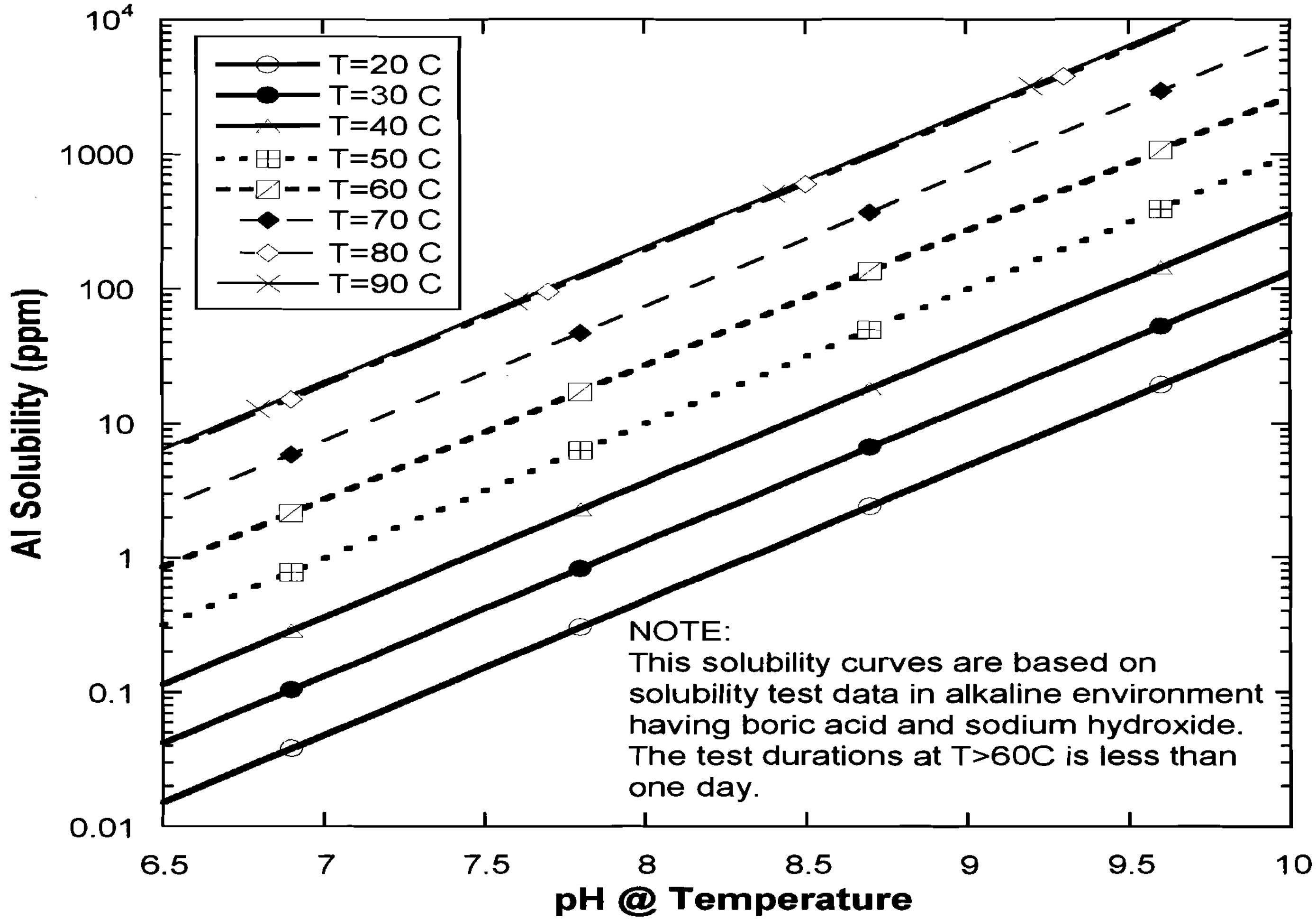
Total Al Contents @ pH=7.5 & 120 F

Long-term Al Hydroxide Precipitation Tests: Al Hydroxide Precipitation Map



- Long-term solubility test results for various pHs and Al concentrations represented in a Al hydroxide precipitation map that plots pH and Al concentration vs. temperature.
- Solubility increases with pH and temperature
- Loop tests with Al alloy plates seem to suggest lower solubility than the chemical Al tests. This may be due to heterogeneous nucleation of Al hydroxide on intermetallic particles and/or on the surfaces of preexisting precipitates.

Aluminum Solubility as a Function of Temperature and pH (includes Al coupons test)



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ANL Tests - Summary

- Vertical head loss loop test results have helped the NRC staff understand the relative performance of different industry chemical effects test methods
- Aluminum intermetallics can influence head loss (particulate and possible precipitate nucleation site) causing about a factor of two reduction in solubility curves
- Longer term aluminum solubility test results will help inform the staff's review of plant-specific chemical effects evaluations
- Vertical loop head loss test with a glass fiber bed at pH=9.0 showed the WCAP AlOOH surrogate was stable over 5 days. At elevated pH, the equivalent of 3.0 ppm aluminum precipitating was needed to produce significant head loss.

Summary – Chemical Effects Status

- NRC Staff has observed tests at each vendor facility
- Vertical head loss loop tests are typically more susceptible to large head losses from chemical precipitates compared to larger scale strainer tests
- Most plants are using test methods that are acceptable to the staff, although some technical issues remain that will be resolved with individual licensees
- Testing at Argonne and at vendor facilities continues to indicate that the WCAP-16530-NP methodology is conservative with respect to the amount and the properties of precipitates
- NRC staff to perform a few chemical effects audits to assess overall evaluations at selected plants
- NRR and RES staff working on remaining peer review items

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Chemical Effects PIRT Update

John Burke

Rob Tregoning

Office of Nuclear Regulatory Research

ACRS Subcommittee on Thermal-Hydraulic Phenomena

September 23, 2008

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Chemical Effects PIRT-Background

- PIRT exercise conducted in mid 2006.
- PIRT was used to identify knowledge gaps existing at that time.
  - The focus was on phenomena not previously addressed by NRC-sponsored research
  - 41 phenomena were ranked as having potential high significance by at least one PIRT panelist
  - No issues were identified that warranted immediate action
  - The PIRT NUREG report is in final review.

Chemical Effects: Evaluation of PIRT Results

- The 41 phenomena ranked as having the highest potential significant impact on ECCS performance were reviewed by a staff working group
  - Assess potential impact on ECCS performance
  - Determine if the phenomenon was already being addressed by current or planned activities.

Chemical Effects: Evaluation of PIRT Results

- Staff concluded that 10 topic areas warranted additional study
- A separate NUREG/CR scoping study was prepared by PNNL to document the evaluation of these 10 topic areas.
- The 10 topic areas are as follows

Chemical Effects PIRT Review

1. Radiation effects (radiolysis)*
2. Carbonation of concrete
3. Alloy corrosion
4. Galvanic corrosion
5. Biological fouling *
6. Co-precipitation & other synergistic solids formation *
7. Inorganic agglomeration*
8. Crud release
9. Retrograde solubility and solids deposition*
10. Organic materials*

* PNNL recommended additional evaluation/study to more fully understand these phenomena

Chemical Effects: Evaluation of PIRT Results

Radiation: Effects of the post-LOCA radiation on the sump chemical environment and constituents (e.g., irradiation from fuel in the reactor vessel, and activated species in containment pool and on the strainer).

- The study concluded radiation effects on sump pool pH were minor in comparison with effects of pH buffering.
- However, knowledge of radiation influence on redox potential is limited and is a complex phenomenon.
  - Mixed potential modeling could be used to further assess it.

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Chemical Effects: Evaluation of PIRT Results

- Biological Fouling: Fouling of the ECCS sump strainer due to bacterial, algal, fungal or other biological growth during the 30-day post-LOCA mission time.
  - There are many stressors to biological growth in a post-LOCA environment, e.g. rapid temperature change, borated water, no light, high radiation fields, low levels of available carbon, etc.
  - However, there are microbes that are known to exist under one or more of these stressors. Growth rate under combined stressors during a 30-day mission time is unknown.

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Chemical Effects Evaluation of PIRT Results

- Crud Release: Effects related to potential post-LOCA metal oxide releases from fuel cladding or RCS components.
  - Crud burst during a LOCA is expected to consistent of relatively dense solid particulates.
  - The quantity is expected to be small compared with other debris particulate (e.g., insulation or coating debris)
  - The additional effect of crud release is considered to be insignificant unless other particulate sources are inconsequential

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Chemical Effects : Path Forward

- Staff continues to disposition all the phenomena originally identified in the PIRT.
- The significance of several phenomena is currently being assessed
  - Again, none of these phenomena were evaluated as warranting immediate action.
  - Initial scoping study has been conducted
  - Additional evaluation may be used to assess remaining uncertainties
- As part of the disposition staff is also considering
  - Plant-specific post-LOCA environments and conditions
  - Results from additional vendor testing conducted since the conclusion of this scoping study
  - Conservatisms that have been used to address GL 2004-02.

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In-Vessel Downstream Effects Fuel Inlet Blockage

Presented by:

Stephen Smith (NRR)

William Krotiuk (RES)

Office of Nuclear Reactor Regulation

Presented to:

Advisory Committee on Reactor Safeguards

Thermal-Hydraulics Subcommittee

September 23, 2008

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Fuel Blockage Testing and Considerations

- Fuel Inlet Designs
- Debris at Fuel Inlet
  - Fibrous
  - Particulate
  - Chemical
- Industry Testing
  - Early CE Guardian Grid
  - Diablo Canyon
  - PWROG
- RES Analytical Models

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Fuel Inlet Designs

- Westinghouse
  - P-Grid
  - Alternate P-Grid
  - Guardian Grid (CE)
- Areva
  - Fuelguard™
  - Trapper™ Coarse Mesh
  - Trapper™ Fine Mesh

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Fuel Inlet Designs

- Diablo Canyon performed significant testing for the Alternate P-grid
- Diablo canyon specific testing also showed that P-grid develops higher dP than Alternate P-Grid
- P-Grid, Guardian Grid, and Alternate P-Grid do not appear susceptible to thin bed based on inlet area, however, a thin bed type phenomenon could occur at several locations in the fuel assembly
- Areva designs have not been tested yet

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Debris at Fuel Inlet

- Debris load is plant specific
- Fibrous bypass (pass through) determined by strainer testing
- Fibrous test debris characteristics are similar to actual bypassed debris
- Testing to date has assumed no filtering of particulate or chemical debris by strainer
  - This is a conservative assumption because some debris will filter out on the strainer
  - Chemical loading determined per WCAP-16530

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Strainer Fiber Bypass Testing

- Vendor Specific
- Staff expects testing to be prototypical or conservative
- Generally performed with fiber only, which is conservative

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Industry Fuel Inlet Testing to Date

- Early Testing of Guardian Grid
  - Documentation Missing (no dP data)
  - Questionable debris preparation
- Diablo Canyon Testing of Alternate P-grid
  - More details on following slides
- PWROG Generic Test
  - Used 3 inch diameter cylinder with screen
  - Likely conservative with respect to Westinghouse/CE designs
  - Degree of conservatism not yet established
- PWROG Fuel Specific Test
  - More details on following slides

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Diablo Canyon Testing

- Westinghouse Alternate P-grid
- Testing Performed at CDI
- Witnessed by staff
- Prototypical Debris for Plant
- Varied Debris Loads
- Bottom Nozzle and One Intermediate Grid Strap
- Hot Leg and Cold Leg Flows Tested
- Tested head losses were within allowable limits

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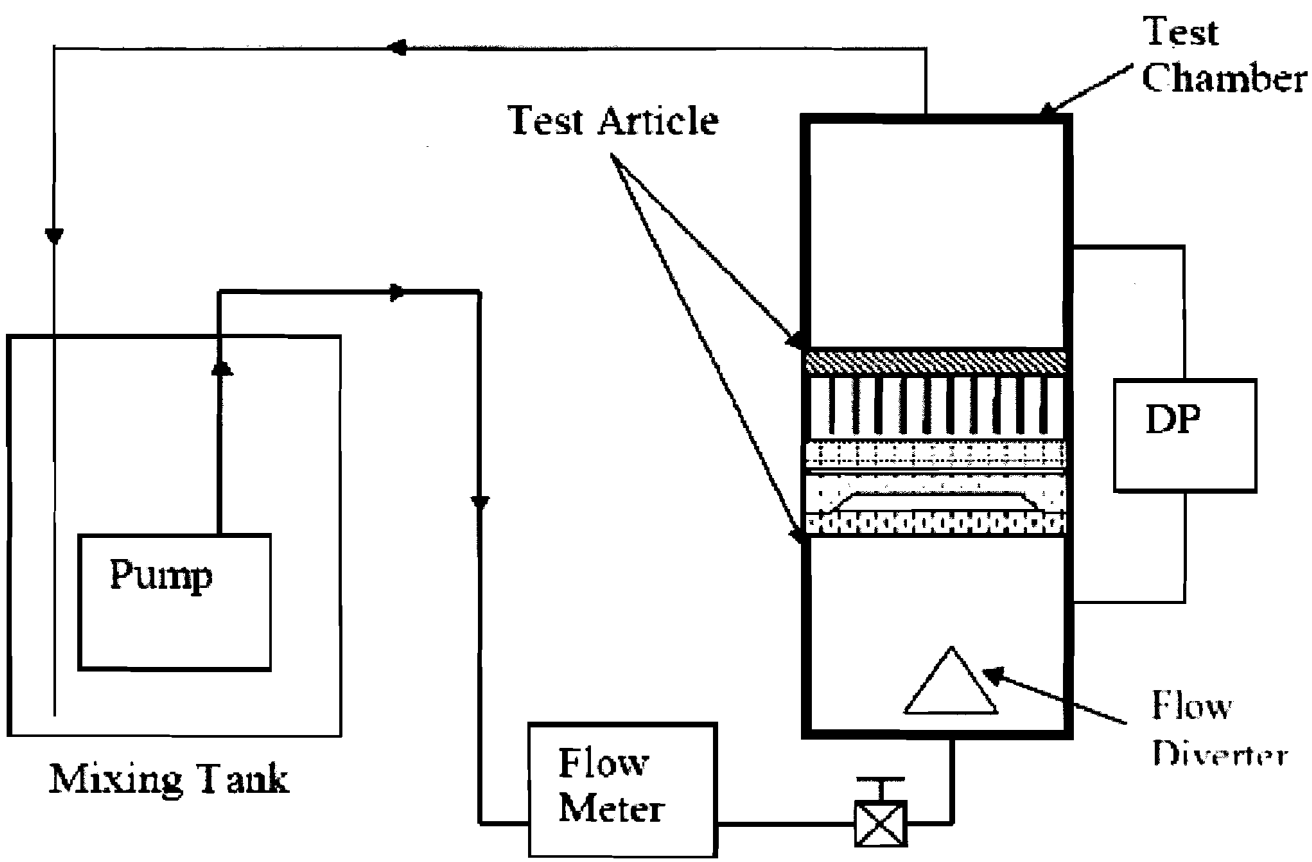
CDI Diablo Canyon Test Loop



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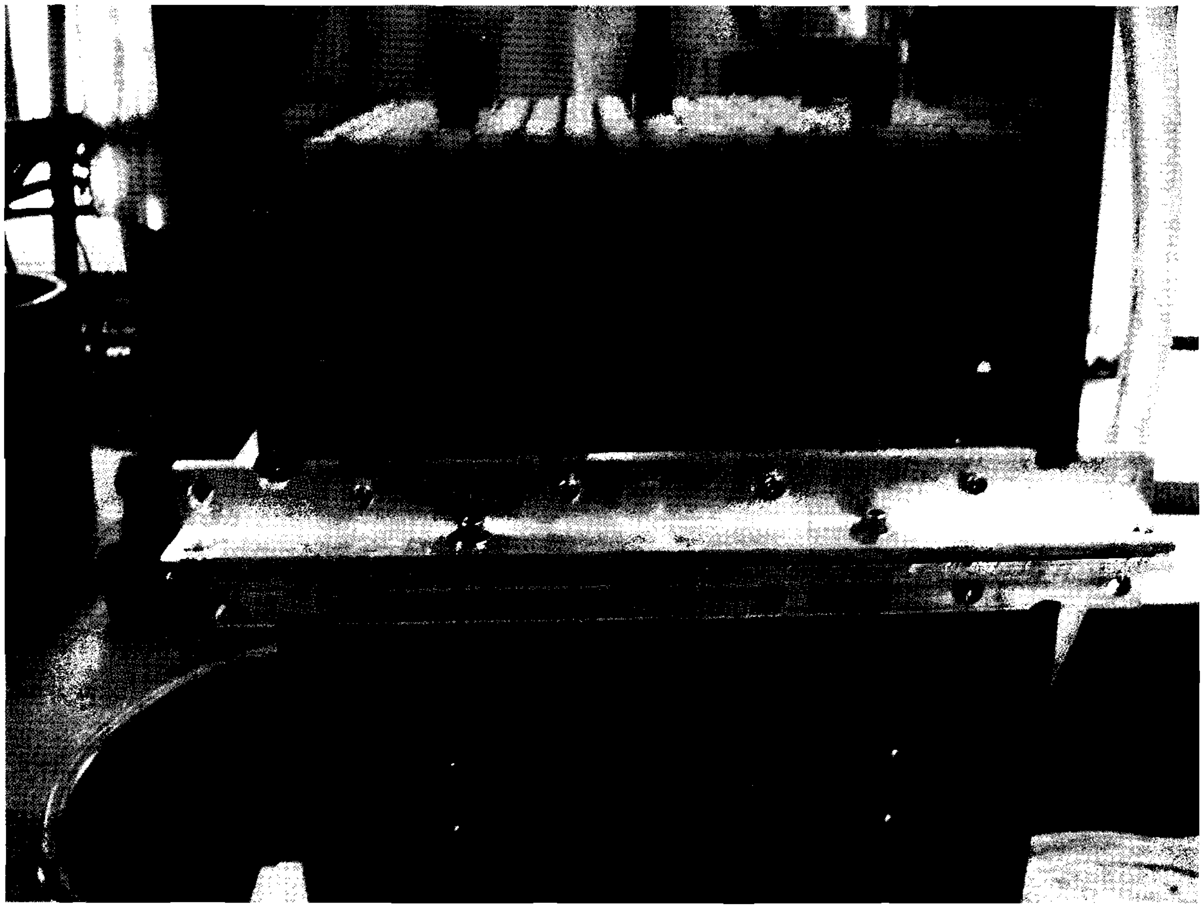
Fuel Assembly Model in Test Column



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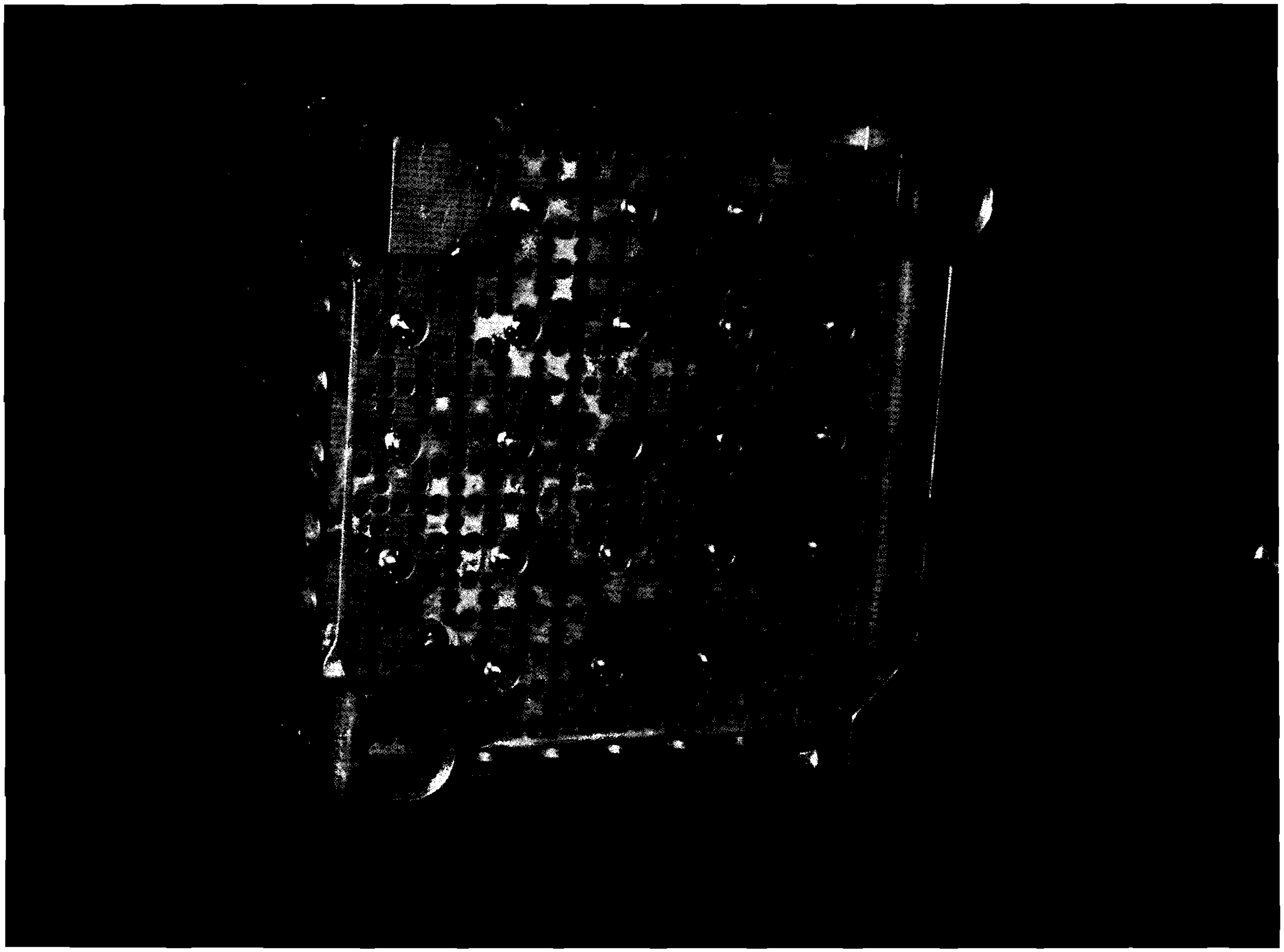
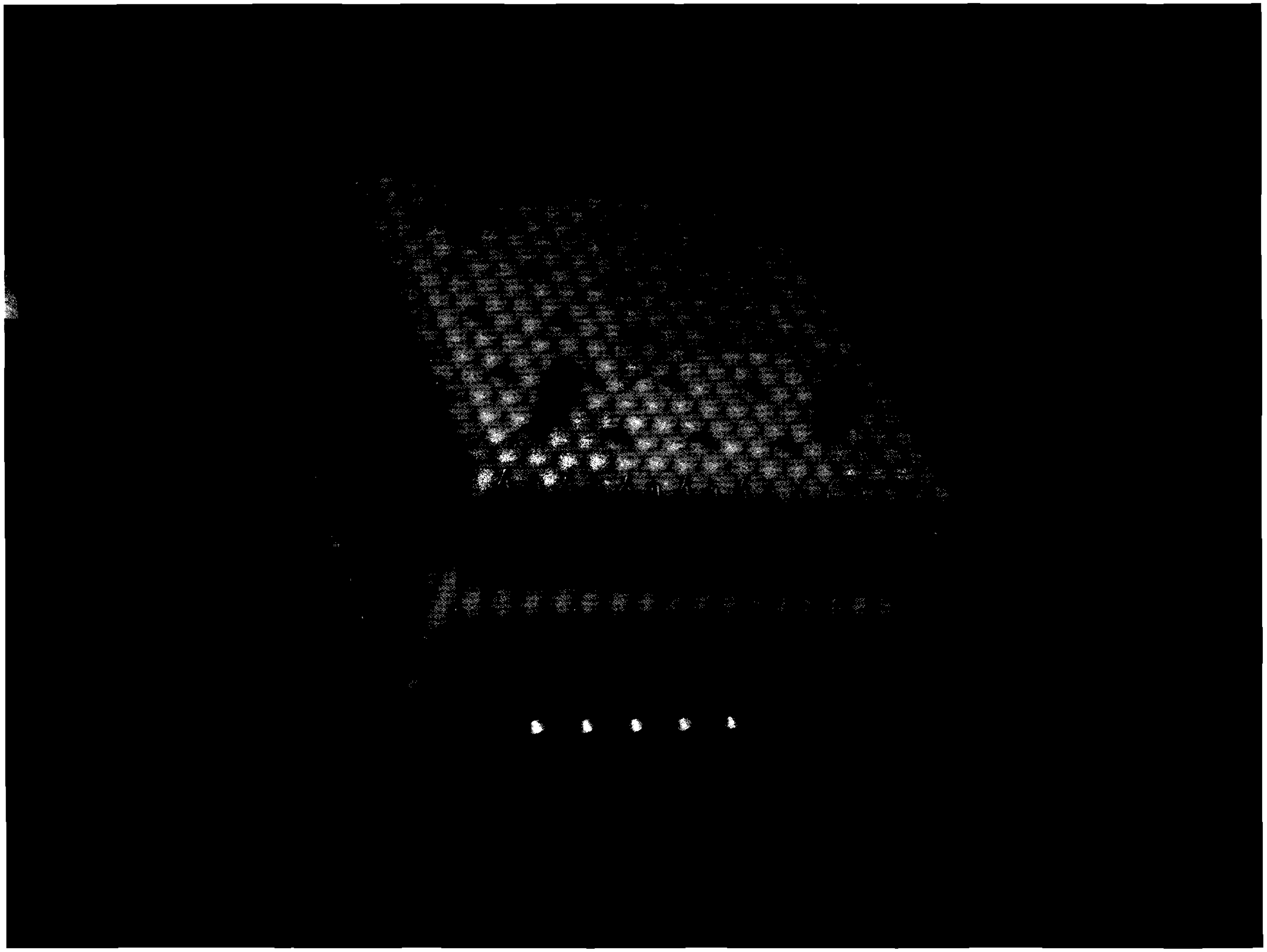
Diablo Bottom Nozzle Pre-Test



Diablo Test Unit Pre-Test



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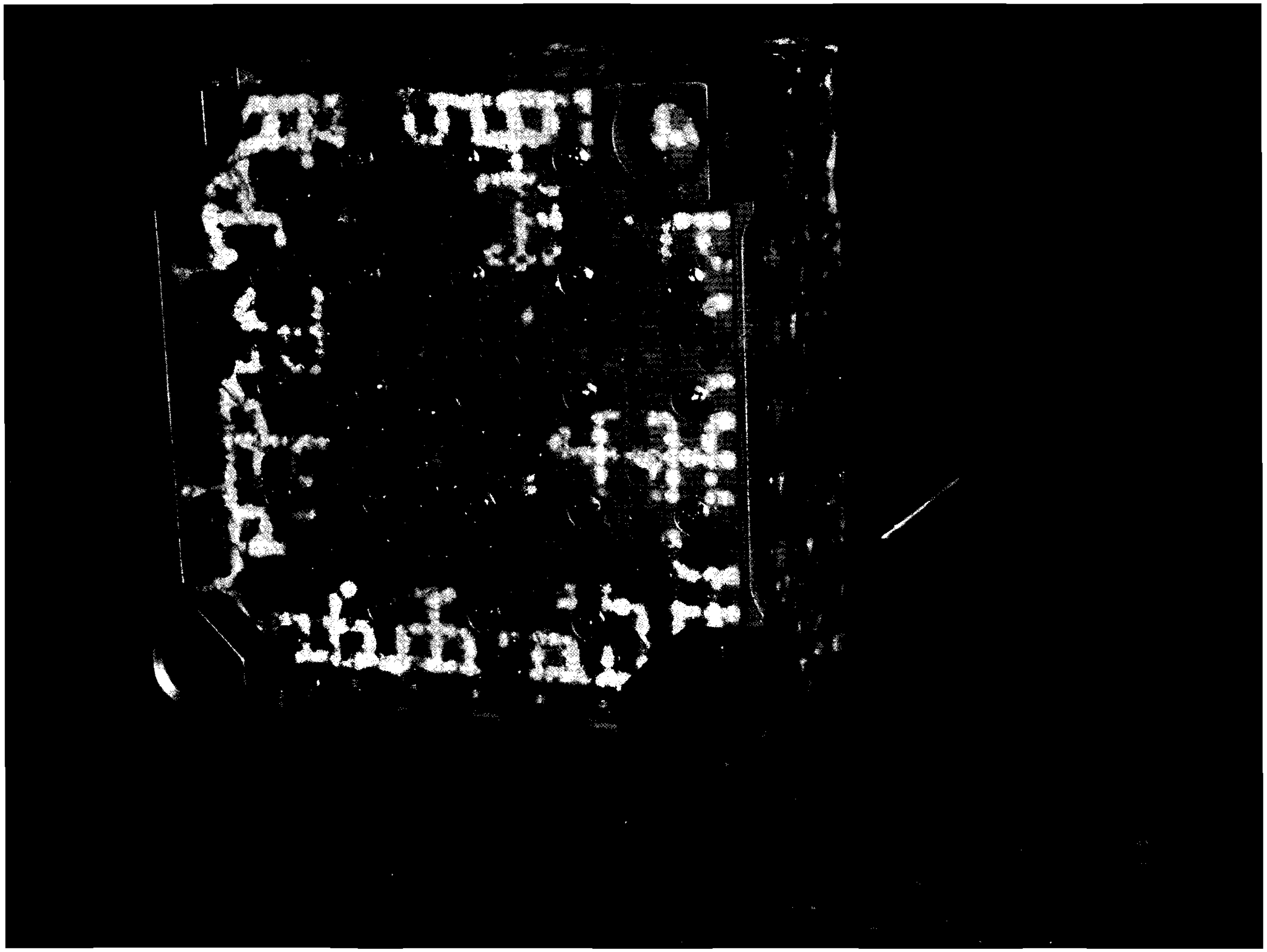
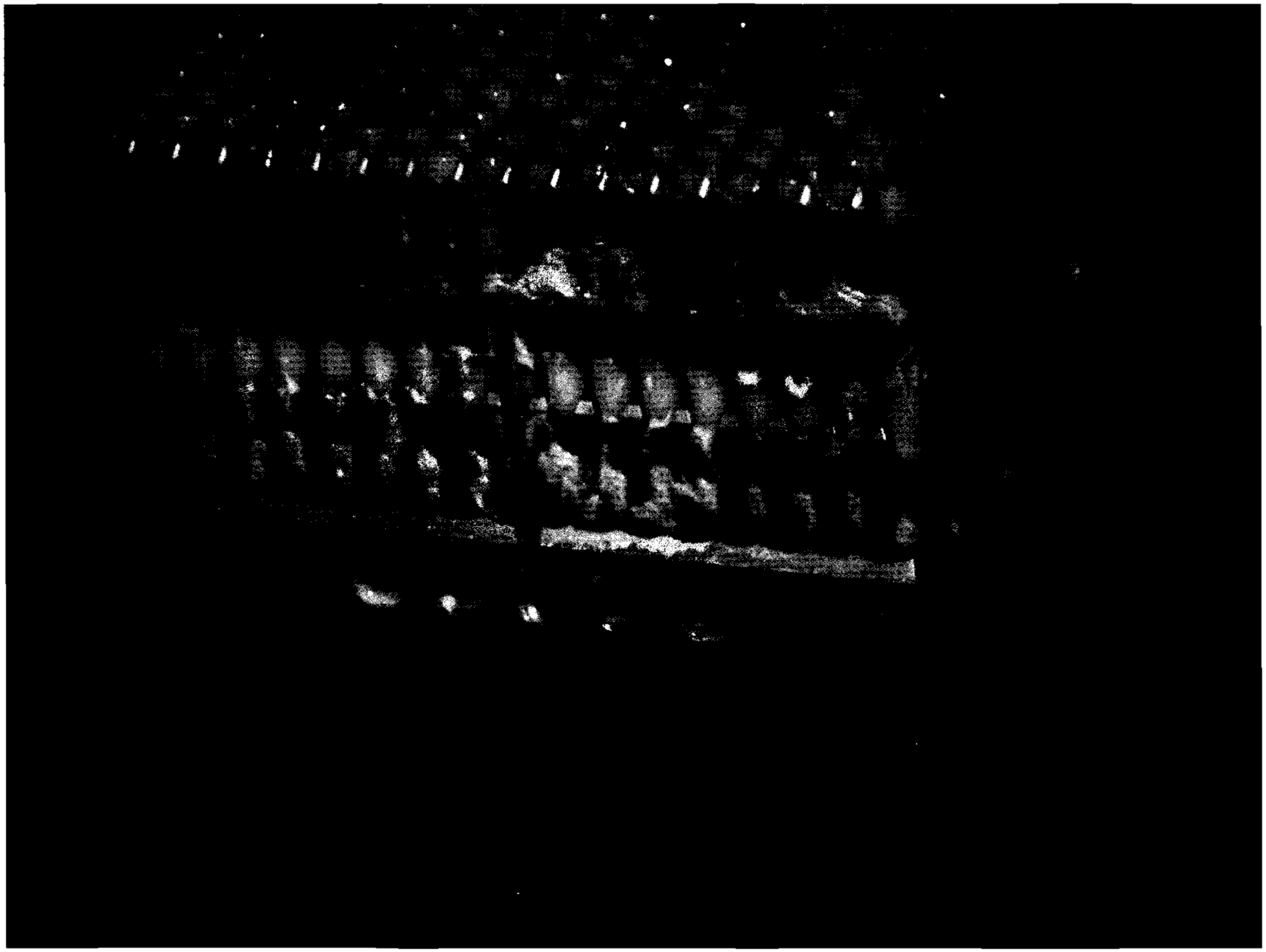
Diablo Bottom Nozzle Post-Test



Diablo Test Unit Post-Test



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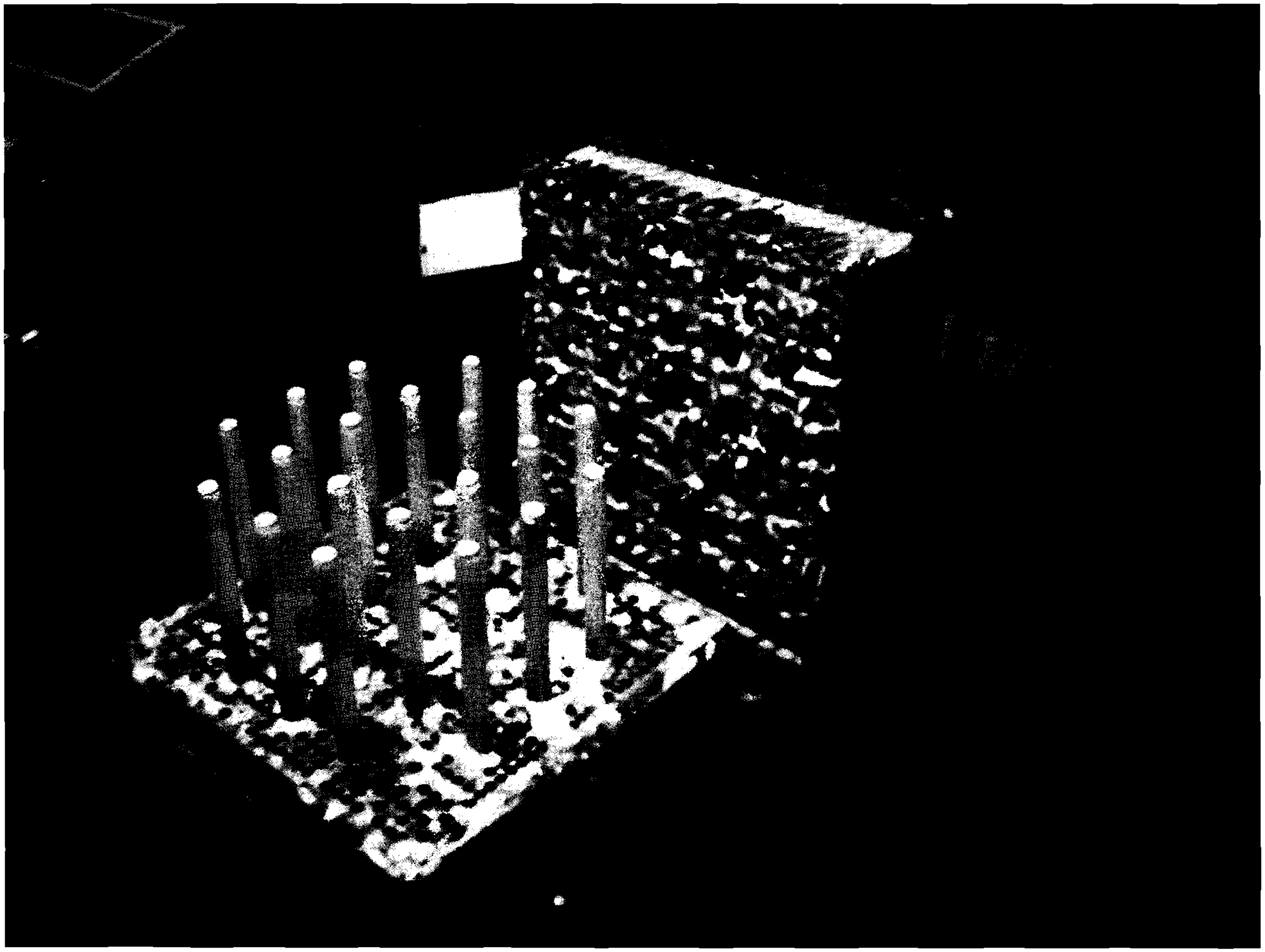
Bottom Nozzle and P-Grid



Diablo Canyon Debris

- Debris Types
  - Nukon
  - Dirt Mixture
  - Marinite
  - Silicon Carbide
  - Calcium Silicate
  - Aluminum Oxyhydroxide
  - Sodium Aluminum Silicate
- Tested combinations of debris loads that conservatively bound plant conditions

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PWROG Testing

- Staff observed testing at Westinghouse
- Standard P-grid was tested
- Testing used hot leg break flow rate
- Debris preparation and introduction was acceptable
  - Observed only fiber and particulate introduction
  - Chemical precipitate settlement was acceptable
- Observations indicate that test program can result in prototypical or conservative results
- Other Westinghouse designs will be tested to ensure that results are bounded
- Testing of Areva fuel designs to be conducted in the future
- PWROG plans to increase debris loads to bound as many plants as possible
- Staff will continue to review data and test information as it becomes available

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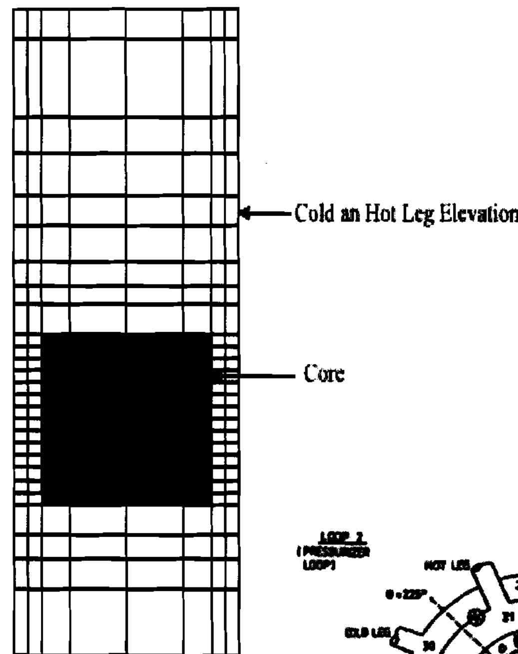
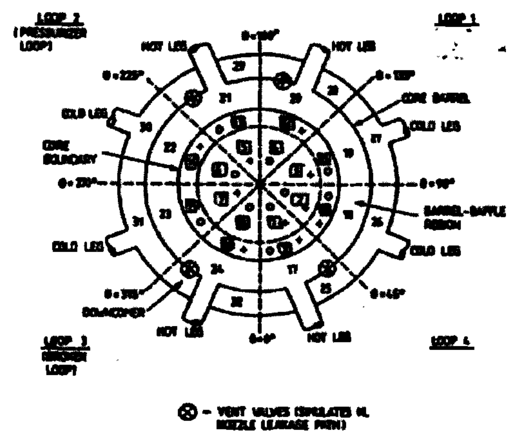
Office of Research Core Blockage Assessment

- RES performed a core blockage assessment
  - In response to ACRS concerns regarding treatment of core inlet blockage in industry models
  - Assumes uniform debris bed across core inlet instead of a percentage of open area
  - Bill Krotiuk to present the assessment

PWR Core Blockage Assessment

- Calculations performed for Typical Four Loop PWR Plant
  - TRACE Calculation
    - Full primary and secondary system
    - Core has 8 radial, 4 ring and 14 elevation segments.
    - No bypass flow between core and volume outside baffles.
    - 80% double ended cold leg break
    - Full HP and LP injection
    - Recirculation starts at 1200 sec.
  - Independent Hand Calculation
    - Considers one and two-phase core and vessel flow resistances.





PWR Core Blockage Assessment

- Uniform Nukon/CalSil debris bed thicknesses assumed instantaneously present at core entrance at recirculation start.
  - Cases analyzed
    - Unblocked
    - Nominal 1.2 inch thick Nukon/CalSil bed
    - Nominal 2.4 inch thick Nukon/CalSil bed
    - Nominal 4.8 inch thick Nukon/CalSil bed
  - Debris bed form loss coefficient relation developed from test data.
    - Δp_{bed} = f(bed thickness, approach velocity)
- Two analysis methods used.
  - TRACE code version developed to use debris bed loss coefficient.
    - Transient calculation run to 2600 s after start of LOCA.
  - Independent Hand Calculation performed at
    - 1200 s (start of recirculation)
    - 2000 s

PWR Core Blockage Assessment

- **Results**
  - TRACE Calculation

Nominal Nukon/CalSil Debris Bed Thickness (inch)	Peak Clad Temperature Following Recirculation (°K)	Peak Clad Temperature Following Recirculation (°F)
Unblocked	410.0	278.3
1.2	411.0	280.1
2.4	411.7	281.3
4.8	787.5	957.8

    - Core uncovery and clad heat-up occurs for debris bed thicknesses greater than critical thickness value (between 2.4 and 4.8 inches).
  - Independent Hand Calculation
    - Good agreement with TRACE calculation
    - Void fraction at core outlet reaches 100% at 2000 s for 4.8 inch bed; therefore core heat-up is possible.

Conclusions

- Westinghouse and CE fuel testing is currently underway
- Areva fuel testing is scheduled to begin later this year.
- Testing will determine acceptable debris loading for various fuel designs, postulated conditions, and debris mixtures