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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

February 15, 2006

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

THERMAL HYDRAULICS SUBCOMMITTEE

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MEETING

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ROCKVILLE, MARYLAND

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WEDNESDAY

FEBRUARY 15, 2006

* * * * *

The Subcommittee met in Room 2TB3 at Two
White Flint North, 14555 Rockville Pike, Rockville,
Maryland, at 8:30 a.m., Graham B. Wallis, Subcommittee
Chair, presiding.

PRESENT

GRAHAM B. WALLIS	Subcommittee Chair
RICHARD S. DENNING	Subcommittee Member
THOMAS S. KRESS	Subcommittee Member
WILLIAM J. SHACK	Subcommittee Member
SANJOY BANERJEE	ACRS Consultant

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P R O C E E D I N G S

(8:30 a.m.)

CHAIRMAN WALLIS: Good morning.

Anything you say now will be on the record.

This is the second day of the meeting of the Thermal Hydraulic Subcommittee of the ACRS. We are looking forward to presentations on research and actually just seeing some figures and data points and that kind of thing.

We're also happy to see Mark Cunningham once again before us, but in a new role, and I believe you have a few words to say.

MR. CARUSO: I have one thing to say. We've got a speaker phone set up today because we received a request from Research to set up a line in case they have some contractors at one of the great national laboratories who wants to chime in with a pearl of wisdom.

CHAIRMAN WALLIS: So this is connected to a national lab right now. Is that --

MR. CARUSO: It's connected to a bridge line, and whenever the national labs wake up.

CHAIRMAN WALLIS: Well, if it's on the West Coast, they must be up pretty early.

Okay, Mark. Go ahead.

1 MR. CUNNINGHAM: Good morning. My name is
2 Mark Cunningham, the Director of the Division of
3 Engineering Technology in the NRC's Office of Nuclear
4 Regulatory Research.

5 It's a pleasure to be here before the
6 committee in a capacity other than risk analysis or
7 security analysis, believe me.

8 (Laughter.)

9 MR. CUNNINGHAM: For the past several
10 years, as you know very well, the ACRS has been
11 involved with discussions with the staff on a number
12 of issues related to formation of chemical byproducts,
13 and the adequacy of data for predicting head loss due
14 to debris accumulation in some screens.

15 I'm coming into this late in the game,
16 hopefully near the end of the staff's discussions on
17 this issue, but we'll see.

18 The role of research in these is to
19 provide and support NRR with technical information
20 that allows them to make regulatory decisions. For
21 the vast variety of decisions they have to make, we're
22 focusing on providing technical information on five
23 particular areas. One is chemical byproduct
24 formation. One is the transport of insulation debris
25 and paint chips to the sumps. The third is the head

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1 loss associated with sump screen clogging. The fourth
2 is the correlations, numerical correlations for
3 understanding head loss, and the fifth is related to
4 downstream effects, potential effects of debris
5 passing through the sumps into some throttle valves
6 and other equipment downstream.

7 Over the next two days you will have the
8 benefit of expertise from a number of different
9 organizations that we have working in concert with the
10 staff. It includes the Center for Nuclear Waste
11 Regulatory Analysis at Southwest Research Institute,
12 Argonne National Laboratory, Pacific Northwest
13 National Laboratory, Los Alamos National Laboratory,
14 and the Naval Surface Weapons Warfare Center, the
15 Carderock Division, local here.

16 CHAIRMAN WALLIS: What does that have to
17 do with the problem?

18 (Laughter.)

19 MR. CUNNINGHAM: They're dealing with the
20 issue of paint chip transport and things. They're
21 good at understanding how things go through water.

22 I should note, and I think we'll touch on
23 this later, that with respect to the chemical effects
24 part of this, recognizing the complexity of it, we're
25 having a peer review performed which Rob will touch

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1 on.

2 Our research is again, as I noted,
3 intended to support NRR's making regulatory decisions.
4 In that context, we provide more generic information
5 so that it should be clear that the information you'll
6 hear over the next few days does not provide
7 sufficient information for any plant specific decision
8 that has to be made either by the staff or by
9 licensees.

10 And we look forward to a continuing
11 dialogue with the committee. These are very, very
12 complicated issues, and we appreciate the insight the
13 committee provides to us.

14 With that, I'll introduce Rob Tregoning.
15 Rob is kind of the technical ringmaster in all of
16 this. So he'll have an introduction, and he and
17 Michelle Evans over on the staff will be the kind of
18 co-leaders throughout the discussion of the next
19 couple of days.

20 thank you.

21 CHAIRMAN WALLIS: As a ringmaster, what
22 kind of a show have you got today? Have you got lion
23 taming?

24 MR. TREGONING: I don't know if that
25 characterization is accurate. I would say maybe wild

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1 bronco riding would be more appropriate here.

2 Thanks, Mark.

3 I'm going to be following up Mark with an
4 overview of the research activities that we have
5 ongoing supporting the Generic Letter 200402
6 resolution.

7 This presentation is merely just to set
8 the stage for the good stuff that we have coming over
9 the next day, day and a half. So my goal and my
10 objective is to be as brief as possible and turn it
11 over to what I think are the real stars of the next
12 day, day and a half that are going to be providing a
13 lot of very good, detailed, technical information to
14 address some really thorny issues that we've been
15 dealing with.

16 So the objective of the research
17 presentations that you're going to hear over the next
18 day and a half. Each of the programs will be
19 discussing the motivation, objective and goals for the
20 research initiatives. They'll be providing overviews
21 and discuss interrelationships among programs where
22 it's appropriate. You'll see that we have several
23 overlapping initiatives ongoing at different labs. So
24 coordination and cooperation has been a fundamental
25 consideration as we go through these research

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1 activities.

2 I'm going to talk a little bit about
3 regulatory coordination and peer review.

4 DR. BANERJEE: How many people are working
5 on this?

6 MR. TREGONING: How many people or how
7 many labs?

8 DR. BANERJEE: People, bodies.

9 MR. TREGONING: Oh, geez, that's almost a
10 semi-rhetorical question. I would guess each of the
11 labs probably has a staff of ten or so people that are
12 supporting this. We're doing work at five labs.

13 DR. BANERJEE: Fifty?

14 MR. TREGONING: That's a rough guess. I
15 mean, we've got NRC-wide just in research, we have a
16 team of about six people that work pretty close to
17 full time on this if not. So, yeah, we've got a
18 fairly large staff of expertise that we've assembled
19 in a relatively quick manner, and we're trying to do
20 a lot of things in parallel to support the resolution
21 schedule.

22 Okay. Again, each of the research
23 programs here in number four will be, as I had
24 mentioned, outlining for each specific program the
25 objective motivation and intended regulatory use of

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1 the information being developed as part of that
2 program. They are also going to go, each of the labs
3 and project managers, will go into their technical
4 approach, but a primary focus is going to be to
5 summarize important results, observations, and
6 analysis conducted to date.

7 These are status report presentations.
8 Nothing that you're going to hear over the next day
9 and a half is completely finished. The ICET program
10 is probably the one that's the closest to being
11 finished at this point.

12 All of the other programs are in progress.
13 So, again, these will clearly be status reports and
14 not final findings and conclusions and analyses will
15 be discussed. Some programs are more mature than
16 others. So some you might not hear any results. Some
17 you'll hear quite significant volume of results.

18 And the other thing that each of the
19 project managers and presenters will do will be to
20 provide the plan and schedules for the remaining work
21 that needs to be completed before we can wrap up each
22 of these projects.

23 I wanted to provide a little bit of a
24 research philosophy for how we identified and selected
25 not only research topical areas but programs to

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1 pursue. I think this is well recognized and certainly
2 ACRS has done a very good job at pointing us towards
3 some issues that we need to provide more technical
4 insight and understanding. So it's certainly widely
5 recognize that some research is necessary to address
6 some important technical areas that we have within the
7 generic letter resolution.

8 What we've tried to do is we've tried to
9 pick research topics to focus on technical areas
10 having the highest uncertainty, and how have we sought
11 out what that uncertainty is?

12 CHAIRMAN WALLIS: Those are better words
13 than reduce uncertainty because you might in your
14 experiments find that there's more uncertainty than
15 you thought.

16 MR. TREGONING: That's certainly possible.
17 That's certainly a possible outcome.

18 CHAIRMAN WALLIS: Your focusing on the
19 highest uncertainty makes sense.

20 MR. TREGONING: We're focusing --

21 CHAIRMAN WALLIS: But promising to reduce
22 uncertainty is something difficult to deliver.

23 MR. TREGONING: Did I say that on my
24 slide?

25 CHAIRMAN WALLIS: Yeah, it says to reduce

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1 uncertainty, yeah. You're going to make the data come
2 closer together, are you?

3 I understand what you're doing.

4 MR. TREGONING: Well, we have the
5 potential to reduce uncertainty. You're right. We
6 could do --

7 CHAIRMAN WALLIS: You need to understand
8 the uncertainty.

9 MR. TREGONING: We need to understand it.
10 That's true.

11 CHAIRMAN WALLIS: Get a handle, measure
12 it, and so on.

13 MR. TREGONING: That's entirely true.

14 So how have we tried to determine which
15 technical areas have the greatest uncertainty? Well,
16 there's been a lot of interaction over the prior two
17 years between not only ACRS comments and
18 recommendations; also quite a bit of interaction with
19 staff, both Nuclear Regulatory, NRR staff and staff
20 within the Office of Research.

21 And we certainly discussed with industry
22 quite a bit a lot of these thornier issues. So we've
23 searched out areas that have high uncertainty, but the
24 other constraint that we have is we're trying to focus
25 on areas where we think generic evaluation will

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1 provide the most impact.

2 I think you heard a lot of the phrase
3 "plant specific" bandied about quite liberally
4 yesterday, and it's true. I think if you look at this
5 problem in total, there are very plant specific
6 attributes, and some technical areas can really only
7 be tackled from a plant specific perspective. We've
8 tried to focus on areas where we think generic
9 evaluation can provide some insight into some of the
10 issues that we're dealing with.

11 For the most part the studies --

12 DR. BANERJEE: Like what? What generic
13 issues? Can you name a couple?

14 MR. TREGONING: Yeah. Chemical effects,
15 head loss, coatings transport, some downstream
16 clogging issues, and we used a surrogate throttle
17 valve study. All of the programs that you hear will
18 be areas that we've identified that we think meets
19 this broad objective.

20 DR. BANERJEE: Yesterday though they
21 seemed to feel that chemical effects were fairly plant
22 specific, right?

23 MR. TREGONING: Specific loads and
24 products I would agree are plant specific in nature.
25 However, again, we still try to mine as much as we can

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1 from general study. I think there's a value from
2 trying to understand in a global sense what's
3 happening, and then as best as you can apply it to
4 your plant specific.

5 CHAIRMAN WALLIS: You might even have a
6 model for some of these effects, which could be
7 applied everywhere, and if you had a really good
8 understanding of what's happening to the chemistry and
9 you have some predictive tools, they could be used
10 everywhere.

11 MR. TREGONING: At least one of our
12 programs we've had an objective where we did some
13 initial exploratory work to see how feasible that is,
14 and you're going to hear about that today. I don't
15 want to -- it's a difficult thing to model. I will
16 say that, and understanding your plant specific
17 environment is crucial to the accuracy of any model
18 that you could possibly develop.

19 So we have done some exploratory work in
20 that area that you're going to hear about.

21 CHAIRMAN WALLIS: Well, everything is
22 difficult until it's easy.

23 (Laughter.)

24 MR. TREGONING: Yes. No argument there.

25 DR. BANERJEE: Are you going to talk about

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1 modeling efforts somewhere?

2 MR. TREGONING: Yes, we're going to talk
3 about two sets of modeling efforts. One is, again,
4 today we'll talk about chemical speciation prediction,
5 which is an analytical modeling study.

6 And then you're also going to hear today
7 work that we've done to do additional head loss
8 correlation development. That so far has focused
9 primarily on particulate and fibrous debris. So at
10 least initial work with the correlation model
11 development has not focused on debris sources such as
12 coatings and chemical effects.

13 But we feel like we need to walk before we
14 can run in some of this model development work. So we
15 want to see if we can handle the standard source term
16 loadings first and then move to some of the newer
17 considerations.

18 DR. BANERJEE: Yesterday they said that it
19 was very difficult if you didn't know the structure of
20 the screens. These results have to, therefore, be
21 tested for each different screen, each different
22 manufacturer.

23 So what are you doing that's taking care
24 of that problem?.

25 MR. TREGONING: Obviously we can't test

1 every potential hypothetical screen design that's out
2 there. A lot of that information is evolving. What
3 you'll see is in many of our programs we've done at
4 least parametrically tried to evaluate if screen type
5 has effects on some of these phenomena.

6 So you'll see testing today that was
7 conducted on -- with a wider mesh screen which, you
8 know, no one to my knowledge is planning to use that
9 sort of a screen in modified sump designs. However,
10 there's some historical basis for the type of wire
11 mesh screen. There was a lot of historical head loss
12 data developed for the wire mesh type of screen, and
13 historically, again, it's finding some use within
14 plants.

15 So there is some work looking at that, but
16 then we're also doing some additional work using the
17 more modern perforated plate types of screens, and in
18 some cases we are definitively having tests which we
19 think or designing tests where the screen may have the
20 biggest impact to see what impact that could possibly
21 have.

22 DR. BANERJEE: Yesterday we also hear that
23 perhaps the time of arrival of various components and
24 so on had an effect on the head loss. How does the
25 correlation take that into account?

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1 MR. TREGONING: Yeah, I don't want to
2 steal thunder from this afternoon.

3 DR. BANERJEE: Right, right, but just give
4 us a preview.

5 MR. TREGONING: If I can give you a flavor
6 at the risk of being, you know, usurped by somebody in
7 the audience, what you try to do is or there's a
8 couple of different strategies that you can do.

9 One of the strategies that we're pursuing
10 that Bill Krotiuk is going to be discussing later is
11 looking at essentially sandwich models where you can
12 consider one layer within the debris bed to have a
13 certain concentration of particulate and another area
14 within the debris bed to have possibly a separate
15 different concentration of particulate. To try to
16 address some of these non-uniform, I don't want to use
17 the word "thin bed." We're trying to get away from
18 thin bed because we think it's a confusing term. We
19 want to say bed saturation effect, and by that we mean
20 bed saturated with particulate either uniformly or
21 over a very thin layer.

22 Either of those situations can be onerous
23 in terms of clogging. So those are both situations
24 that you want to understand from a modeling
25 perspective, and then from a plant perspective you

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1 likely want to avoid those types of situations if you
2 can or at least design against it.

3 DR. BANERJEE: So you can predict when
4 this sandwich will form?

5 MR. TREGONING: No, no. Again, one of the
6 things you'll see, there's a lot of information being
7 presented later. I think you can identify certain
8 variables that might promote cake filtration or
9 sandwich formation or particulate saturation. I think
10 there are certain variables that we can identify that
11 would get at this.

12 Saying that we can predict it though is
13 probably too strong a word. You're going to see that
14 the bed formation of the sump screen is a very
15 stochastic process. I don't know how else to describe
16 it.

17 DR. BANERJEE: What do you mean by
18 "stochastic"? It's like turbulence?

19 MR. TREGONING: No, there's a lot of
20 variables that go into determining what's actually
21 going to arrive at the screen, how it's going to
22 arrive there, how the particulates are going to form
23 within the fibrous bed to lead the head loss. There's
24 a number of very important variables that go into
25 that.

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1 So trying to predict when relatively small
2 changes in some variables could dramatically affect
3 your head loss, that's what I mean by --

4 DR. BANERJEE: You have a fluid dynamic
5 calculation going on, right, which delivers these
6 particles or fibers or whatever?

7 MR. TREGONING: You have transport going
8 on, yes. I don't want to say --

9 DR. BANERJEE: But they are carried by
10 fluid, liquid, right?

11 MR. TREGONING: Sure.

12 DR. BANERJEE: They don't arrive by
13 themselves. So --

14 MR. TREGONING: That's right, unless they
15 were deposited directly on the sump screen by the LOCA
16 itself. I mean, that's another possible transport
17 mechanism.

18 DR. BANERJEE: But now assuming you're
19 doing these fluid calculations, you should be able to
20 calculate at least the first approximation, what
21 deposit is out, what arrives, and you have to have
22 sort of a dynamic model of what's going on on the
23 screens, right? Whereas I see you just have static
24 correlations.

25 MR. TREGONING: Well, again, I don't want

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1 to get into too much of today. I mean, I think there
2 correlations are, you know, beyond just static
3 correlations and flow --

4 DR. BANERJEE: Not in the material you've
5 sent us.

6 MR. TREGONING: Flow transport is just one
7 variable here.

8 DR. BANERJEE: But I'm saying the
9 correlation itself. Now, you are giving us an
10 overview of what's going on. I don't see anything
11 tackling the dynamic nature of this, at least in the
12 material you've sent us.

13 MR. TREGONING: And just so I understand,
14 when you say "dynamic nature," what do you --

15 DR. BANERJEE: Build up of the bed. I
16 mean there are whole lots of technology out there
17 today which handled this type of modeling. I have
18 given a copy of the paper to --

19 CHAIRMAN WALLIS: Predicting how things
20 vary with time during an experiment.

21 MR. CUNNINGHAM: Would it be okay if we
22 held this until the particular experts --

23 CHAIRMAN WALLIS: We're going to hear
24 about that. I do have another question. Are you
25 studying back-flush? You said the difference between

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1 wire screens and perforated screen. I think wire
2 screens are particularly susceptible to having the
3 fiber sort of go through and get tangled up on the
4 screen, and they're harder to get away when you back-
5 flush.

6 So back-flushing is something that might
7 be interesting to plant, obviously the question of do
8 chemical effects glue the stuff to the screen more
9 effectively. I'd suggest that you do some simple
10 back-flushing experiments if you haven't done so
11 already.

12 MR. TREGONING: Okay. Certainly,
13 certainly.

14 CHAIRMAN WALLIS: I know there's a whole
15 bureaucracy that says what you can and cannot do.

16 MR. TREGONING: No, no, it's not
17 bureaucracy.

18 CHAIRMAN WALLIS: You actually can go out
19 and say, "Go and do it"? You don't have --

20 MR. TREGONING: We do that all the time,
21 but again, we try to do things here that make the most
22 sense.

23 CHAIRMAN WALLIS: I'm glad that you have
24 freedom to do what's sensible instead of having to go
25 through all the paper work.

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1 MR. TREGONING: I didn't say that.

2 (Laughter.)

3 MR. TREGONING: We still have to go
4 through quite a bit of paper work.

5 MEMBER KRESS: Another question, Rob.
6 Since it's very difficult to predict the dynamics of
7 how the things would build up on a screen and in what
8 order and how much, if you're given a given source of
9 materials, different types of debris and different
10 amounts of it, potential chemical forms and so forth.
11 Have you thought about looking at what combination of
12 those and in what order on the screen would give you
13 the worst and maybe you could bound the problem with
14 that sort of thing?

15 MR. TREGONING: When we set up our testing
16 matrix, quite often we're trying to, again,
17 parametrically search out what are benign versus
18 malignant sort of conditions. So one of the things
19 we've clearly tried to do, and you're going to see
20 information later, we have tried to search out
21 conditions that might be particularly onerous.

22 Getting back to -- I'm happy that you let
23 me get to Slide 3 so quickly.

24 DR. BANERJEE: We still have not
25 understood how pieces fit together. You're going to

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1 tell us that, right?

2 MR. TREGONING: Yeah, a little bit, but I
3 think, you know, again, there's five broad technical
4 areas. You're going to see later there's some areas
5 that we have quite a lot of overlap. There's other
6 areas where we have less overlap. Certainly in the
7 area of chemical effects, there is a tremendous amount
8 of overlap. Some of the coatings transport work,
9 there's almost no overlap because that's really a
10 separate, stand alone project. So you're going to see
11 that in a second.

12 I think we've covered this. Mark covered
13 this. The goals, again, provide basic technical
14 knowledge. There's only one program that you're going
15 to hear that's non-confirmatory in nature, and that's
16 the integrated chemical effects testing program.

17 This is a joint program that we conducted
18 with industry to even determine if we had to worry
19 about chemical effects at all. So that was really the
20 basic objective of that program.

21 Beyond that test program, all the other
22 programs that you're going to hear about over the next
23 day and a half are confirmatory in nature, and the
24 intent is to provide information for the staff's use
25 in conducting their review and assessment of these

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1 generic letter evaluations.

2 Certainly while that's the goal, as we get
3 a report and report results, we have in many cases
4 already and will continue to strive to make results
5 publicly available so that they can inform the
6 industry and ongoing activities with respect to this
7 resolution.

8 So while these are confirmatory programs
9 by their nature we are trying to be open and make sure
10 that industry has the benefit of this knowledge as
11 well as quickly as we can.

12 CHAIRMAN WALLIS: I think it's wise that
13 you have several different labs at times doing what
14 appears to be the same experiment, especially when
15 those experiments have given anomalous results in one
16 lab. You want to see can you get anomalous results in
17 another lab or is it something to do with the way they
18 did the experiment, but they weren't aware of --

19 MR. TREGONING: I wouldn't categorize any
20 of these results as anomalous that you're going to
21 hear in the next day and --

22 CHAIRMAN WALLIS: Well, I've seen the word
23 "anomalous" in some of the results.

24 MR. TREGONING: Okay. Well, maybe I need
25 to go back and edit those reports a little bit more

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1 carefully.

2 (Laughter.)

3 DR. BANERJEE: Really? Meaning
4 politically correct or --

5 MR. TREGONING: No, no. Anomalous may not
6 be the correct word to use. I mean, I think we've
7 seen --

8 CHAIRMAN WALLIS: Well, there are other
9 words, but we wouldn't use them.

10 MR. TREGONING: I think you're going to
11 see that a lot of the effects we are able --

12 CHAIRMAN WALLIS: Interesting effects.

13 MR. TREGONING: Interesting effects.
14 We're able to replicate them. We may not fully
15 understand them, you know. So it depends on how we're
16 using the word "anomalous" there.

17 I don't want to use it in the sense of
18 meaning sporadic.

19 CHAIRMAN WALLIS: Well, anomalous is
20 something that you expect it to behave this way and it
21 behaves some other way, and you can't understand why.

22 MR. TREGONING: Yeah.

23 CHAIRMAN WALLIS: Presumably that's
24 anomalous.

25 MR. TREGONING: There's one result that I

1 would.

2 CHAIRMAN WALLIS: Or you can get an
3 anomalous presentation sometimes, and you probably get
4 anomalous questions.

5 (Laughter.)

6 CHAIRMAN WALLIS: Let's move on.

7 MR. TREGONING: Okay. These are the
8 technical areas of study. I think a little bit is
9 trying to get at your question of how do the pieces
10 fit together.

11 We've got four areas that we're looking at
12 that Mark mentioned, one in the area of chemical
13 effects. The basic objective of that is to determine
14 the potential for chemical byproduct formation within
15 containment pool environments and characterize and
16 predict as best as we can the byproducts that form.

17 These are the first two talks you're going
18 to hear today. The first one will be the ICET test
19 that was conducted at Los Alamos National Lab.

20 The second is the speciation prediction
21 work that was conducted by CNWRA.

22 One point I will make here with respect to
23 synergy. Even though CNWRA is the lead in chemical
24 speciation prediction, LANL in support of their own
25 experiments has done a lot of their own predictions on

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1 the side to try to develop baseline variable
2 conditions for the ICET test, determine how much
3 product that they need to mix in to get a certain pH.
4 So, again, there's some synergy and overlap there in
5 terms of some of the expertise that's being applied.

6 In the area of head loss, we have two head
7 loss programs that are primarily, again, a
8 confirmatory research program to looking at head loss
9 associated with PWR containment materials both with
10 and without chemical effects.

11 You're going to hear about the chemical
12 effects head loss testing program at Argonne National
13 Lab, and then later today the particulate head loss
14 testing program. And by "particulate" I really mean
15 standard insulation debris. At least so far the
16 results you're going to hear will be mainly fibrous
17 and CalSil type of particular testing, although there
18 is plans to move on and look at some coating head loss
19 testing at PNNL.

20 And then the more stand alone programs.
21 We have one program that touches on the area of
22 downstream effects, one aspect of the downstream
23 analysis, and particularly it's looking at blockage.
24 I'll say flow blockage due to restricted pathways.

25 Now, we've studied it here by using

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1 surrogate HPSI throttle valves, but I think you'll see
2 a lot of the findings have some more generic
3 application as well.

4 MEMBER DENNING: Rob, that is a very
5 limited objective as well.

6 MR. TREGONING: Yes.

7 MEMBER DENNING: And from the things we
8 heard yesterday there are broader areas of
9 uncertainty. Do you have plans to look at in-core
10 types of blockage?

11 MR. CUNNINGHAM: We have no plans for that
12 right now.

13 DR. BANERJEE: Or even transport to the
14 core. I mean, that was the issue. Where does it
15 deposit out or like that?

16 MR. CUNNINGHAM: Our focus has been on
17 what would be happening in the -- we would expect to
18 be happening in the containment. See, this is a
19 little step into that next regime, but it's the only
20 steps we're doing right now.

21 CHAIRMAN WALLIS: But if it doesn't block
22 the throttle valve, then it goes further. Where does
23 it go?

24 DR. BANERJEE: How big is the throat of
25 the throttle valve?

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1 MR. TREGONING: That varies. That is
2 truly a plant specific consideration. I think what
3 you'll see in the testing is we did some surveys to
4 try to understand the range of throttle valve
5 settings, and we studied in this LANL work blockage
6 conditions over those ranges of applicable settings.

7 There was some --

8 DR. BANERJEE: Are they typically one
9 inch, five inch?

10 MR. TREGONING: No, no, no. They're
11 typically less than the screen openings -- I'm
12 sorry -- slightly greater than the screen opening
13 size. So if the screen opening size is a quarter
14 inch, they might be around a quarter inch. If it's an
15 eighth inch, they might --

16 CHAIRMAN WALLIS: But when it's closed
17 it's got no area. the problem is when it doesn't
18 quite close because maybe it closes on a piece of
19 metal or something. There's flow through it, but it's
20 a very small hole. Then you can bung (phonetic) it
21 up, and then when you try and start it up again,
22 that's the sort of situation where you really gather
23 debris. It's where it's not quite closed for some
24 reason. It could be it just didn't close all the way.

25 MR. TREGONING: Right. If you've got a

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1 valve --

2 CHAIRMAN WALLIS: If it's open, there's
3 probably no problem at all, but it's just when you
4 close it and then want to open it again. They may
5 find it's clogged up.

6 DR. BANERJEE: Come again?

7 CHAIRMAN WALLIS: You close the valve; you
8 almost close the valve. Then you've got a flow
9 through it, but you've got a restriction. You've got
10 a small area. So that's when you could lock it up
11 with debris.

12 So now you might have a pile of debris
13 going back from the valve in the pipe that has built
14 up this stuff, which is now ready to lean on the wall
15 and so on, and actually create a --

16 DR. BANERJEE: The valves are used to
17 control the flow.

18 CHAIRMAN WALLIS: Yeah, they can open and
19 close them, and in fact, in events they sometimes
20 open. They do and close them, don't they?

21 MR. TREGONING: Yes. At the risk of
22 overstating my knowledge in the area, I mean, my
23 understanding is they have set points and --

24 CHAIRMAN WALLIS: Especially when they
25 think they're losing their net positive suction head.

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1 They may vary the throttle valves in it.

2 MR. TREGONING: Yes, that's true. Ralph,
3 did you want to enlighten us a bit?

4 MR. ARCHITZEL: Architzel from NRR staff.
5 Particularly like in the Westinghouse
6 house, they flow balance ahead of time, the flow
7 through the HPSI injection lines, and so they have set
8 points. Like Rob is saying, those are fixed normally
9 and they stay and they're throttled down to achieve
10 balanced flow in case a line breaks. So those aren't
11 variable types of situations. They're normally set,
12 that condition, during the accident.

13 DR. BANERJEE: The opening is pretty small
14 in each of these?

15 MR. ARCHITZEL: Yes, as Rob said, the
16 opening is small, and that's why we had things
17 reasonably asked to be looked into, but the valves are
18 typically set in those conditions to achieve balanced
19 flow.

20 CHAIRMAN WALLIS: But they're instructed
21 to throttle under certain conditions. Don't they have
22 some flexibility in where they actually end up in the
23 position in the valve?

24 MR. ARCHITZEL: But ahead of time these
25 are set before the accident.

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1 CHAIRMAN WALLIS: It's either all or
2 nothing then? It's either throttled or nothing or --

3 MR. ARCHITZEL: No, they're set to
4 specific conditions to balance the flow through
5 various lines.

6 CHAIRMAN WALLIS: So how do they control
7 the flow?

8 MEMBER SHACK: I guess they don't.

9 CHAIRMAN WALLIS: They don't control the
10 flow?

11 MR. ARCHITZEL: Once the accident starts,
12 it's balanced. You expect --

13 CHAIRMAN WALLIS: No, but they're total
14 throttle, and when they think they're losing their
15 pumps from the sump, they're instructed to throttle.

16 MR. ARCHITZEL: Those are different
17 situations to throttle down. Those weren't the valves
18 we were talking about.

19 CHAIRMAN WALLIS: Oh, it's different
20 valves which they use to control. Maybe you test
21 those, too. Okay. Well, we'll get to that.

22 Thank you.

23 DR. BANERJEE: So these are the most
24 restrictive, these throttle valve.

25 MR. TREGONING: I wouldn't use that word.

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1 Again, you'd need to look at a specific ECCS layout in
2 a given plant. There's certainly one potential or
3 likely minimum gap area, you know, restricted area
4 flow.

5 DR. BANERJEE: The velocity is pretty high
6 through them.

7 MR. TREGONING: Yes, the velocities are
8 pretty high.

9 DR. BANERJEE: So if you had fine, they
10 would go through.

11 MR. TREGONING: Potential, although I
12 think, again, at the risk of stealing too much thunder
13 from tomorrow, I think you'll see when we did this
14 program we had basic questions if we could under these
15 conditions with relatively high velocities, if we
16 could even get blockage at all, and we were able to
17 under certain conditions generate significant
18 measurable blockage in these valves.

19 So, you know, I think maybe at that point
20 let's defer to tomorrow because I think you're going
21 to have a lot of additional interesting questions that
22 we can tackle then.

23 DR. BANERJEE: But I guess it's the broad
24 issue of the arrangement of this program. In arriving
25 at these things, did you do something like a PIRT and

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1 look at all of the downstream things and decide this
2 was the most important component or that was? How did
3 you do this systematic? That's what I'm trying to
4 understand.

5 MR. TREGONING: Yeah, we didn't do an
6 official PIRT, but I mean, certainly some of those, we
7 had those discussions among staff as well as with
8 contractors. We had been trying to identify areas
9 like I mentioned that we thought particular
10 vulnerabilities existed and, again, where we thought
11 we could do generic research to deal with topics that
12 maybe hadn't previously been addressed.

13 Certainly pump wear and degradation if you
14 were doing a PIRT would be something that would be
15 relatively high. We --

16 DR. BANERJEE: Or core blockage.

17 MR. TREGONING: Or potentially core
18 blockage. With pump degradation, I mean, one of the
19 issues we've had with that, as Steve Unikewicz
20 mentioned yesterday, there's been a lot of work in the
21 area of wear and tribology that can be applied to pump
22 design studies, and the other aspect that we've often
23 stumbled under is there's such a wide variety of pumps
24 that it has been difficult to try to craft any sort of
25 program in a generic sense that really captures the

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1 variability that's out there in the area of pumps.

2 So when we've picked programs, we've had
3 discussions to try to identify specific
4 vulnerabilities, as well as, again, try to have an eye
5 toward what we think we can tackle in some sort of
6 generic sense.

7 CHAIRMAN WALLIS: It would seem you cannot
8 ignore core blockage. We had discussions yesterday --

9 MR. TREGONING: No.

10 CHAIRMAN WALLIS: -- and since we're
11 talking about much larger screens, it's quite possible
12 there will be screen bypass debris. We're talking
13 about self-cleaning screens which chop up debris and
14 debris goes through the screen. Where does it go?
15 It's hard to imagine why someone is not doing a
16 program on core blockage.

17 DR. BANERJEE: Well, there was a PIRT done
18 in the early days. I've been looking through the old
19 documents. I thought there was something done, oh,
20 way back. Somebody, Ralph may know or somebody might
21 know.

22 MR. TREGONING: Well, Bruce?

23 DR. BANERJEE: Wasn't there something like
24 this done back in the early '90s or something or '80s
25 or something?

1 MR. LETELLIER: Yes, you're right. GSI-
2 191 was initiated with a PIRT on both the large dry
3 and the ice condenser containments, but at that time
4 in the regulatory process, the GSI specifically
5 excluded downstream effects. There was an interface
6 defined where that safety concern would be treated
7 separately.

8 So although it may have been itemized, it
9 was not thoroughly investigated.

10 DR. BANERJEE: So this program that's
11 coming out, does it come out of that PIRT, at least
12 leaving out the downstream effects, or is it just sort
13 of reacting to concerns which are arising in a sort of
14 semi-random way? Maybe NRR concerns. I don't know
15 from where they're coming.

16 MR. TREGONING: Let me follow up with what
17 Bruce said. There was an early PIRT that was done.
18 There has been a lot of research in this area over the
19 last ten, 11 years. So this is really just touching
20 on the research associated with the last year to six
21 months of the program. So there's been a lot of
22 baseline information.

23 I wasn't involved in that. So let me
24 speculate. My speculation is, and Bruce --

25 DR. BANERJEE: But somebody was, right?

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1 So we can hear from the horse's mouth here.

2 MR. TREGONING: My speculation would be
3 that a lot of that baseline research was a direct
4 result from the PIRT that was conducted. That's why
5 you do PIRTS obviously.

6 I mean, Bruce, do you want to elaborate on
7 that? No?

8 DR. BANERJEE: Because there is usually --

9 MR. TREGONING: Thanks.

10 DR. BANERJEE: -- systematic --

11 (Laughter.)

12 DR. BANERJEE: There is a systematic
13 procedure after a PIRT I evaluates whether the
14 experiments are applicable, they do a scaling study.
15 There's a whole process there, which is laid out, and
16 there doesn't seem to be an equivalent process being
17 taken care of.

18 MR. TREGONING: Well, Bruce talked about
19 the PIRT, but there has been other generic studies
20 that have been done as well. I mean, back in, you
21 know, the latter part of the '90s or early 2000, there
22 was a very extensive knowledge based study that was
23 done at Los Alamos National Laboratory, and part of
24 that knowledge based study was to really lay out what
25 we knew and what we didn't know.

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1 Now, that wasn't a formal PIRT, but in
2 some ways it had many of the same results as a PIRT
3 would in that it identified areas where we had
4 particular uncertainties, particular concerns.

5 DR. BANERJEE: But it dealt with the whole
6 thing, including downstream effects, everything.

7 MR. TREGONING: Well, refresh me. Was
8 downstream dealt with by the knowledge based study?

9 MR. LETELLIER: The purpose of the
10 knowledge based report was to capture all of the work
11 that had been done to date, and to my knowledge, this
12 work that you're going to hear about tomorrow is the
13 first of its kind regarding downstream blockage, and
14 my understanding of the history behind this is that
15 the throttle valve was specifically examined because
16 it represents one of the smallest gap openings in the
17 internal flow. It's not the only area of concern, but
18 it is one of the smallest, and in proportion to the
19 debris sizes and the screen penetration, it was simply
20 chosen for examination, as Mark said, for the first
21 step in looking at downstream concerns.

22 CHAIRMAN WALLIS: Well, we probably have
23 to go on, but I think we learn with this program that
24 PIRT or not, you can discover things while you do
25 research which you didn't expect. Then you have to

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1 respond somehow.

2 MR. TREGONING: Okay. Here's the group of
3 research team that we formulated to deal with these
4 issues. We have a very informal working group. The
5 working group -- and I've identified Los Alamos,
6 Southwest, Argonne, and Pacific Northwest National
7 Laboratory -- they're primarily dealing with issues
8 and chemical effects, and then debris head loss.

9 The Carderock Division work is separate
10 from the working group. They're looking at the
11 coating transport issue. So the working group of the
12 four labs and the NRC, we were charged with test plan
13 development, test coordination and review of results.

14 So this is something that all the members
15 do. We usually ask, you know, if we have results that
16 were developed at Argonne, we ask Los Alamos or the
17 Center to at least be aware of and in some cases
18 review that work to make sure that we're happy with
19 not only the quality of the work, but more
20 importantly, to make sure that we understand it as
21 much as we can.

22 CHAIRMAN WALLIS: That's a very
23 interesting plot because it shows that everybody
24 communicates with Los Alamos, but PNNL has nothing to
25 do with Southwest Research.

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1 MR. TREGONING: That's true. That's true.

2 CHAIRMAN WALLIS: That's true?

3 MR. TREGONING: Because PNNL -- Southwest
4 is the group doing chemical speciation work. PNNL is
5 not doing any chemical effects work.

6 CHAIRMAN WALLIS: I see. Okay.

7 MR. TREGONING: So that is a true plot.

8 CHAIRMAN WALLIS: It's true. It's true.
9 Okay.

10 MR. TREGONING: It's a true plot. Now,
11 we're certainly all together on a lot of research
12 costs. So they are at least, you know, indirectly
13 communicating with these guys, but there's no direct
14 collaboration.

15 CHAIRMAN WALLIS: There's no direct -- a
16 completely independent phenomenon we're looking at.

17 MR. TREGONING: Yes.

18 DR. BANERJEE: Do you have access to the
19 industry data or is it all proprietary and you can't
20 use it? For example, in model development and things
21 like that.

22 MR. TREGONING: We have some access. We
23 certainly have access when industry submits that
24 information either formally or informally. Now, you
25 know, some of the Alion work, I mean, I think you

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1 heard yesterday, I think, John Butler, maybe John
2 Butler; somebody characterized that they had done, you
3 know, 2,000 some odd tests in the Alion test loop. I
4 personally have not seen that work. That would be
5 very valuable data to add to the experiential
6 database, to say the least.

7 So, you know, I'd say it's a bit sporadic.
8 We certainly see the things that they give us, but we
9 don't see everything.

10 DR. BANERJEE: Yeah, you'd also probably
11 need quite a lot of details of the tests to see how
12 this stuff went there and how it deposited.

13 MR. TREGONING: Yeah, raw data may or may
14 not be very useful certainly.

15 DR. BANERJEE: Now, the Carderock
16 Division, why did coatings become such an important
17 issue? What happened? I missed that.

18 MR. TREGONING: Coatings have always been
19 an important issue.

20 DR. BANERJEE: Is it because they form
21 very fine particles or --

22 MR. TREGONING: Coatings have always been
23 important, and I think you heard a presentation from
24 NRR yesterday to talk about some of the concerns. One
25 of the issues with coatings, because there was a lack

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1 of knowledge in terms of failure mechanisms and amount
2 of coating loading that you could get, the safety
3 evaluation, and the staff took a very conservative
4 position and essentially assumed that you had a large
5 amount of debris which formed.

6 So then the next question is, well, if you
7 really have that much debris formed, how much of it do
8 you think will transport.

9 Now, the particulate is one thing, you
10 know. Anything within the ZOI is assumed to be
11 particulate. One of the reasons it's assumed to be
12 particulate is that it's more readily transportable.

13 But the bigger question and the bigger
14 loading potentially is for coatings outside of the
15 ZOI, which the particulate assumption is much less
16 defensible in that case.

17 DR. BANERJEE: But yesterday we heard --
18 and maybe these tests will clarify this -- we heard
19 they did some autoclave tests for the region outside
20 the ZOI, and these were on samples that were sent. It
21 wasn't a very comprehensive program. They only did
22 about 15 -- I don't remember. It's a small number
23 anyway, but they didn't measure the particle sizes.

24 If particle sizes are concerned, they only
25 sort of measure how much of the coating spalled off or

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1 whatever it did, you know, in the steam spray system.
2 So is your program trying to fill those gaps or what
3 is the motivation?

4 MR. TREGONING: As much as we can. What
5 you'll see, again, it's a parametric study. We've
6 looked at transport of different sizes of chips and --

7 DR. BANERJEE: Oh, this is transport
8 rather than actual formation.

9 MR. TREGONING: This is transport. This
10 is not formation. The industry is dealing with the
11 formation and the damage issues. We in this program
12 are looking at the transportability issues.

13 DR. BANERJEE: Because the program that
14 was discussed yesterday doesn't give us any sense of
15 what the size of the flakes or particles are. There
16 seems some disconnect between knowing 50 percent is
17 gone, but we don't know in what form it is, and doing
18 all of this transport work because --

19 MR. TREGONING: We do have some
20 independent information beyond just what has been
21 measured or not measured in some of these experiments.
22 There's certainly visual evidence within some of the
23 plans of coatings under normal operating conditions
24 which are not adhered anymore, and they've come off in
25 chips and so we at least have a crude sense in terms

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1 of what sizes we're seeing, you know, and we've used
2 that to try to guide the range of study within the
3 Carderock Division.

4 I mean, there's some other evidence as
5 well that's been applied in setting up these
6 experiments.

7 Move on?

8 CHAIRMAN WALLIS: Yes. You're way behind.

9 (Laughter.)

10 DR. BANERJEE: It's all his fault, right?

11 MR. TREGONING: I'm more than happy to go
12 right through these and get us back on schedule.

13 CHAIRMAN WALLIS: Well, we can move
14 through the next slide pretty quickly.

15 MR. TREGONING: Okay. We talked about
16 regulatory coordination a little bit. We have staff
17 in both NRR and Research that we're coordinating with.
18 We've got three levels of peer review, NRR and
19 Research review. We also, as I discussed a little
20 bit, we have peer review among the research team
21 members.

22 And in the area of chemical effects, we're
23 also conducting an external peer review. We have five
24 members on the peer review group, and we've received
25 some preliminary feedback. We're not going to touch

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1 on the peer review effort much today, but I know when
2 we come back in June, if not before, we'll have a more
3 extensive session concerned with some of the peer
4 review comments.

5 I did want to indicate who the peer
6 reviewers were. We've tried to get a pretty diverse
7 group in terms of not only their affiliation, but
8 their areas of technical expertise.

9 DR. BANERJEE: So you have a chemical
10 industry person. That's wonderful.

11 MR. TREGONING: Yes, we do. So we have
12 five people from both national labs, academia, and
13 industry. We have filtration guys. We have
14 speciation modeling guys. We have people that have
15 experience with nuclear waste, analytical chemistry,
16 experimental chemistry, electrochemistry, and
17 experimental testing. So I think we've got a pretty
18 good group of external peer reviewers here.

19 DR. BANERJEE: And Digby is a very
20 thermodynamicist as well.

21 MR. TREGONING: Yes, yes. Understanding
22 Digby has been my personal challenge.

23 DR. BANERJEE: He's from New Zealand.

24 MR. TREGONING: No, I don't mean that. I
25 just mean technically.

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1 (Laughter.)

2 MR. TREGONING: It's 'not communication.
3 It's level of understanding. He's up here; I'm down
4 here.

5 DR. BANERJEE: Well, that's a good team.

6 MR. TREGONING: So just briefly, we've
7 touched on most of these, and Mark touched on these
8 more thoroughly. I just wanted to outlines some
9 important messages that I think all of the talks are
10 going to touch on within the next couple of days.

11 We've designed these research programs to
12 provide some basic conceptual understanding. We've
13 tried to identify several important technical issues
14 which impact functionality of the ECCS system. As we
15 mentioned several times, our primary role --

16 CHAIRMAN WALLIS: I think, Rob, one of
17 your jobs here is to avoid future surprises. You'd
18 better know now if something is going to happen.

19 MR. TREGONING: Sure. We want to know.

20 CHAIRMAN WALLIS: You recognize that when
21 you do an experiment and say, "Gee, whiz. That's
22 something new. We'd better pay attention to that,"
23 rather than saying, "Let's correlate it," or
24 something.

25 Thank you.

1 MR. TREGONING: No, understanding if there
2 are features of this phenomena which might surprise us
3 in either a bad or a good way is really --

4 CHAIRMAN WALLIS: And then it might be a
5 good way.

6 MR. TREGONING: It might be a good way,
7 and that has been really a fundamental consideration
8 in the research as well. Again, primarily we're
9 providing confirmatory information. You're going to
10 hear about a lot of interesting findings over the next
11 day or so.

12 One point is, again, that these findings
13 are going to be generic in nature and are really
14 understanding, and considering plant specific related
15 issues, that's what's really needed in order to assess
16 the importance of some of these research findings for
17 a particular situation.

18 So that's where the plant specific part of
19 this really comes back into play. We might show some
20 very onerous head loss results, but if they're not
21 representative of any particular plant conditions,
22 they're not applicable to that particular plant.

23 CHAIRMAN WALLIS: It would be interesting
24 if at the end of the day you could give us a homework
25 assignment which says explain particular obligations

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1 in Experiment X-23 and you know.

2 MR. TREGONING: You're offering that?

3 CHAIRMAN WALLIS: Well, I don't know. It
4 may well be that we'll go away with some assignments
5 to think about.

6 MR. TREGONING: You know, we're always --
7 Research, given our limited constraints, we're always
8 looking for additional help and support in
9 understanding phenomena. So if ACRS is offering that,
10 I'll certainly be more than happy to accept.

11 CHAIRMAN WALLIS: Sometimes we can't
12 restrain ourselves.

13 DR. BANERJEE: One member of ACRS.

14 (Laughter.)

15 MR. TREGONING: I noticed you didn't make
16 the same offer.

17 That's it.

18 DR. BANERJEE: I think before you take
19 that slide off, basically I've understood the various
20 components of the program, but taking this from this
21 generic point to the point where it's useful on a
22 plant specific basis usually needs some sort of
23 modeling glue, right, to do that transformation?

24 I mean, there is understanding which is
25 the first thing, but then that has to be translated

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1 into something relatively quantitative so that people
2 can use it. How is that going to happen?

3 MR. TREGONING: You know, modeling is one
4 approach. There's quite a lot of things that we're an
5 engineering organization, and these are engineering
6 problems that at the end of the day we're concerned
7 with making sure that we have solutions to, and we
8 have a lot of things that we have engineering
9 solutions for that we're confident work without
10 necessarily having rigorous, robust models to
11 understand all of the details associated with whatever
12 phenomena are studied. So --

13 DR. BANERJEE: So then you have to put
14 live safety models or something.

15 MR. TREGONING: Potentially, potentially
16 not. It depends on how well you understand the
17 phenomena. So that's the challenge here. I mean,
18 modeling is one avenue. I don't think it's
19 particularly --

20 DR. BANERJEE: It's complementary, right?

21 MR. TREGONING: It's certainly
22 complementary. Certainly modeling in the sense --
23 and that's what we're trying to do with the
24 correlation work. Modeling, I think, is really good to
25 make sure that you've covered your bases, that you

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1 make sure that there's no phenomena on those
2 particular set of conditions that can get you into
3 trouble.

4 But the models themselves, quite frankly,
5 traditionally have limitations as well, and I think we
6 need to keep in mind some of the uncertainties in our
7 knowledge base, and I think that needs to factor into
8 the engineering solutions that we develop for this
9 problem.

10 So modeling is important. Don't get me
11 wrong, but I don't want to paint modeling up as a
12 savior that if we understand everything well enough
13 we'll be able to get the best engineering design.

14 I think some of these situations can be
15 dealt with without modeling at all, just by making
16 some prudent choices within, you know, potentially
17 how the plants are configured, how they're designing
18 against these functionality issues.

19 DR. BANERJEE: So how will you, let's say,
20 predict or study, let's say, the problem of downstream
21 effects without a model to look at where deposition
22 might occur? Are you going to take a full-scale
23 reactor and pump this stuff in if this would happen?

24 MR. TREGONING: Well, you know, again, you
25 need to walk before you can run. We need to see in

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1 these new screen designs. We need to understand what
2 types of things and the volume or the amount of things
3 that are going to be ingested beyond the sump strainer
4 screens.

5 That fundamental understanding is still
6 unknown to some extent because, again, we're still in
7 the design modification phase.

8 DR. BANERJEE: We know right now that
9 there are stream designs where a significant amount of
10 stuff will pass downstream. Yesterday we heard about
11 the active stream designs where 30 percent of stuff
12 goes through, and they go through as fine.

13 So this is a given. So what happens after
14 that?

15 MR. TREGONING: Again, 30 percent of
16 stuff, but you still don't know. It's a plant
17 specific determination of how much that stuff is.

18 DR. BANERJEE: Well, I know, but what I'm
19 saying is without a model what are you going to do?
20 There's going to be a very wide range of stuff,
21 whatever it is, going through. So if you can
22 characterize it by size distribution, by composition
23 or whatever, to go from there to the amount of
24 blockage that you might experience or where it might
25 be, I just don't see you doing it without a model.

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1 I don't think any engineering judgment, at
2 least not mine, is going to give you that.

3 MR. TREGONING: Well, it depends on what
4 you mean by model, and you know, the Westinghouse
5 Owners Group at least has a methodology for what needs
6 to be considered in a downstream effect analysis, and
7 again, that's where the details of the particular ECCS
8 system design are very important. Just because you've
9 ingested debris, how much of that makes it to the core
10 is still potentially highly variable, and we --

11 CHAIRMAN WALLIS: Well, Rob, I think we're
12 going to have to stop your presentation because we
13 could talk to you all day.

14 MR. TREGONING: All right.

15 CHAIRMAN WALLIS: Now you've started with
16 the first slide again here.

17 (Laughter.)

18 CHAIRMAN WALLIS: I'm getting nervous.

19 DR. BANERJEE: We'll come back to this.

20 CHAIRMAN WALLIS: You're going to be
21 around, aren't you? You're going to be around.

22 MR. TREGONING: I'm more than happy to
23 defer at this point.

24 CHAIRMAN WALLIS: Yes, but you're going to
25 be around the rest of the day if we need to talk to

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1 you again.

2 MR. TREGONING: I think I'm going to be up
3 here poking slides the rest of the day. So I'll be
4 readily visible. I'll be readily visible.

5 CHAIRMAN WALLIS: So you can even get
6 involved in the conversation from time to time.

7 MR. TREGONING: I'm going to try to avoid
8 it, but, yes, I will be here.

9 CHAIRMAN WALLIS: Thank you. That was
10 very good, I think, but we do have to move along.

11 B.P., are you going to start this one?

12 MR. B.P. JAIN: Yes.

13 CHAIRMAN WALLIS: Okay. So when you're
14 ready, please go ahead.

15 MR. B.P. JAIN: Good morning. I am B.P.
16 Jain, the Office of Research, and with me is Bruce
17 Letellier from Los Alamos National Laboratory, and
18 together we will provide you a brief status of the
19 ICET program.

20 The ICET program was concluded last
21 August, and we have presented to the committee the
22 results of the first three tests from last July
23 meeting.

24 The research program was a cooperative
25 program with industry, and the industry had provided

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1 input to the test plan, the test matrix, and test
2 operation, as well as the characterization
3 requirement. So it's a truly joint program, and the
4 results of this program have been shared with
5 industries and they have been made available to the
6 public as well.

7 Next one please.

8 CHAIRMAN WALLIS: Can I ask you? The
9 overview here and to go back to the concern that we've
10 had all the time, we just hear it from Dr. Banerjee.

11 MR. B.P. JAIN: Right.

12 CHAIRMAN WALLIS: These tests, do they
13 result in some understanding which enables you to
14 predict things better or are you just finding out
15 things which might be important? Is there some
16 predictive capability that results from all of this?

17 That's, I think, one of the key questions
18 that we're going to have for you.

19 MR. B.P. JAIN: Well, the objective of
20 this program was -- I'll get to the next slide -- was
21 primarily to find out if --

22 CHAIRMAN WALLIS: Find out if things
23 happened because if you read your preamble to the
24 report, it sort of says, yeah, we found out some
25 things, but it's going to be plant specific and,

1 therefore, industry has to do all of that work to
2 study each plant.

3 MR. B.P. JAIN: Right.

4 CHAIRMAN WALLIS: There's no model that
5 has come out of your work which will help shorten
6 their work in any way?

7 MR. B.P. JAIN: Not as a part of the ICET
8 program.

9 MR. TREGONING: The one thing I will say
10 is the results from that program have been used both
11 by us to try to calibrate some of our models and then
12 also industry as well. I think you heard about the
13 Westinghouse program where they tried to calibrate
14 their model with respect to the ICET program.

15 CHAIRMAN WALLIS: I'm sure they've been
16 useful. It's a question of how far you have to go
17 before you can actually use it for plant predictions.

18 Okay. I'm sorry to --

19 MR. B.P. JAIN: So basically would provide
20 this brief recap in this presentation, rehash our
21 objectives, the test plan and significant research
22 findings we provided last July. What we did not
23 provide last time was Test 4 and 5 because they were
24 being planned or partially complete. So we'll have
25 more details of Test 4 and 5. And then where we go

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1 from here and where we get more information.

2 This is core data. Last time we presented
3 the test plan, the matrix, and the test loop and
4 operation itself, much more detail, and the results of
5 Test 1 through 3.

6 Now, Bruce is going to go over briefly on
7 this test plan, test operations, so will give you the
8 completeness of the whole presentation. But primarily
9 focus would be Test 4 and 5 results in this one.

10 Next one, please.

11 Just to emphasize the objective of this
12 program, we're to determine if the cantil (phonetic)
13 byproducts can be formed in the LOCA sump pool
14 environment, and if there could be some gelatinous-
15 like material that could be formed. Those were the
16 primary two objectives, emphasizing objective was not
17 to conduct a head loss study under this program. It
18 was just being done separately at ANL, mechanical head
19 loss effects.

20 Some of the main, obviously the tests have
21 been completed, and we have made an objection where
22 the test results did show that chemical products and
23 precipitates can form, and some of these products are
24 amorphous in nature.

25 As we had shown last time, and we will

1 show some of the slides today, when there's a change
2 in pool variables, for example, the pH, the
3 temperature, or the insulation can affect the type and
4 the qualities of the kind of products you get.

5 And obviously some of the tests like, for
6 example, Test 3 showed that depending on the nature of
7 the environment, you can get products quickly or some
8 time later as in Test 1. So those are the objectives.

9 Next one, please.

10 The staff is using the results of the ICET
11 program in their evaluation for GRE clarit (phonetic)
12 2004-02, and factoring that in our head loss testing
13 at ANL and the industry as well using those results.

14 Next one.

15 This will give you a brief overview. This
16 is a test matrix which we used to run this program.
17 The five tests were planned. Each test ran for 30
18 days, and the primary difference among the differing
19 tests was the buffering agent and the insulation type.

20 CHAIRMAN WALLIS: You didn't run any tests
21 with no buffering agent? I mean, if a plant takes out
22 its TSP and has no buffering agent, what happens?

23 MR. B.P. JAIN: Well, that was not part of
24 the --

25 CHAIRMAN WALLIS: Yeah, but you did not do

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1 any tests with no buffering.

2 MR. B.P. JAIN: We did not.

3 CHAIRMAN WALLIS: What is the pH of the
4 liquid which comes out of the reactor, the primary
5 coolant loop? What is the pH and the LOCA for the
6 normal boration?

7 MR. B.P. JAIN: Paul.

8 MR. KLEIN: Paul Klein from NRR.

9 It's one of the questions we asked the
10 CalSil TSP plants, would be the minimum expected pH
11 before any TSP would dissolve, and the answers were
12 typically around four and a half or so.

13 CHAIRMAN WALLIS: Thank you.

14 So it might be interesting to do an
15 experiment with four and a half pH without any
16 buffering. I don't know. The program may be over,
17 but, you know, when we get a question of a plant which
18 is going to take out its buffering agent, it would be
19 interesting to have some idea of what might happen.

20 MR. B.P. JAIN: In tests, there are three
21 types of buffering agents. I'm sure by now we all
22 know that: sodium hydroxide, TSP, and sodium
23 tetraborate. Tests 1, 2, and 5 consider 100 percent
24 fiberglass insulation, and Tests 3 and 4 have 80
25 percent CalSil mixture with 20 percent Nukon.

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1 Next one, please.

2 This gives you what we had shown last time
3 just to give you a flavor of significant findings from
4 Test 1 through 3. Test 1 is a sodium hydroxide and
5 Nukon combination environment where we saw a white
6 precipitant at room temperature, and on the right side
7 of the figure shows insulation where you see the web
8 structures of chemical products in the individual
9 fibers, a web-like material.

10 You see a similar trend in Test 2 to a
11 lesser degree. The difference in Test 2 obviously is
12 the buffering agent is different. Insulation remains
13 the same 100 percent insulation.

14 CHAIRMAN WALLIS: And so it's your
15 determination of what this web-like stuff is?

16 MR. B.F. JAIN: Well, on the precipitate
17 it's more like aluminum hydroxide. That analysis
18 indicated that.

19 CHAIRMAN WALLIS: Okay.

20 MR. TREGONING: Let me clarify here a
21 little bit. We had a lot of discussion about this
22 last July when we showed the first pictures of this.
23 Now, since that time LANL has gone back and done quite
24 a bit of characterization work.

25 Are you going to cover this or not?

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1 That's the only reason I was dealing --

2 MR. B.P. JAIN: Not today, I guess.

3 MR. LETELLIER: We're probably not going
4 to revisit the composition of the Test 1 precipitates
5 and the coatings, film coatings. I did want to
6 mention, however, though that some of the photographs
7 that we showed in July of the film type of webbing
8 between fibers may have exaggerated the concern.

9 After that briefing we actually went back
10 to the lab and reproduced that in an artificial manner
11 by dipping fiberglass into solutions of various
12 types.

13 So some of this is a surface tension
14 effect that occurred when we drained the tank. I'm
15 convinced that some of the more granular deposits were
16 formed in situ, but there's a visual misperception
17 there that doesn't need to be exaggerated.

18 MR. TREGONING: Yeah, we shared pictures
19 where it looked like film in July, and we truly
20 believe as Bruce said, after some additional work that
21 those are film, films that were brought about during
22 the drying process.

23 DR. BANERJEE: Do you think those little
24 powders on those stick-like structures are just due to
25 drying?

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1 MR. LETELLIER: Some of the more granular
2 appearing deposits I believe to have been formed in
3 situ because this type of structure appears on a lot
4 of the solid surfaces.

5 DR. BANERJEE: Can you just point so I
6 will know which structures you're meaning?

7 MR. LETELLIER: These more granular
8 structures on individual fibers, they look like
9 barnacles perhaps, and this is not a particularly good
10 example, but in the lower frame the webbing in between
11 fibers is much thinner and that can be formed from a
12 surface tension effect like a silt bubble. We've
13 demonstrated that in an artificial environment that
14 did not experience 30 days of exposure. We simply
15 dipped the fiber and produced the same structures.

16 DR. BANERJEE: Okay.

17 MR. TREGONING: We don't have a picture of
18 the webbing in this presentation. We did in July, but
19 the appearances are quite different.

20 MR. B.P. JAIN: This is for the Test 3,
21 the gel-like material.

22 CHAIRMAN WALLIS: Excuse me. Is the flow
23 through this? There's no flow through this matrix.
24 So whatever gets in there is diffused in there
25 somehow?

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1 MR. LETELLIER: That's correct, except
2 for at the end of the test the water was drained away
3 from the sample, and that is a directed flow. During
4 exposure we did expose fibers to various localized
5 flow conditions, but in my opinion, none of these bulk
6 samples had a substantial flow through the medium.

7 MR. TREGONING: But we did have additional
8 samples that we put by the drain column and then a few
9 at later tests where we specifically put near the
10 inlet water jets to try to simulate some more higher
11 flow conditions.

12 MR. LETELLIER: But these samples were
13 never exposed, for example, across a sump screen
14 environment so that the bulk flow is drawn through
15 them.

16 CHAIRMAN WALLIS: But there was some
17 agitation in the tank. So it probably isn't just
18 diffusion. Diffusion is very slow.

19 DR. BANERJEE: So you did agitate the
20 tank.

21 MR. LETELLIER: We'll get into the
22 physical attributes, but you'll see that where the
23 water was injected there's clearly structure in this
24 tank.

25 MR. B.P. JAIN: The next one, please.

1 This is for Test 3, which is a TSP in
2 CalSil, which we've talked about quite a bit. It just
3 shows the picture of that gel-like --

4 CHAIRMAN WALLIS: Is this something like
5 pizza dough or something. What kind of --

6 MR. B.P. JAIN: Looks like, yes.

7 CHAIRMAN WALLIS: Is that the way it
8 feels? Is it gooey and tough?

9 MR. B.P. JAIN: It's a gooey stuff, yes,
10 and I think we have a little more information later on
11 in this presentation on this Test 3 stuff.

12 CHAIRMAN WALLIS: It's stuff which would
13 be hard to wash off if you just put it under a faucet?

14 MR. LETELLIER: It would be disbursed
15 under a faucet. It has a texture of face cream.

16 CHAIRMAN WALLIS: Oh, so it's not quite as
17 gooey as something like pizza dough.

18 MR. LETELLIER: It's not as sticky as it
19 might appear.

20 CHAIRMAN WALLIS: I don't even know what
21 face cream is.

22 (Laughter.)

23 DR. BANERJEE: It's an emulsion.

24 MR. B.P. JAIN: Bruce will go over the
25 details, give you a brief overview of the test plan

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1 and the test operation and the results.

2 Bruce.

3 MR. LETELLIER: From B.P.'s talk you're
4 going to want to hold onto page number 6, the test
5 matrix, just to remind yourselves of which pH
6 conditions and which combinations of debris that there
7 were.

8 I'd like to begin by acknowledging the
9 other team members at Los Alamos. I'm representing
10 the work of a group of very dedicated individuals. In
11 particular, our principal investigator, Jack Dallman,
12 who is responsible for daily operations for developing
13 a quality insurance plan and largely for documenting
14 our results, and I think Jack is on the line this
15 morning to help me answer questions.

16 I do want to offer the committee an
17 overview of the project because several of you were
18 not present in July, but this is review material. So
19 if we need to skip ahead, we can do so.

20 Page 10 shows the develop time line.
21 Conceptual design started almost two years ago now
22 when we first became serious about committing
23 resources to chemical test investigation. Structural
24 design occurred during the summer of '04, and our
25 first test began in late November of 2004.

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1 As BP said, we had a series of five 30-day
2 tests that were run in sequence with approximately a
3 three-week delay time in between each one. The fifth
4 and final test was just completed in August the past
5 summer.

6 Photographs on page 11 give you some
7 impression of size and scale. The central piece of
8 apparatus is a tank of approximately 250 gallons of
9 reverse osmosis water. The principles of scaling
10 we're trying to preserve here are the proportionality
11 between the surface area of metals and the dilution
12 volume of the liquid.

13 So in essence, this is a miniature
14 containment building. Although it does not preserve
15 the spatial scale of flow, it does preserve the
16 chemical proportionality of corrosion and dilution.

17 The samples were introduced in racks as
18 shown in the lower frame. There are actually six of
19 these racks are suspended above the water in the head
20 space and one of these racks is submerged throughout
21 the duration of the 30 days.

22 So this volume does accommodate the
23 proportionality of the entire containment building.
24 We were concerned about exposure to sprays and wash-
25 down of corrosion products to the pool. Opinions vary

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1 about whether that was important in retrospect, but
2 all of the tests were executed in the same way.

3 The water level in this photograph extends
4 up to that, about one third of the tank to that lower
5 flange. So there are observation ports that you can
6 see, one below the surface, one immediately above the
7 surface, and then one on the covering of the lid.

8 This tank was wrapped in thermal
9 insulation throughout the test, which is not shown in
10 this picture.

11 The next frame --

12 DR. BANERJEE: Was the water agitated at
13 all?

14 MR. LETELLIER: You can see -- let me
15 point -- where the water was introduced at this point
16 near the top of the water. There is a parallel
17 injection manifold on the opposite side, and this is
18 literally a distribution header that was meant to
19 inject the water uniformly across the cross-section of
20 the tank. That's the point of highest velocity and
21 highest turbulence.

22 DR. BANERJEE: And is this recirculated,
23 the water?

24 MR. LETELLIER: It is continuously
25 recirculated. The drain is at the bottom of the tank

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1 DR. BANERJEE: And so this was like a
2 spaja (phonetic), was it?

3 MR. LETELLIER: Exactly. We did design
4 that header to try and minimize, I guess, reduce the
5 maximum flow rate and try to avoid direct impingement
6 on the samples. We wanted to have velocities that
7 were representative of conditions in the containment
8 pool throughout the long period of exposure.

9 DR. BANERJEE: And the drain was a multi-
10 drain or just a single point?

11 MR. LETELLIER: No, the drain is a single
12 point at the bottom of the tank, which is not shown
13 here.

14 DR. BANERJEE: To get flow to the drain
15 then.

16 MR. LETELLIER: Of course. That's right.

17 DR. BANERJEE: So does that give a region
18 of high velocity at the bottom?

19 MR. LETELLIER: It does, and as Rob
20 mentioned, we later introduced fiberglass samples in
21 a collar around that drain area to try and increase
22 the velocities that we were exposing our material to.

23 CHAIRMAN WALLIS: You have a screen down
24 there presumably, too, don't you?

25 MR. LETELLIER: There was a screen just

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1 to protect the pump from the large quantities of
2 debris that were introduced. It was not intended as
3 a surrogate sump screen design, but in fact, we took
4 good advantage of that localized flow area to collect
5 our samples.

6 DR. BANERJEE: But the samples you show,
7 they're all consolidated. There's no debris there,
8 right? If there's debris formed, it would be just
9 washed off there just in time or what?

10 MR. LETELLIER: Oh, you're talking about
11 deposits on the plates that are shown here?

12 DR. BANERJEE: Right. Those plates are
13 your various materials, aren't they?

14 MR. LETELLIER: They do represent the
15 stainless steel, aluminum, copper, zinc, paint and
16 concrete that are present in containment. In addition
17 to this we introduced stainless steel bags, if you
18 will, of fiberglass and calcium silicate.

19 DR. BANERJEE: Where are those?

20 MR. LETELLIER: There's actually a
21 photograph two slides down.

22 DR. BANERJEE: Okay. I went back.

23 MR. LETELLIER: And the one that B.P.
24 showed give you an impression of.

25 CHAIRMAN WALLIS: But you didn't throw in

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1 zinc paint chips or anything. All of the materials
2 were in the form of these plates.

3 MR. LETELLIER: Let's itemize the debris
4 types. There are actually stainless steel mesh bags
5 containing the Nukon fiberglass that were also
6 immersed. There was a certain quantity of crushed
7 concrete that was mixed into the solution, as well as
8 dust and dirt, literally containment sweepings that
9 would represent latent debris.

10 We did not specifically include degraded
11 coatings in any way.

12 DR. BANERJEE: And the fiberglass or the
13 insulation, did you chop these up or what did you do
14 with them?

15 MR. LETELLIER: These were pre-shredded
16 and also heat treated to simulate the service life of
17 the insulation. So we did a crude form of accelerated
18 aging on the insulation process.

19 CHAIRMAN WALLIS: You took off the organic
20 coating from this fiberglass?

21 MR. LETELLIER: That's part of the reason
22 for the heat treatment. This was done dry on a hot
23 plate simple to induce a thermal gradient across the
24 blanket. This was done before it was shredded to
25 simulate the accident environment.

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1 As it is immersed in the hot solution, the
2 organic biter (phonetic) does degrade as well.

3 DR. BANERJEE: So when you say
4 accelerated, you heated it up above what it would be
5 expected to be heated at and looked at some kinetic
6 law like Arrhenius' Law or something, right?

7 MR. LETELLIER: It was rather crude by
8 comparison to your description. We did do roughly a
9 time-temperature integral to simulate the service life
10 of 20, 25 years of plant service.

11 DR. BANERJEE: So the reaction is roughly
12 double every ten degrees. Okay.

13 CHAIRMAN WALLIS: Now, what is in plant
14 service? Does the organic coating evaporate off
15 because the stuff gets hot?

16 MR. LETELLIER: Yes. Yes, it does.

17 CHAIRMAN WALLIS: So after a while it's
18 all gone.

19 MR. TREGONING: Well, again, a lot of
20 it -- we went a little bit above the reactor operating
21 temperature, but not a substantial amount above, and
22 what you see, you know, they do these bake-offs in the
23 plant. Most of it has evolved very quickly, and when
24 they did the bake-off in the Nukon here, you could
25 smell when the bake-off was occurring certainly. So

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1 a similar type of phenomenon.

2 CHAIRMAN WALLIS: Sniffing Nukon is
3 hazardous to your health.

4 MR. TREGONING: Among other things, yes.
5 Yes, it can be.

6 DR. BANERJEE: Now, you shredded it with
7 what, a leaf shredder or a blender or what was it that
8 you used?

9 MR. LETELLIER: The product that we
10 emersed in the tank was run through a leaf shredder so
11 that the flocks are roughly one inch and smaller.
12 Now, that's the case when it comes out of the leaf
13 shredder as it sits in the boxes and as we pack the
14 blankets, it does re-agglomerate.

15 So these bags were necessary to control
16 the migration of fiber in the test, but people will
17 argue about how realistic this represents the exposure
18 environment in the accident. We have conducted prior
19 testing in past years where we introduced debris into
20 a much larger containment pool, a simulated one-tenth
21 scale environment, and the debris has the luxury of
22 oscillating and fluctuating with local flows. In this
23 case it did not. We were simply trying to reproduce
24 the exposure conditions so that the chemical leaching
25 could occur in a proportional way.

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1 DR. BANERJEE: Do you think the size of
2 the shredded samples -- I mean the particle size,
3 would that have any effect on what you see or it's
4 independent of that?

5 MR. LETELLIER: The degree of shredding
6 was minor compared to the size of the fiberglass
7 strands. We did not chop or degrade this into an
8 appreciably larger surface area. We physically
9 separated it, and that's all.

10 CHAIRMAN WALLIS: The difference would be
11 if fiberglass when it's intact is less reactive than
12 when it's broken. The ends presumably are fresh, and
13 they're sort of broken up more. They might be more
14 reactive than the --

15 DR. BANERJEE: It may affect the kinetics.

16 MR. TREGONING: The separation of the
17 fiberglass I would argue is probably more important
18 then.

19 DR. BANERJEE: Now, in the ZOI do you form
20 fibers or do you form particles/ Experiments, what do
21 they show?

22 MR. LETELLIER: Well, in past testing
23 that has been done with air jet surrogates looking at
24 debris generation, you form flocs. You form shreds of
25 the original insulation blanket.

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1 DR. BANERJEE: But in a steam water jet,
2 which is coming out of these enormous velocities what
3 happens?

4 MR. LETELLIER: There is no direct
5 evidence of two phased jet impingement on fiberglass.
6 However, I still think that the primary effect would
7 be to physically separate rather than to break the
8 fibers.

9 DR. BANERJEE: There would be no erosion
10 to particles?

11 MR. LETELLIER: These are very low
12 density materials that will accelerate quickly.
13 They're not held in place. In comparison to the
14 calcium silicate product, for example, which is bound
15 to the piping structures and physically experiences an
16 erosion phenomenon, there is test data to support the
17 behavior of that product.

18 DR. BANERJEE: Okay.

19 CHAIRMAN WALLIS: So that's an interesting
20 statement. There's no direct evidence of two phased
21 jet impingement effects on fiberglass.

22 MR. LETELLIER: Not to my knowledge.
23 Now, there may be evolving evidence on the industry
24 side where they're beginning to commit resources to
25 that question.

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1 DR. BANERJEE: So what happens? Steam
2 generators have fiberglass insulation, don't they?

3 MR. LETELLIER: There is a diversity of
4 insulation products throughout containment.

5 DR. BANERJEE: But many of them do have
6 fiberglass.

7 MR. LETELLIER: Many of them do, yes.

8 DR. BANERJEE: So if you get a break near
9 that and you hit the steam generator with a jet, it
10 will be a two phased jet hitting this fiberglass.

11 MR. LETELLIER: That's correct.

12 CHAIRMAN WALLIS: It peels it off, I
13 think.

14 DR. BANERJEE: God knows what it does.

15 MR. LETELLIER: Our estimates of debris
16 generation are very large. You can easily estimate up
17 to 2,000 cubic feet of debris that might be stripped
18 from a steam generator compartment.

19 DR. BANERJEE: If you hit most of the
20 surface, right? Ten diameters.

21 MR. LETELLIER: Yes, ten diameters is
22 probably an exaggeration for the equivalent volume.

23 DR. BANERJEE: Why is that? A liquid two-
24 phased jet will penetrate pretty --

25 MR. LETELLIER: It does extend --

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1 DR. BANERJEE: That seems actually small
2 to me.

3 MR. LETELLIER: It does extend to that
4 distance. No question about that, and beyond.

5 DR. BANERJEE: Have you ever seen a steam
6 water jet coming out? That water will make a hole
7 through it.

8 MR. LETELLIER: That's true. It extends
9 to 25 and 30 diameters. The methodology at present is
10 to take that physical geometry and convert it to a
11 spherically equivalent volume wherein the pressure
12 contours are capable of damaging the insulation.

13 MR. CARUSO: We were told yesterday that
14 that was not what they did, that they went out to the
15 distance at which it was affected and then just took
16 a sphere of that diameter.

17 MR. LETELLIER: In the case of coatings,
18 you're exactly right. That assumption was made
19 because no prior evidence existed for the damage
20 pressure associated with a paint coating, and so the
21 staff took a conservative position consistent with
22 prior regulatory applications to simply, as you
23 suggest, take a reasonable penetration distance and
24 revolved that or rotate that into a comparable sphere.

25 MR. CARUSO: But they did something

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1 differently for insulation.

2 MR. LETELLIER: That's correct. It was
3 a conservative position that was adopted before recent
4 evidence of damage pressures for coatings.

5 MR. ARCHITZEL: Ralph Architzel from NRR.

6 I just wanted to make a comment, and Bruce
7 knows this. I just remind ACRS for the pressurized
8 water reactors, we did take a 40 percent reduction in
9 insulation damage compared to the air jet test which
10 effectively tripled the volume that was used for the
11 air jet testing for insulation materials absent two
12 phased testing.

13 So it wasn't the same test volume that was
14 used for BWRs or that were demonstrated by the air jet
15 testing. It was a triple volume basically. I didn't
16 want to really get into this too much, but there was
17 some recent testing. We have had some fiberglass and
18 that coatings test. My understanding, it would sort
19 of confirm that the destruction was similar to what
20 was observed in air jet test, and it was floc. It
21 blasted all over the place with fines as well. That
22 wasn't intended to be the target, but was over the
23 material.

24 MR. LETELLIER: You're speaking of recent
25 industry testing?

1 MR. ARCHITZEL: Yes.

2 MR. LETELLIER: Very recent testing.

3 MR. ARCHITZEL: It wasn't the intent to
4 test the fiberglass, but it did basically.

5 DR. BANERJEE: Inadvertently.

6 PARTICIPANT: Collateral damage.

7 MR. LETELLIER: That is a topic in and of
8 itself that we could devote a significant amount of
9 time to. I'll just mention that more of the physical
10 attributes are itemized on page 12. We don't need to
11 go through them, except to mention that the flow rate,
12 pH, and temperature were controlled through an
13 automatic data acquisition system.

14 So this needed to sit unattended for 30
15 days with daily samples extracted for the purpose of
16 monitoring concentrations.

17 MR. CARUSO: You used RO water. You
18 didn't use tap water. Why didn't you use tap water?
19 Everyone else seems to be using tap water. Is there
20 a difference?

21 MR. LETELLIER: Well, the tap water is
22 adopted for convenience in cases where you're looking
23 at the fluid dynamics of head loss. We're trying to
24 have a much more controlled environment where we're
25 looking at chemical effects. We did not take the

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1 extra step of going to reagent grade purity water, but
2 we felt that RO water was easy enough to do, and it
3 was appropriate for this test.

4 DR. BANERJEE: But it was deionized,
5 right? There were no ions.

6 MR. LETELLIER: There are subtle
7 differences between reverse osmosis process and
8 deionization, and we had an RO unit physically on site
9 to generate our make-up water. I apologize I can't
10 explain the differences.

11 MEMBER SHACK: Do you know what your
12 resistivity was coming out?

13 MR. LETELLIER: We do. I'm not sure that
14 I can quote that.

15 Jack, are you on line?

16 MR. DALLMAN: Yes, I am.

17 MR. LETELLIER: Can you help? Bill Shack
18 is asking about the resistivity from our RO unit.

19 MR. DALLMAN: I don't recall right now,
20 Bruce.

21 MR. LETELLIER: That was monitored just
22 to look at the cleanliest level just to make sure that
23 the unit was operating within its specifications.

24 So let's move on to page 13 to talk a
25 little bit more about the daily tank operations. The

1 upper frame shows loading the racks into place to
2 initialize the test. The upper right-hand panel shows
3 you how congested the space is to physically fit all
4 of the coupons.

5 There are 374, 375 plates in each of the
6 tests, which were all identical. The lower left panel
7 shows you what the water condition looks like just
8 before initiation of the test. It is very murky as we
9 throw in the dust and dirt, and the lower right-hand
10 panel illustrates our limited visual perspective
11 during the test. We could basically see the edges of
12 the plates, and at some perspective you could look
13 across the depth of the tank to judge the clarity.

14 Daily water samples were extracted from
15 the associated plumbing. The temperatures were
16 monitored and held constant throughout the duration of
17 the test at 60 degrees Celsius.

18 Page number 14 lists, in the first bullet,
19 lists some of the common test parameters with one
20 exception which I'll note at the bottom. You see that
21 various types of metals were used, including concrete
22 and zinc coated paint. The temperature was held
23 constant. These are all ambient pressure tests.

24 Actually the staff used some of the CNWRA
25 modeling results of a year and a half ago to make

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1 judgments about the pins (phonetic) of corrosion on
2 pressures and temperatures. We were basically making
3 a tradeoff between the very early phase of high
4 temperature LOCA sequence compared to the long
5 duration of moderate temperature exposure, and we
6 opted on the size of a conservatively high, long-term
7 exposure and simply ignoring the very short duration
8 of high temperature.

9 The recirculation flow throughout the tank
10 is 25 gallons per minute out of --

11 DR. BANERJEE: Did you do any sort of
12 scoping test to look at this brief duration, high
13 temperature on a smaller scale or anything?

14 MR. LETELLIER: We actually did the
15 modeling simulations to help make that judgment, and
16 using published literature values for corrosion rates
17 as a function of temperature. There were no bench
18 scale experiments done to make that determination.

19 That was one of the first commitments we
20 made before designing and building the facility,
21 whether it needed to be pressurized to sustain a
22 higher temperature or not.

23 DR. BANERJEE: Well, this facility clearly
24 is too large, but I wondered if you had done some
25 smaller tests in that little autoclave or something,

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1 but anyway, you haven't.

2 MR. TREGONING: No, but a lot of the basic
3 corrosion information for most of these metallic and
4 nonmetallic species is pretty well known. So we've
5 relied on literature for those parameters.

6 DR. BANERJEE: But this has got boric acid
7 and stuff in it, right?

8 MR. LETELLIER: That's what we were less
9 certain about, was the dependence of chemical reaction
10 rates on pressure and temperature. That's what we
11 took advantage of the modeling efforts to help make
12 judgments.

13 The last three bullets which cite the --

14 MR. VIJAY JAIN: Vijay Jain, Center for
15 Nuclear Waste.

16 We did do some studies with respect to the
17 individual materials. We looked at the corrosion
18 rates from 60 degrees to 110 degrees Centigrade, and
19 you are right. As the temperature increases. Your
20 corrosion rate increases by a factor of two or three.
21 You go from 60 degrees to 110 degrees.

22 But if you will do the same study with a
23 function of time as Bruce said, you can basically
24 replicate that increased corrosion rate can be
25 accommodated as a function of time running for 15 days

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1 instead of half an hour.

2 Thank you.

3 MR. TREGONING: Thanks for clarifying.

4 MR. LETELLIER: You did it with boric
5 acid and things.

6 MR. VIJAY JAIN: Yes. We used the same
7 conditions that were used in ICET test for Test No. 1
8 and Test No. 3.

9 MR. TREGONING: Thank you for clarifying
10 that.

11 MR. LETELLIER: The last three bullets in
12 the first topic of common parameters, those were held
13 constant for Tests 1 through 4, but in Test No. 5 when
14 we introduced the sodium tetraborate pH control
15 system, the boron concentrations in hydrochloric acid
16 were modified as appropriate for that test.

17 Tests No. 1 and 4 used the sodium
18 hydroxide as a pH control system with a target of ten.
19 Test No. 2 and 3 used the trisodium phosphate, the
20 TSP, with a target pH of seven.

21 And test --

22 CHAIRMAN WALLIS: Doesn't the sodium
23 hydroxide eat up the HCl's pretty well? You put in
24 this HCl and then you eat it up with sodium hydroxide?

25 MR. LETELLIER: That's true. The purpose

1 of the HCl was to represent chlorides that might be
2 present from polyvinyl cable degradation due to the
3 thermal environment. So it does not really
4 participate in the pH system. It's simply there for
5 the chlorides.

6 Next slide.

7 We took full advantage of our simulated
8 containment environment to collect samples on almost
9 everything that we could see. Because chemical
10 speciation is very difficult in a complex system like
11 this, we made the judgment to treat physical samples
12 as being unique through our analysis and investigation
13 process. We tried very hard not to presume that two
14 things are equal, and until we had some chemical assay
15 to help us confirm that.

16 So we have a proliferation of sample
17 types. The primary fiberglass blankets you've been
18 able to see, but in addition to that there were
19 smaller sacrificial samples of about three to four
20 inch square which we could extract at various time
21 points during the test. Those were exposed in high
22 flow and low flow regions of the tank.

23 We collected daily water samples obviously
24 which were sent for off-site chemical analysis. We
25 conducted during our daily samples, we conducted --

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1 well, we collected both a raw, unfiltered sample, and
2 also a filtered sample, filtered out the tap, so that
3 we could differentiate between suspended solids.

4 We noted any visible precipitates and
5 collected samples. At the end of the test we
6 collected floor sediment which was composed of the
7 initial particulate debris, which was introduced. In
8 addition, any sort of chemical products which happened
9 to form and settle.

10 The metal coupons were examined for
11 corrosion, corrosive attack. In one case, in test
12 number one, we collected significant quantities of
13 precipitate, this sludge material which was produced
14 after cooling the test solution.

15 We also examined the tank and pipe residue
16 during our cleaning process and in Test No. 3 noted
17 significant build-up of material internal to the
18 circulation system.

19 DR. BANERJEE: Build up in what sense?
20 Was it --

21 MR. LETELLIER: It was a surface coating.
22 We do have a back-up slide to that demonstrating that.

23 DR. BANERJEE: It was adherent?

24 MR. LETELLIER: It was adherent, loosely
25 adherent. It was easy to remove by mild agitation,

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1 but, in fact, it built a substantially uniform coating
2 on the walls of the pipe, on the struts of the flow
3 meter, and including fouling the turbine at one point.

4 DR. BANERJEE: What was it?

5 MR. LETELLIER: Test No. 3, if you'll
6 remember from the matrix, was our first experience
7 with calcium silicate in combination with trisodium
8 phosphate. That test was unique as we explained in
9 July in that we observed a chemical flocculent within
10 30 minutes of the test. It was visibly suspended in
11 the tank. We're speculating that that was a calcium
12 phosphate product, and in fact, the compositions of
13 the deposits on the walls are consistent with that
14 assumption.

15 I'm hesitating to say that's exactly what
16 it was because it is a very complex chemical reactor,
17 if you will.

18 The EDS analysis that we did showed
19 calcium phosphorus and oxygen in the proper
20 proportions for calcium phosphate.

21 DR. BANERJEE: Was it in suspension then,
22 this floc?

23 MR. LETELLIER: Visibly so.

24 DR. BANERJEE: Do you think that's what
25 happened?

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1 MR. LETELLIER: Very early in Test No. 3
2 it was visibly apparent swirling in the circulation
3 flow, and we can examine the turbidity to show how
4 quickly it settled, over what rates the water
5 clarified, and at the end of Test No. 3, as B.P.
6 showed in his figure, substantial quantities of this
7 material on every surface.

8 DR. BANERJEE: Would it also be on the
9 reactor core surfaces?

10 MR. LETELLIER: It very likely would be.
11 That's one of our principal findings from Test No. 3.

12 DR. BANERJEE: How thick was it there?

13 MR. LETELLIER: On the walls of the pipe
14 or in the tank itself?

15 DR. BANERJEE: Wherever.

16 MR. B.J. JAIN: The tank was about an inch
17 and a half or so.

18 DR. BANERJEE: and the walls of the pipe?

19 MR. LETELLIER: One-eighth inch nominal.

20 DR. BANERJEE: Of that order.

21 MR. LETELLIER: Of that order.

22 CHAIRMAN WALLIS: I thought it was thinner
23 than that. It was actually an eighth of an inch on
24 the pipe?

25 MR. LETELLIER: There's actually a back-

1 up slide that you can flip to.

2 DR. BANERJEE: And it's friable, very
3 friable.

4 MR. LETELLIER: No, it's -- I'd have to
5 describe it as a finely divided particulate. It is
6 not brittle in any way. It could be scraped or
7 removed with mild agitation, but in fact, it was
8 surprisingly adherent under flow.

9 DR. BANERJEE: So it's a bit like fouling
10 of some sort.

11 MR. LETELLIER: Yes.

12 PARTICIPANT: Yeah, you have to page
13 through or try and blow it up.

14 MR. LETELLIER: Yeah, I think it is the
15 very last slide in your package.

16 DR. BANERJEE: That certainly is an
17 interesting finding.

18 MR. LETELLIER: It is. The upper right-
19 hand panel shows the whitish-yellow deposit with a
20 scraped section that shows a fingernail or some sort
21 of cleaning that was attempted. This material built
22 up on the streets of the flow meter on the left-hand
23 panel.

24 DR. BANERJEE: And it was only observed in
25 Test No. 3 or in all the tests?

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1 MR. LETELLIER: Primarily Test No. 3.

2 MEMBER SHACK: Well, you've labeled them
3 here as CalSil rather than calcium phosphate.

4 MR. LETELLIER: I apologize for that. As
5 I said, we were trying not to presume what the actual
6 chemical composition was. Because this test was our
7 first experience with calcium silicate as a debris
8 type, in very high concentrations, that's certainly
9 one of the constituents.

10 It is noteworthy, however, that the other
11 labs who have -- and actually Los Alamos has conducted
12 head loss testing with calcium silicate. We've never
13 experienced the same type of accumulation, and I don't
14 think that Argonne or PNNL has experienced that
15 either, at least not with tap water and nominal
16 temperature conditions.

17 So it's not unreasonable to attribute this
18 to a chemical product formation. It's something
19 unique.

20 DR. BANERJEE: You didn't see any deposit
21 in any of the other tests?

22 MR. LETELLIER: Not on the internal --
23 well, that's not true. Jack, if you'd like to make a
24 comment on our cleaning process for the other tests.

25 MR. DALLMAN: Well, we cleaned the piping

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1 and the tank thoroughly between tests, and I recall
2 that after Test 3 that was certainly the hardest test
3 to get it cleaned up.

4 We did see some of this what's called
5 deposits on the other tests, but not nearly to the
6 extent of this one.

7 DR. BANERJEE: What was not nearly? It
8 was much thinner than one-eighth inch or did you find
9 any deposit at all?

10 MR. DALLMAN: On the other tests?

11 DR. BANERJEE: Yeah.

12 MR. DALLMAN: Yes, we did. I mean, it was
13 very fine, and I would not say that this was one-
14 eighth of an inch thick by any means.

15 MR. LETELLIER: Not as thick as that.

16 MR. KLEIN: This is Paul Klein from NRR.

17 If I could jump in for a second, Bruce, my
18 recollection at the end of ICET 3 was that the
19 deposition on the side of the tank was probably less
20 than a sixteenth. It certainly wasn't an eighth inch
21 thick deposit that I recall.

22 MR. LETELLIER: Not in the tank. I was
23 basing that on my just visual assessment of these
24 turbine struts in the panel, which are very, very thin
25 to begin with and they've formed an accumulation.

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1 Maybe Jack would describe the deposits in other tests
2 as a residue that was actually flushed during our
3 cleanliness procedure.

4 Test No. 3 took a fair amount of effort to
5 clean the pipes to our tolerance.

6 DR. BANERJEE: So where did this fine
7 stuff come from? I mean, what do you speculate the
8 origin was?

9 MR. LETELLIER: The calcium silicate
10 debris was precrushed and contains a large, large
11 quantity of fine particulate by itself. What was most
12 interesting about Test No. 3 is the formation of a
13 chemical product that's also extremely fine. I would
14 like to say that it's a crystalline product in the
15 case of calcium phosphate, very small particulate.

16 MEMBER SHACK: I mean, you had vast
17 amounts of CalSil in Test 4, again, and you're not
18 seeing a deposit.

19 MR. LETELLIER: That's right. That's why
20 I'm saying that the chemical reaction behaved in a
21 unique manner. It's not simply the calcium silicate
22 by itself. We simply don't see accumulation on
23 internal piping from CalSil in exclusion.

24 DR. BANERJEE: It's very interesting.

25 MR. LETELLIER: Jump back to page --

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1 CHAIRMAN WALLIS: B.P. said something
2 about an inch thick tank wall. Did I mishear that?

3 MR. LETELLIER: In the bottom.

4 PARTICIPANT: Sediment.

5 CHAIRMAN WALLIS: In the bottom.

6 MR. LETELLIER: Settling on the bottom.
7 That was in the introductory slide. It showed a very
8 good photograph of that material.

9 DR. BANERJEE: Slide No. 8.

10 To return now --

11 CHAIRMAN WALLIS: We're going to have to
12 speed up, I think. Maybe when we get to the figures
13 we can pick out the ones which are most interesting.

14 MR. LETELLIER: Sure.

15 CHAIRMAN WALLIS: Or are they all backups?

16 MR. LETELLIER: I'd like to present some
17 of the trends actually.

18 Page number 16 is just a laundry list of
19 the diagnostics and supporting analyses that we
20 brought to bear. I will, however, note that chemical
21 speciation is a very difficult task. We were
22 moderately successful in the case of precipitates from
23 Test No. 1 at conducting nuclear magnetic resonance to
24 actually look at the chemical bonds in the precipitate
25 and confirm that at some phase of aluminum hydroxide.

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1 Beyond that, elemental compositions in
2 proportionality is the most accessible diagnostic that
3 we have.

4 So moving into a survey of results, we'll
5 focus on Test 4 and 5 because the committee has not
6 seen this information before.

7 CHAIRMAN WALLIS: But Test 3 is also the
8 interesting one, isn't it?

9 MR. LETELLIER: Test 3 is --

10 CHAIRMAN WALLIS: You might want to say a
11 bit about that.

12 MR. LETELLIER: It is also included as
13 backup slides, and we're free to look at that as well.

14 In Test No. 4, just to remind everyone,
15 this was a sodium hydroxide pH system with 80 percent
16 calcium silicate, 20 percent fiber. My sort of bird's
17 eye view of this is it was one of the more benign
18 tests as far as chemical product formation goes. So
19 there's not a great deal to say in the
20 observations. MEMBER SHACK: You've actually found a
21 beneficial effect of calcium.

22 MR. LETELLIER: That's perhaps true. In
23 Test No. 4, although we had a high pH, we had very
24 little aluminum corrosion, and it may well be due to
25 a surface passivation by the presence of the calcium.

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1 One of the few good things that I could
2 say about it.

3 MR. TREGONING: Let me just elaborate a
4 little bit. Test 4 was nominally similar -- I don't
5 want to say identical -- to Test No. 1 with the sole
6 exception being the incorporation of CalSil in Test 4,
7 the same buffering agent, and in less amounts of Nukon
8 in Test 4, and in Test 1 we saw relatively copious
9 amounts of precipitate at least at room temperature.
10 We didn't see that at all in Test 4.

11 So there's an indication of at least one
12 single variable change having a relatively large
13 effect.

14 MR. CAFUSO: All of the metallic samples
15 were electrically isolated from one another, correct?
16 So there was no galvanic -- opportunity for any
17 galvanic results.

18 MR. LETELLIER: The coupon racks that
19 were shown in the previous figures were made of
20 chlorinated polyvinyl chloride. They're plastic
21 pipes, and they are simply physically restrained in
22 the slots. They are not physically touching in any
23 way.

24 We did perhaps observe some evidence of
25 electroplating transfer between copper and aluminum

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1 plates in one very localized case. There was no
2 evidence of pitting or aggressive electrochemical
3 behavior.

4 So I think that our coupon racks were
5 reasonably successful in that regard. They served a
6 convenient way to load and to manage a large volume of
7 samples.

8 CHAIRMAN WALLIS: Well, presumably someone
9 has done this. I Mean, the difference between one and
10 four is some sort of effective calcium preventing
11 aluminum coming into solution. You could do that in
12 a benchtop test, couldn't you?

13 MR. LETELLIER: Indeed, we've tried to
14 reproduce some of that. It's a plausible explanation
15 for the suppressed aluminum concentration.

16 CHAIRMAN WALLIS: Yes, but it would be
17 useful to have some check that it wasn't some
18 peculiarity of a particular experiment if you could
19 duplicate it in some other way.

20 MR. LETELLIER: As we get into some of
21 the trends and concentrations, you'll see that there's
22 a very large reservoir of calcium. I've tried to
23 remember. Do we have 50 pounds?

24 PARTICIPANT: Fifty-five pounds.

25 MR. LETELLIER: Fifty-five of crushed

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1 calcium silicate, which basically almost fills the
2 lower one-third, I guess one-fourth of the tank. Up
3 to the level of the bottom of the coupon rock is
4 completely full of this sludge material. Not all that
5 is immediately available to dilution, but nonetheless,
6 there's a very large inventory.

7 CHAIRMAN WALLIS: It's a huge amount.

8 MR. LETELLIER: Yes.

9 CHAIRMAN WALLIS: That's not typical of a
10 plant though.

11 MR. LETELLIER: No, it is actually.

12 CHAIRMAN WALLIS: It is?

13 MR. LETELLIER: The volume, the amounts
14 were scaled in proportion to our estimate of debris
15 generation. What is obviously not preserved here is
16 the spatial scaling of the containment versus the
17 tank. This is a much more congested environment, and,
18 in fact, were it not for the fact that our calcium
19 concentrations are very high and remained noticeably
20 high, you might suspect that we were isolating this
21 material in some artificial way.

22 We talked about mixing this tank or
23 repeating this in some other manner, but the fact is
24 you have more than enough CalSil participating here.
25 This dominates the chemical system.

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1 DR. BANERJEE: So the volume or the mass
2 of various components to the water is preserved in
3 comparison to the real system, right?

4 MR. LETELLIER: To our best available
5 estimates, yes.

6 DR. BANERJEE: Yes, it is estimated.

7 MR. TREGONING: Let me clarify Bruce's
8 CalSil statement. This CalSil load was I don't want
9 to use the word "representative." It was certainly
10 chosen to be more of a conservative type of estimate.
11 It was based on the assumption that you had a break
12 near a steam generator that had CalSil insulation.

13 PARTICIPANT: And it took 5,000 cubic
14 feet.

15 MR. TREGONING: Yeah, it took 5,000 cubic
16 feet of CalSil off. Most plants do not have -- in
17 fact, I'm not aware of any plant that has that
18 concentration of 80 percent CalSil compared to 25
19 Nukon. Most of the plants are down around 20 percent
20 CalSil, and many have as they're replacing steam
21 generators and doing other plant modifications,
22 removing all of the CalSil that they can.

23 So even at this point in time, that CalSil
24 loading represents a bounding condition that I
25 wouldn't expect in any of the plants as they're

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1 currently configured.

2 DR. BANERJEE: So what would happen at a
3 lower CalSil rate?

4 MR. TREGONING: Well, that's a very good
5 question, and that's one of the questions that this
6 testing has raised, especially with this passivation
7 phenomena. How much do you need to enjoy the benefits
8 of passivation in this one instance?

9 MR. LETELLIER: But nonetheless, Argonne
10 has showed that the dilution rates of calcium are
11 very, very rapid. So it doesn't take a large physical
12 quantity to dominate and saturate the chemical
13 inventory of calcium in the system. We could argue
14 about how much physical product, but nonetheless, it's
15 available, readily available.

16 So let's move on to the photograph on page
17 19.

18 CHAIRMAN WALLIS: I'm puzzled by that
19 because I thought you crushed the CalSil, but it looks
20 like rocks down there.

21 MR. LETELLIER: We tried our best to
22 reproduce a size distribution at --

23 CHAIRMAN WALLIS: It looks like big rocks.

24 MR. LETELLIER: Indeed, a large portion
25 of the volume is in physical sizes three inches

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1 nominal diameter.

2 CHAIRMAN WALLIS: Didn't crush it very
3 well then. I mean it's pretty friable stuff.

4 MR. LETELLIER: That represents
5 approximately 40 percent of the inventory. Sixty
6 percent was crushed to fines.

7 CHAIRMAN WALLIS: Which is probably on the
8 bottom?

9 MR. TREGONING: If you see the sediment to
10 the left, a lot of that is mixed particulate CalSil
11 with -- in fact, in that test it's largely particulate
12 CalSil.

13 CHAIRMAN WALLIS: -- enough anyway whether
14 it's crushed or not.

15 MR. LETELLIER: Yes, and it's a very
16 porous medium nonetheless.

17 This photograph is markable by its
18 comparison to Slide No. 6 in the introduction. This
19 is a calcium silicate test, but you see only minor
20 residue on the piping. You don't see the large
21 volumes of secondary product.

22 MR. TREGONING: And the residue is the
23 white scale. It's nominally gray CPVC. So some of
24 the white scale you see there.

25 DR. BANERJEE: So this is after the test?

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1 MR. LETELLIER: Yes. This is after 30
2 days when the water has been drained.

3 DR. BANERJEE: So how did you get sediment
4 to go on one side?

5 MR. LETELLIER: It's a little bit
6 deceiving. This bag of CalSil is actually placed in
7 last.

8 DR. BANERJEE: Oh, I see.

9 MR. LETELLIER: It's on the top.

10 Test No. 5, general observations. This
11 test was unique in that we were investigating a sodium
12 tetraborate system, which is utilized for ice
13 condenser plants. The sodium tetraborate is frozen
14 into the ice column, and it is released gradually
15 during the ice melt.

16 We made every effort within the limits of
17 our experimental apparatus to reproduce the time
18 history of the chemical introduction. For example,
19 sodium hydroxide sprays, we tried to match the maximum
20 initial pH and to introduce it over a time period so
21 as not to exceed our expectations for the actual plant
22 conditions.

23 And similarly, for the sodium tetraborate
24 we introduce a portion of that inventory before the
25 sprays and a portion during the sprays in order to

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1 match most closely our understanding of the accident
2 rates.

3 The turbidity of the tank was very small,
4 .7 NTU before latent debris and the concrete dust,
5 about 14 NTU after the latent debris. Just a little
6 bit of intuition about these unfamiliar units.
7 Nephelometric turbidity units are a little bit arcane
8 to my experience. As you would visually look through
9 the windows of the tank, a level of one NTU represents
10 visual clarity through the depth of this tank. Above
11 that there's a noticeable level of suspension.

12 MR. TREGONING: And tap water is about .5.
13 So just for frame of reference there.

14 MR. LETELLIER: This test seemed to
15 remain turbid. It was cloudy much longer -- well,
16 relatively longer than the other tests, and we'll look
17 at the trend in a later slide.

18 For example, we could not see through the
19 depth of the tank until after day six.

20 CHAIRMAN WALLIS: Even though this stuff
21 is -- well, it is being stirred. So I guess this is
22 all in suspension around the whole loop with this
23 stuff.

24 MR. LETELLIER: It is never mechanically
25 stirred. It's only agitated by the --

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1 CHAIRMAN WALLIS: -- stay in suspension.

2 MR. LETELLIER: That's correct. The
3 other tests would clarify and settle relatively
4 quickly, within two to three days' time frame.

5 The hydrogen generation, we're going to
6 look at a slide. It remained very low through the
7 first half of the test, and it was basically
8 nondetectable thereafter, which hydrogen generation is
9 an indicator of corrosive behavior which was clearly
10 evident in Test No. 1. It was almost nonexistent
11 here.

12 I will qualify and say that our
13 measurements of hydrogen were executed to serve a
14 safety function. We were concerned about flammability
15 limits. It was a rather crude field survey instrument
16 and was not collected to be quantitated. However, I
17 believe that it's very useful as an indicator of
18 reactivity in the tank.

19 CHAIRMAN WALLIS: Well, those hydrogen
20 bubbles might affect what happens in the sump if they
21 were to be formed there.

22 MR. LETELLIER: It's interesting to note
23 -- we'll look at the slides later -- that even in Test
24 1 where the hydrogen generation was clearly evident,
25 the turbidity remains very low and so --

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1 CHAIRMAN WALLIS: Yeah, but hydrogen in
2 combination with particulate matter.

3 MR. LETELLIER: There's a large quantity
4 of particulate present, but the turbidity remains low,
5 which indicates to me it's not agitated to the point
6 of mechanical resuspension, and there's no significant
7 buoyancy change as well.

8 MR. TREGONING: We did see in Test 1 some
9 bubble formation on the surface of especially the
10 aluminum specimens, right?

11 MR. LETELLIER: Yes, yes.

12 MR. TREGONING: But at the risk of being
13 overly simplistic, it was -- you know, there was a
14 relatively periodic sort of -- it wasn't like it was
15 deluged with hydrogen initially. It was relatively
16 consistent at least over the first ten days or so of
17 the test. Is that an accurate characterization?

18 MR. LETELLIER: I'd have to defer to
19 someone who had daily visual experience, but the
20 traces of hydrogen generation for Test 1 show a fairly
21 constant level of activity, and yes, there are micro
22 bubbles present on the surfaces. It --

23 CHAIRMAN WALLIS: Of the aluminum?

24 MR. LETELLIER: Of the aluminum
25 primarily.

1 We've conducted various exposure tests
2 looking at hydrogen generation all the way from
3 reagent grade aluminum powder that's held in inert
4 environments. That literally fizzes like Alka Selzer
5 as it corrodes very rapidly compared to an industrial
6 grade sample which has a well established oxide layer,
7 which is passivated to these exposure conditions.

8 PARTICIPANT: Thanks for clarify that.

9 MR. LETELLIER: Continuing on page 21
10 with general observations, remember now this is
11 similar in pH to the sodium hydroxide conditions. We
12 did observe visible precipitates in the daily water
13 samples after they had cooled to room temperature.
14 Remember we're extracting 100 milliliter samples and
15 archiving them, sending them for analysis.

16 And also Test No. 5, we had learned
17 enough, anticipated enough about our concerns that we
18 were able to do a rudimentary heat exchanger test
19 where we took some of the raw solution from 60 degrees
20 and rapidly cooled it over a period of about ten
21 minutes, and we were able to visibly see formation of
22 precipitates.

23 It was a rather qualitative test at that
24 time, but we were able to collect some direct evidence
25 of head loss behavior, which will be presented in the

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1 future.

2 No apparent trend in the kinematic
3 viscosities. Relatively little discoloration and mass
4 loss in the metal plates by comparison to other tests.

5 CHAIRMAN WALLIS: I think you're measuring
6 dynamic viscosity. We had this little -- kinematic is
7 Nu over Rho , isn't it?

8 MR. LETELLIER: Yes, and these are all
9 presented in meters squared per second. These are
10 kinematic.

11 CHAIRMAN WALLIS: So they are Nu over Rho .

12 MR. LETELLIER: Yes. Some clarification
13 to the very last bullet. The fiberglass condition, I
14 should have just rewritten this. It was relatively
15 clean compared to other test, but there were minor
16 floc deposits on the interior and the exterior, but
17 only minor particulate deposits on the exterior of the
18 fiberglass samples.

19 The remaining slides are probably best
20 presented on the floor of your living room with
21 everything out in front on the table. This is the
22 first opportunity we've had to look at the trends over
23 the full 30 days for all five tests in combination.

24 Pages 22 and 23, you can compare those two
25 side by side. It represents the kinematic viscosity

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1 at room temperature compared to the same viscosity at
2 the test temperature of 60 degrees.

3 Test No. 1 shows a clear departure as
4 visible precipitates were being formed more and more
5 rapidly during the course of the test at room
6 temperature, but at 60 degrees there was never any
7 visible precipitate formed.

8 There are some reference points noted
9 there in the text box, what pure water, the behavior
10 of pure water would be at the same temperatures, and
11 in all cases, you can convince yourself that this was
12 at the measurement accuracy or slightly above the
13 behavior of water within the limits of the
14 measurement.

15 There is a slight bump in the test
16 temperature for viscosity for Test No. 1 which
17 represents a procedural change. These tests were
18 confounded --

19 PARTICIPANT: You mean at 60 C.

20 MR. LETELLIER: Yes, at 60 C. I can point
21 to it on the viewgraph at approximately day number 13
22 or 14. We had to modify our procedures to account for
23 the unexpected presence of chemical precipitate.

24 DR. BANERJEE: So the increase at 23
25 degrees Celsius for the Test 1 you attribute to the

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1 formation of the suspension due to precipitates.

2 MR. LETELLIER: Clearly so. This was a
3 visible quantity of material. In fact, we had
4 difficulty executing the procedure as we extracted it
5 from the tank and moved it to a water bath. The
6 solution would floc in real time, visibly so.

7 DR. BANERJEE: And it would stay
8 suspended. It wouldn't settle out.

9 MR. LETELLIER: It did settle over the
10 course of -- I don't know -- a few hours, tens of
11 minutes to an hour. In fact, at the end of the test
12 it's useful to look at our archive bottles and just
13 simply look at the depth, increasing depth of the
14 precipitate over time.

15 DR. BANERJEE: So these measurements were
16 made almost immediately after extraction, and so they
17 were still suspended.

18 MR. LETELLIER: That's correct.

19 DR. BANERJEE: So there's sort of a stock
20 (unintelligible) effect.

21 MR. LETELLIER: That's right. So there's
22 a clear perturbation of the particulate to the
23 viscosity measurement.

24 MR. TREGONING: I think these were made
25 within ten minutes of extraction. Even the room

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1 temperature results, the higher temperature of
2 viscosity measurements were made immediately
3 obviously.

4 MR. LETELLIER: We corrected our
5 procedure in mid-course to introduce a water bath so
6 that they could be immersed immediately, you know,
7 within seconds. So until the apparatus was properly
8 prepared to avoid temperature fluctuation.

9 MR. CARUSO: Why didn't you see this
10 effect in ICET 3?

11 MR. LETELLIER: That's a very good
12 question.

13 MR. TREGONING: Do you mean ICET 3 or 4?
14 ICET 3 if you've got your matrix is a TSP buffered
15 environment. ICET 1 is a sodium hydroxide buffered
16 environment.

17 MR. CARUSO: Which was the one that
18 produced the large amounts of precipitant?

19 MR. TREGONING: ICET 3.

20 MR. LETELLIER: I understand your
21 question. I think if we look at the turbidity, you'll
22 see that although this precipitate was formed very
23 quickly, it also settled. So it was not present in
24 solution as a solid.

25 MR. CARUSO: So these were measurements of

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1 the solution without the precipitant in ICET 3, but in
2 ICET 1 the precipitant was still there, and it had an
3 effect.

4 MR. LETELLIER: At the test temperature
5 in Test No. 1, there was never any visible
6 precipitate, but when we extracted a raw sample, it
7 would immediately flocculate. So there's a very high
8 concentration near a saturation or agglomeration
9 point.

10 DR. BANERJEE: So due to the cooling,
11 right?

12 MR. LETELLIER: Yes. It was a
13 temperature effect.

14 MR. TREGONING: It becomes visible upon
15 cooling. I think that's an important observation.

16 MR. CARUSO: Does that imply that if you
17 had changed those ICET 1 conditions slightly, you may
18 have seen a lot of precipitant form?

19 MR. LETELLIER: There has been that
20 speculation, that if the test had been executed at a
21 lower temperature, in effect, we would have reached a
22 saturation point.

23 MR. CARUSO: I mean not just temperature,
24 but I mean if you had changed the -- let's see. That
25 was sodium hydroxide?

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1 MR. LETELLIER: Yes.

2 MR. CARUSO: If you had changed the sodium
3 hydroxide slightly, if you had changed the boron
4 concentration slightly, if you had changed something
5 else slightly, you may have seen a lot more
6 precipitant?

7 MR. LETELLIER: It is possible. I would
8 be most suspicious of the temperature. That's why I'm
9 emphasizing the fact that it precipitated upon cooling
10 because our tests were isothermal in nature, but the
11 power plant is not. There are clearly heat exchangers
12 and other temperature variations.

13 MEMBER SHACK: But since we have to try to
14 replicate this stuff without going through this thing,
15 what we do find is, of course, it is a tricky balance
16 between temperature, pH and concentration. It's not
17 surprising because if you were at a different pH, you
18 would get to a different concentration, and obviously.
19 So the concentration and the pH are not independent
20 variables, you know. You have to kind of couple them
21 together. So to say what would happen at a different
22 pH is a little tricky to answer because you don't know
23 what the corresponding concentration. If you kept
24 this concentration and lowered the pH, yeah, you're
25 going to drop stuff like a rock.

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1 MR. CARUSO: I'm just saying there are
2 lots of degrees of freedom here, and you know, you
3 found that when you lowered the temperature, but maybe
4 something else might have precipitated it.

5 MR. LETELLIER: There are. As we
6 struggle with the issue of chemical speciation, trying
7 to determine exactly what chemical form these
8 materials have, you begin to understand that the phase
9 of the association between these materials affects its
10 physical solubility. It affects the saturation
11 levels. It affects the physical formation of colloids
12 and larger agglomerates.

13 DR. BANERJEE: So why did you measure
14 kinematic viscosity? Because it seems to me that it's
15 a function of time after you do this cooling or
16 whatever, you know. So it's not a robust measure.
17 It's an indicator of maybe a suspension, if nothing
18 else.

19 MR. LETELLIER: Indeed, that's very true,
20 and we modified our procedure to accommodate the time
21 dependence. So we've proceduralized the cooling times
22 and the measurement times in order to have a common
23 basis for comparison.

24 But, in effect, this was exploratory in
25 nature. We knew that turbidity could be a sensitive

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1 indicator of the presence of products, and indeed, we
2 found some.

3 MEMBER SHACK: It's still interesting
4 though. I mean, you know, we've had discussions
5 before whether there's a trend. I think you really
6 have to agree there's still an upward increase in
7 viscosity there from Day 15 on where the concentration
8 is constant.

9 DR. BANERJEE: So you've got more stuff
10 suspended.

11 MEMBER SHACK: No, no. If he shows his
12 aluminum concentration.

13 MR. LETELLIER: That's right. If we
14 could flip back, we'll see that. The aluminum
15 concentration has apparently flat lined. It has
16 reached some equilibrium level. I won't say that it
17 is saturated because I don't understand the physical
18 chemistry, but nonetheless it has stabilized, and Dr.
19 Shack is right. The room temperature viscosity
20 continues to increase.

21 As I describe it, these samples would
22 precipitate faster and in larger quantities as the
23 test progressed.

24 CHAIRMAN WALLIS: There's an anomalous dip
25 at three weeks. I don't think we need to spend too

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1 long on this slide, do we?

2 MR. LETELLIER: No. Let's move on.

3 CHAIRMAN WALLIS: I'm not sure this is
4 going to affect the sumps very much.

5 MR. LETELLIER: These slides will evoke
6 many questions --

7 CHAIRMAN WALLIS: I bet they will.

8 MR. LETELLIER: -- that I'm not prepared
9 to answer. There are many open questions here,
10 although there are coherent pictures. Explanations of
11 the trends and the behavior of our chemical systems
12 are starting to make sense. They're starting to
13 emerge.

14 I will note a couple of --

15 DR. BANERJEE: So this is the supernatant
16 solution you're taking off.

17 MR. LETELLIER: That's correct.

18 CHAIRMAN WALLIS: Yes.

19 MR. LETELLIER: Page number 24 simply
20 illustrates that the pH is relatively stable
21 throughout the test. They were initialized as close
22 as possible to a target level, and they did not drift.

23 You should understand that we made no
24 attempt to control the pH. The test was initialized
25 and observed.

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1 Slide number 25 is one of the obviously
2 more interesting and somewhat erratic plots. However,
3 the quantity of suspended solids is also an important
4 indicator of --

5 CHAIRMAN WALLIS: To see the yellow one
6 you have to sort wiggle this thing around.

7 DR. BANERJEE: You can't see it here.

8 MR. LETELLIER: It is very difficult on
9 the photograph. If you look at the figure on the
10 wall --

11 CHAIRMAN WALLIS: You don't see it at all?
12 It doesn't appear at all on the black and white ones.

13 MR. LETELLIER: If you look at the
14 screen, you can probably trace it. You can make out
15 between the dots what the trends are. That is for
16 Test No. 3 in yellow.

17 CHAIRMAN WALLIS: Well, the other one is
18 something remarkable on Day 24.

19 MR. TREGONING: That measurement.

20 MR. LETELLIER: It may very well be an
21 anomalous measurement on day 24.

22 (Laughter.)

23 MR. LETELLIER: For Test 3.

24 MR. TREGONING: Not using that word,
25 remember?

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1 DR. BANERJEE: How do you do these
2 suspended solids?

3 MR. LETELLIER: This is actually
4 measurements that's made by our water quality
5 laboratory off site, and my understanding is they do
6 an ultra filtration basically to look at the
7 comparison of suspended --

8 CHAIRMAN WALLIS: These are milligrams per
9 liter. All you need is one little grain, which is
10 big, and it warps everything.

11 MR. LETELLIER: That's true, but if we
12 look at the next few slides on turbidity, you will see
13 that the supernatant is very clear. It's very clean,
14 except for the finely divided material.

15 MR. CARUSO: What sort of error bars
16 should appear on these data points?

17 MR. LETELLIER: That's a fair question
18 that's immediately begged by a plot of this level of
19 variability. The measurements at the lab were taken
20 within quality assurance standard to the limits of
21 accuracy, and their methods were repeatable. Those
22 errors vary according to the concentrations that were
23 measured and we can look that up for you.

24 What I would like to say is that the
25 measurement errors were small compared to the

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1 variability between the samples, and that's what we're
2 seeing evidence of here.

3 CHAIRMAN WALLIS: Now, the lines you show
4 here through the dots, those are the theoretical
5 predictions?

6 MR. LETELLIER: No. No, sir. They're
7 simply spline threads to guide the eye.

8 MR. CARUSO: I mean, what would you
9 estimate that they are? On the order of a few units
10 or tens of units or a fraction of a unit?

11 MR. DALLMAN: Bruce, are we talking about
12 TSS?

13 MR. LETELLIER: Yes, we are.

14 MR. DALLMAN: Those were not sent to the
15 lab. That was just the difference in weight of our
16 filter paper.

17 MR. LETELLIER: That explains a lot of
18 the variability. These are very small quantities.
19 Jack, this is the comparison between the raw water
20 sample and the filtered sample; is that correct?

21 MR. DALLMAN: I'm sorry. I'm having a
22 hard time hearing you, but I just realized what you're
23 talking about. The total suspended solids we
24 determined just by weighing the clean filter paper and
25 then the filter paper after we had run solution

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1 through it. And so there is a fair amount of -- as
2 you said, there's not much difference in weight. So
3 there could be a lot of uncertainty here.

4 MR. LETELLIER: But the accuracy of the
5 mass measurement is within one-hundredth of a
6 milligram.

7 MR. DALLMAN: That's correct.

8 MR. LETELLIER: Typically. The
9 volumetric measurements are more uncertain.

10 DR. BANERJEE: So let's understand the
11 protocol here. You take the sample out, and then you
12 let it settle for a period of time. So you take out
13 the larger things?

14 MR. LETELLIER: No, as Jack --

15 DR. BANERJEE: How do you do these
16 experiments?

17 MR. LETELLIER: As Jack reminded me,
18 there is a sample tap on the primary plumbing. So
19 when we extract the water, it comes directly out of
20 the flow, and we are able to measure the mass of a
21 filter paper and attach it to a cassette and draw off
22 a measured volume of water. And by drying the filter
23 and comparing the weights, we have evidence of total
24 suspended solid.

25 DR. BANERJEE: So this is recirculating

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1 water. You're drawing it off as you go along.

2 MR. LETELLIER: Yes, that's right, and
3 these do have a limit of filtration efficiency. These
4 are, I believe, Jack, .45 micron filters.

5 MR. DALLMAN: Yes, yes.

6 CHAIRMAN WALLIS: How big is the sample in
7 liters that you draw off?

8 MR. TREGONING: About 100 milliliters?

9 MR. LETELLIER: These were also the 100
10 milliliter samples, Jack?

11 MR. DALLMAN: I believe so, yes.

12 CHAIRMAN WALLIS: A hundred milliliters.
13 So you're talking about milligrams per liter. You're
14 talking about measuring pretty accurately.

15 MR. LETELLIER: Averaged over a volume of
16 100 milliliters. Now, we also extracted higher volume
17 samples periodically, but not daily.

18 CHAIRMAN WALLIS: The one speck of dust
19 would make a difference here.

20 MR. LETELLIER: It would. That
21 substantiates my comment that the variability in the
22 samples is driving the behavior here, not the accuracy
23 of the measurement.

24 Now, the filtration efficiency is
25 important because we have evidence that there are very

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1 large inventories of aluminum perhaps bound in
2 colloidal formations that would happily go through
3 this filter. So although they're present in the
4 liquid, there's a fine line between suspended solid
5 and colloidal suspension.

6 DR. BANERJEE: Did you do any light
7 scattering?

8 MR. LETELLIER: We did, not as a daily
9 exercise and to some limited success for particle
10 sizing.

11 DR. BANERJEE: These are colloidal. Do
12 you think these are colloids?

13 MR. LETELLIER: We do. In fact, there
14 will be later presentations in the summer that show
15 some of our particle sizing looking at the aluminum
16 hydroxide suspensions.

17 CHAIRMAN WALLIS: These are all the tests.

18 MR. LETELLIER: We can quickly flash
19 through the turbidity, Slides 26 and 27. It's
20 important to note that most of the tests quickly
21 clarify at the test temperature they're substantially
22 clear within three to four days, and test number two
23 seemed to take slightly longer by comparison.

24 At room temperature, the turbidity follows
25 the viscosity trend for Test No. 1, and there is a

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1 typographical error on Slide 27. This is turbidity
2 measured at 23 degrees C., the same as the viscosity.

3 DR. BANERJEE: Is it possible to get a
4 volume fraction of suspended solids from the
5 turbidity?

6 MR. LETELLIER: We have attempted in the
7 past to do some controlled calibration where we
8 introduce a known mass of material into a suspension
9 and try to calibrate the units. The turbidity meter,
10 turbidimeter is an optical measurement, and I
11 apologize. I don't know enough about the theory to
12 speculate on the success of that conversion factor.
13 It's primarily a physical dimension and has nothing to
14 do with the mass of the material.

15 DR. BANERJEE: If you filtered this in the
16 way you did before, there was no trend, if I remember,
17 to the mass for ICET 1. There was just --

18 CHAIRMAN WALLIS: Well, he's speculating
19 that the colloids go right through the filter.

20 DR. BANERJEE: Oh, I see.

21 CHAIRMAN WALLIS: But the affect the
22 turbidity now.

23 DR. BANERJEE: Yes.

24 MR. TREGONING: At the risk of over
25 generalizing, I think most of the measurements that we

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1 conducted in all of these tests, there was not a
2 significant difference between filtered and unfiltered
3 results in general.

4 MR. LETELLIER: That's correct.

5 I just noticed something. Ralph had a
6 question about the presence of the precipitate and
7 test number. No, I'm sorry. Test No. 2 -- I'm going
8 to retract that statement.

9 MR. TREGONING: You didn't make it.

10 MR. LETELLIER: Just in time. Let's move
11 on to Slide 28, the hydrogen generation. Test No. 1
12 obviously shows the most activity as far as our semi--

13 CHAIRMAN WALLIS: What is the unit on
14 this?

15 MR. LETELLIER: These are percent
16 composition.

17 CHAIRMAN WALLIS: Of the gas.

18 MR. LETELLIER: Yes.

19 CHAIRMAN WALLIS: So it doesn't tell you
20 about the rate of evolution.

21 MR. LETELLIER: That's right. It does
22 not. There is some qualitative information. For
23 example, in the curve for Test No. 2, which is the
24 solid diamond, there is a modest increase at Day 11.
25 Just as an exercise, we closed the passive ventilation

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1 lines to let this accumulate and so the slope of that
2 curve does tell you something about the rate of
3 evolution, but keep in mind these gas samples were
4 taken from the head space, and it is not designed as
5 an airtight system. The measurements were done from
6 the point of view of safety consideration, but
7 nonetheless the trends here are evident.

8 In Test No. 1, there were several days,
9 several times where we would remove the cover for
10 various reasons, the equipment hatch, and completely
11 evacuate the head space through passive ventilation.
12 that's evidenced here through these dips in the trend.

13 DR. BANERJEE: So the highest one is Test
14 1.

15 MR. LETELLIER: Test 1, yes.

16 CHAIRMAN WALLIS: That's the aluminum,
17 yeah.

18 MR. LETELLIER: And now we're getting
19 into pages 29 and 30. We're beginning to look at the
20 trends in elemental concentrations. Test No. 1 showed
21 the highest levels of aluminum in the solution, and
22 here's where you can see that there may have been
23 evidence of some plateau in effect.

24 It's very tempting to say that this is
25 dissolved material, but there are very fine

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1 definitions between suspended and dissolved ions in
2 solution. Because we speculate that there's a large
3 inventory of colloids, I would not describe this as
4 the dissolved aluminum inventory.

5 There's clearly a bad data point on Day 16
6 that's suspicious, but the trend is there nonetheless.

7 Test No. 5 also showed a measurable
8 aluminum concentration. None of the other tests
9 really appear on this scale, and in many cases they
10 were not reported, period.

11 What is notable for Test No. 1, which
12 we'll see later, is the silica concentrations were
13 surprisingly low. We had some evidence from beaker
14 tests and simulation studies that the fiberglass
15 should be leaching substantial quantities, and in
16 fact, --

17 CHAIRMAN WALLIS: This is what you found
18 in the tests you did before this.

19 MR. LETELLIER: Yes, in the bench scale.

20 CHAIRMAN WALLIS: It was a big discovery,
21 as I remember. There was a lot of silica.

22 MR. LETELLIER: The silica concentration
23 is shown on page 32, and for Test No. 1 it's extremely
24 low. That surprising effect led us to investigate
25 more, looking at the interactions between the silica

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1 and the aluminum phases and how they affect the joint
2 solubility.

3 So in Test No. 1 we speculate that the
4 evolution of silica was suppressed by the high
5 concentration of aluminum, and conversely, in Test No.
6 4, we had a suppressed aluminum concentration with a
7 high inventory of silica, which came from the calcium,
8 calcium silicate.

9 So there's sort of a converse relationship
10 here where they're interacting in a dominant fashion,
11 but on opposite ends of the concentration spectrum.

12 Calcium concentrations on page 30 --

13 CHAIRMAN WALLIS: How do I convert this to
14 what's in the sump? I've got milligrams per liter.
15 So how many liters are there in the typical sump? I'm
16 trying to get some idea of how much stuff there is in
17 a typical sump.

18 MR. LETELLIER: Five hundred thousand
19 gallons or less.

20 CHAIRMAN WALLIS: Could you do the
21 arithmetic?

22 PARTICIPANT: Two million liters.

23 CHAIRMAN WALLIS: Roughly two million
24 liters?

25 MR. LETELLIER: Or slightly less.

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1 CHAIRMAN WALLIS: If I multiply milligrams
2 by two million or at least a million, so I get
3 kilograms.

4 DR. BANERJEE: And this is all sort of --

5 CHAIRMAN WALLIS: So I get something like
6 hundreds of kilograms.

7 DR. BANERJEE: Clear liquid.

8 CHAIRMAN WALLIS: That makes it sound more
9 dramatic than milligrams per liter.

10 MR. LETELLIER: Indeed. And some of the
11 small scale chemistry work that was done indicated
12 that, for example, solubility saturation limits would
13 be reached within a few kilograms of corroded
14 material, 23 kilograms of aluminum in a million
15 gallons of water, for example, represented the
16 saturation point for -- Mark will correct me -- for a
17 crystalline form, a solid phase of aluminum.

18 Now, we're seeing much higher inventories
19 of aluminum than the solid phase would suggest, but
20 much lower levels of aluminum than the amorphous phase
21 would permit. And so we're stuck somewhere in the
22 middle, and it's a very complicated system between the
23 aluminum and the silica that are in the solution.

24 CHAIRMAN WALLIS: When all of this is
25 done, is someone going to tell us what this means for

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1 the sump program?

2 MR. LETELLIER: We are --

3 CHAIRMAN WALLIS: It's fascinating.

4 PARTICIPANT: Dr. Shack.

5 CHAIRMAN WALLIS: Dr. Shack will.

6 MR. LETELLIER: We are presently working
7 to analyze this information and put it in context. I
8 suspect we will fall short of implications. It's
9 probably LANL's job and responsibility to explain what
10 we've seen. Extrapolating that to the plant condition
11 is another level of effort we'll talk about.

12 DR. BANERJEE: But this is all relatively
13 clear liquid.

14 MR. LETELLIER: Yes, visibly clear.

15 DR. BANERJEE: Visibly clear liquid, and
16 these are, let's say, the unfiltered calcium. Is this
17 also in colloidal form you think or let's say you're
18 trying to explain this stuff, right? Or is it in
19 solution?

20 MR. LETELLIER: I have less information
21 available about the physical form of the calcium. For
22 example, Test No. 3, which obviously was introduced
23 through the calcium silicate as a dominant source
24 term, some of this material is suspended as a physical
25 particulate.

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1 Bill would you like to comment on the true
2 dissolution of calcium?

3 That's also very high as a constituent.

4 MEMBER SHACK: The CalSil fines will
5 remain suspended for a long time. So that you will
6 get some contribution there, but you also get
7 substantial dissolution of the CalSil. So you
8 probably have a combination of both.

9 DR. BANERJEE: So this curve there is a
10 combination of suspended --

11 MR. LETELLIER: And it's really a
12 question of which dominates. I would suspect that
13 this is more soluble than suspended based on --

14 DR. BANERJEE: How did you determine this
15 curve?

16 MR. LETELLIER: This is done by ICP
17 analysis. This is part of our daily water sample
18 that's sent off site. So there's actually a spectral
19 signature of concentration.

20 DR. BANERJEE: but will that give you the
21 suspended concentration as well?

22 MR. LETELLIER: No, it gives you the
23 total

24 MR. TREGONING: It can't differentiate
25 what the form is. The only way to do that, if you

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1 filter something out, if it's physically large enough
2 to be filtered out, you can get some inference that
3 way, but if it's not physically large enough,
4 distinguishing whether it's dissolved or colloidal,
5 this diagnostic is not applicable for that.

6 DR. BANERJEE: Yeah, I'm trying to
7 understand this deposit that you form there. So
8 you're circulating the stuff around, and when you draw
9 it out, it looks clear. But there is some amount of
10 this which is obviously coming out over a period of
11 time on the five quals, right?

12 MR. LETELLIER: Yes. Jack, could you
13 remind me at what point the flow meter was fouled by
14 deposits in Test 3?

15 MR. DALLMAN: Day eight.

16 MR. LETELLIER: Day No. 8?

17 MR. DALLMAN: Correct.

18 MR. LETELLIER: So the large inventory of
19 precipitates was formed within 30 minutes, very short
20 term, and the tank clarified within a few days. So
21 it's very reasonable to assume that those deposits
22 occurred relatively early in the test.

23 MR. TREGONING: And just go be clear,
24 "clear" is a relative term. It didn't look -- most of
25 the time the water at a minimum was discolored, quite

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1 often either yellowish in appearance or rosy in
2 appearance, depending on the exact composition of the
3 initial make-up of the tank.

4 So I mean, there was discoloration
5 observed in all of these tests, at least in the water
6 sample. So, yes, it's clear in a turbidity sense, but
7 you know, there's certainly evidence that there are
8 additional constituents within this water than would
9 be apparent in either --

10 DR. BANERJEE: But it could be in
11 solution.

12 MR. LETELLIER: It could be in solution,
13 certainly.

14 MEMBER SHACK: Right, and one of the other
15 things he's not showing is phosphate levels here.
16 But, in fact, his phosphate levels have dropped
17 substantially through the tests. So basically he's
18 got enough calcium here to take all of the phosphate
19 out, and then the CalSil still keeps dissolving, and
20 there's no more phosphate to take it out. So it
21 builds up.

22 So it's all, you know, a consistent
23 picture.

24 MR. LETELLIER: Day three in Test No. 3
25 is when the phosphate became depleted at least by Test

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1 3. It's interesting that you see a little dip there
2 in the calcium concentration about day one, and then
3 it elevates pretty quickly by Test 3 and then the
4 trend is more gradual, but still accumulating.

5 That initial trending may be related to
6 this phosphorus depletion.

7 CHAIRMAN WALLIS: Tell us what CalSil is
8 and what is its chemical constituents? We always call
9 it CalSil, but in what form is the calcium? Is it a
10 silicate or a carbon? It's not a carbon?

11 MR. VIJAY JAIN: It comes from silicate.

12 CHAIRMAN WALLIS: Is the calcium aluminum
13 silicates, no aluminum silicates? Isn't it made from
14 diatomaceous earth or something?

15 MR. LETELLIER: Indeed.

16 CHAIRMAN WALLIS: So that has all sorts of
17 stuff in it.

18 MR. LETELLIER: Yes.

19 MR. CARUSO: But depending on the source
20 it could potentially, yes.

21 CHAIRMAN WALLIS: But it's mostly calcium
22 silicate. Is that what it is?

23 MR. VIJAY JAIN: This is Vijay Jain from
24 the Center for Nuclear Waste.

25 The majority of it is calcium silicate,

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1 but it has about ten percent sodium silicate which is
2 used as a binder to put it together, and it has
3 aluminum and some other impurities that go along with
4 it, including potassium, magnesium, and so on.

5 CHAIRMAN WALLIS: It probably has aluminum
6 silicate, doesn't it? These things have that.

7 MR. VIJAY JAIN: Compared to calcium, the
8 aluminum is very, very small fraction.

9 CHAIRMAN WALLIS: Very small, okay.

10 MR. LETELLIER: The diatomaceous earth is
11 a biological product, and you wouldn't necessarily
12 expect the aluminum silicates to be concentrated in
13 that manner.

14 CHAIRMAN WALLIS: All right.

15 MR. LETELLIER: But we talked yesterday
16 about the diversity of the insulation product. In
17 some respects CalSil is much like concrete. It
18 depends on where you take the raw materials and how
19 you thermally combine it, the history.

20 CHAIRMAN WALLIS: So that's something that
21 has to be taken into account then. That's why
22 everything is plant specific, is it?

23 MR. TREGONING: That's another factor for
24 consideration. How important it is, I think, remains
25 specifically on what portion of the problem you're

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1 really looking at.

2 MR. CARUSO: Do any of the chemical
3 species you saw have reverse solubilities?

4 MR. LETELLIER: Indeed, they do. The
5 calcium is one.

6 MR. CARUSO: So what happens to all of
7 that calcium when it gets in the core?

8 MR. LETELLIER: It may precipitate
9 depending on where its point of origin, if you will,
10 in terms of dissolution occurs. If it's principally
11 dissolved in the containment pool, eventually it will
12 experience both higher and lower temperature regimes
13 in the RCS.

14 CHAIRMAN WALLIS: Well, it goes through
15 the RHR heat exchanger.

16 MR. TREGONING: Right.

17 CHAIRMAN WALLIS: Isn't that the place
18 where it gets cold?

19 MR. LETELLIER: Yes. And it also goes
20 through the core.

21 CHAIRMAN WALLIS: Well, it doesn't get so
22 cold in the core, does it?

23 MR. LETELLIER: I imagine it would
24 experience both extremes compared to the pool. That's
25 right.

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1 DR. BANERJEE: but all of your deposition
2 you'd think occurred in the early part of this.

3 MR. LETELLIER: For Test No. 3
4 specifically that --

5 DR. BANERJEE: Yes, specifically.

6 MR. LETELLIER: -- that's right.

7 DR. BANERJEE: And the other stuff was
8 slowly growing over a period of time or what? You
9 never measured. You didn't have a coupon or something
10 that you were measuring deposition with over time.

11 MR. LETELLIER: Except for our
12 sacrificial fiberglass samples which were pulled out
13 periodically, that's basically our only evidence of
14 surface phenomena. Post test we were able to break
15 open the lines and inspect the surfaces.

16 CHAIRMAN WALLIS: You are about ready to
17 wind up, I think.

18 MR. LETELLIER: I think we are. Some of
19 the most coherent explanations are associated with the
20 silica and the aluminum trends in Test No. 1 and also
21 the calcium and phosphate interactions for Test No. 3.

22 If we jump to the very end of the package,
23 page number 35, I'll just remind you that the ICET
24 program has been very prolific as far as generating
25 information and documenting sharing this evidence. So

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1 there's a library of test reports for your reading
2 pleasure.

3 DR. BANERJEE: Is it on the Web site?

4 MR. LETELLIER: Yes.

5 MR. CARUSO: You have all of this stuff
6 that's on the CD.

7 DR. BANERJEE: It's on the Web site, too.

8 MR. TREGONING: Theoretically, yes.

9 CHAIRMAN WALLIS: But the striking thing,
10 as I say, back the beginning when you read your
11 summary in the report, you sort of indicate we found
12 all of sorts of interesting stuff, but each plant is
13 different. Therefore, everything has to be done on a
14 plant specific basis, and we don't have any sort of
15 general conclusions or models or something which you
16 can take and apply right away.

17 MR. LETELLIER: But by its nature the
18 ICET test was a very sparse sampling of the parameter
19 space.

20 CHAIRMAN WALLIS: Sure.

21 MR. LETELLIER: And yesterday I forget
22 who presented the matching of how many plants most
23 closely associate with each test. I think that the
24 ICET series represents a very good starting point. We
25 now have benchmarks on which to stand and look for the

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1 more subtle variations between plants, if you will.

2 CHAIRMAN WALLIS: We have a starting
3 point, and the question is when do we get to the
4 finish line or how do we get to the finish line.d

5 DR. BANERJEE: Marathon.

6 MR. LETELLIER: Many of the questions
7 associated with the resolution involve rates, rates of
8 production, rates of accumulation. ICET test was not
9 specifically instrumented to study that level of
10 detail.

11 There are proposals and a lot of
12 discussion about what we would do next if given the
13 opportunity, but right now we're very busy digesting
14 the information we have.

15 DR. BANERJEE: Did you measure the total
16 amount of precipitates and reaction? You talked a lot
17 about this clear liquid, but there was the reactions
18 produced, precipitate that stayed in the tank, and so
19 on. So what happened there?

20 MR. LETELLIER: You're basically asking
21 whether we were able to do a mass balance on the whole
22 system, and --

23 DR. BANERJEE: And compositional balance.

24 MR. LETELLIER: I cannot claim that we
25 were successful in compositional balance, and even the

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1 mass balance was rather crude because of the
2 difficulties of reclaiming the material from the tank
3 and the fact that we have evaporation and water
4 replacement during the course of the test.

5 It's physically dispersed. While we might
6 start with a handful of crushed concrete at the
7 beginning, it now appears as residue on every single
8 surface. So it's quite problematic to look at that.

9 In the global perspective, tests like
10 number three, as Dr. Shack mentioned, we can look at
11 the stoichiometry of available calcium versus
12 available phosphate, and we can argue that that
13 reaction went to completion essentially, and because
14 we know the concentrations of phosphate in the
15 chemical buffering system, we can speculate on the
16 quantities, actually reasonably good estimates of
17 total quantity that would be formed over time.

18 Again, it's the rate. If it's all
19 produced in 30 minutes or if it takes substantially
20 longer in the plant environment.

21 DR. BANERJEE: So let me ask this.
22 Suppose you took what was there after the event and
23 you mixed it all up, and now you did a chemical
24 analysis to find out what the species were and how
25 much there was in a sample of this awful mixed goo.

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1 Did you do something like that or this is obviously a
2 very unrealistic experiment, but nonetheless is there
3 a way to say what happened looking at the residues?

4 MR. LETELLIER: I'm afraid that the
5 physical heterogeneity of this goo, this residue would
6 preclude that effort. We did recover sediment
7 samples, and under SEM analysis you see granules of
8 sand. You see broken fibers. You see chemical
9 products. It's very diverse.

10 In addition to that, on a larger physical
11 scale, you see shreds of original insulation material
12 an even larger than that, you see the metal plates.

13 The question of what sample size would you
14 choose to homogenize is very difficult.

15 DR. BANERJEE: So the clear samples
16 provide two types of -- maybe more -- types of
17 information. One is it indicates what reactions have
18 occurred potentially and what have gone to completion
19 or not. It gives you some indicator of that.

20 Second, it tells you, I suppose what
21 materials might be transported past the filters and so
22 on because it's basically clear liquid or maybe
23 turbid, but very fine. So it has implications on
24 downstream deposition.

25 MR. LETELLIER: From a chemical

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1 perspective, yes, that's right.

2 DR. BANERJEE: From a chemical
3 perspective, right?

4 MR. LETELLIER: Un-huh.

5 DR. BANERJEE: But the third thing, I
6 suppose, is that it might clarify the deposition that
7 you're getting on the walls. I don't see that
8 connection having been made.

9 CHAIRMAN WALLIS: Did you scrape this
10 stuff off the walls and then take it away and analyze
11 it?

12 MR. LETELLIER: We did, but you need to
13 remember that we recovered those samples after the
14 tank was drained and substantially cooler. So whether
15 or not that's present in situ --

16 CHAIRMAN WALLIS: Well, I think in the
17 pipes it probably was present because it's unlikely to
18 have that much liquid in the pipe to throw out the
19 stuff on the wall after it has cooled.

20 MR. LETELLIER: For Test No. 3, that's
21 obviously true. For the other tests, we're talking
22 about white residue.

23 CHAIRMAN WALLIS: Very small.

24 MR. LETELLIER: Yes.

25 CHAIRMAN WALLIS: You said eighth of an

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1 inch. I think it isn't an eighth of an inch, is it?
2 It's more like --

3 MR. TREGONING: Maybe thumbnail, smaller
4 than that.

5 DR. BANERJEE: Thirty-second of an inch,
6 but still --

7 MR. LETELLIER: Again, that may be too
8 quick of a judgment based on the thickness of those
9 veins and the flow meter, which they're actually a
10 flow perturbation which tends to have an impaction
11 perhaps larger than the walls and accumulate much
12 thicker than the walls.

13 DR. BANERJEE: There's a lot of
14 information left over in the non-supernatant liquid,
15 right? So what did you learn from that? What stuff
16 is left in the tanks?

17 MR. LETELLIER: Well, again, recovery of
18 those samples was complicated by the location and the
19 mixture. In cases like Test No. 3 where there was
20 simply such a large inventory of chemical product, we
21 were reasonably successful at recovering a sample
22 which we thought represented the more pure form, and
23 so we were able to put more credibility in the
24 elemental proportions of that sample.

25 In Test No. 1, which showed indications of

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1 precipitate upon cooling, it was more difficult to
2 isolate that material in the sediment of the tank.
3 Where we discovered large volumes is in the inventory
4 of the bulk water in the storage containers. After it
5 was cooled, it suddenly precipitated and formed 15 or
6 20 gallons of semi-solid sludge.

7 That material was also examined for its
8 chemical composition.

9 CHAIRMAN WALLIS: Well, really what the
10 big messages are, that with NaOH and no CalSil, you
11 get a fair amount of aluminum dissolved, and if you
12 put in CalSil and this TSP, then you get calcium
13 phosphate in fairly large quantities. Those are the
14 two big messages, aren't they?

15 MR. LETELLIER: Yes. And the other tests
16 actually substantiate those observations in a more
17 subtle way.

18 CHAIRMAN WALLIS: Are we ready to take a
19 break do you think?

20 You've done very well. Thank you. A very
21 nice, clear presentation, very responsive to
22 questions, and we're going to see you again today or,
23 no, we don't?

24 MR. LETELLIER: Tomorrow.

25 CHAIRMAN WALLIS: Tomorrow, tomorrow.

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1 Gee, whiz. Twenty-five after can we get back? Do you
2 remember that we're going to be back here at 25 past
3 11? We'll take a break.

4 (Whereupon, the foregoing matter went off
5 the record at 11:11 a.m. and went back on
6 the record at 11:25 a.m.)

7 CHAIRMAN WALLIS: Please come back into
8 session where we will hear the next presentation about
9 chemical speciation prediction. And maybe we'll make
10 it to lunch at a reasonable time.

11 Please go ahead.

12 DR. BANERJEE: You're in an advantageous
13 position right now.

14 MR. B.F. JAIN: We're here to talk about
15 the chemical speciation predictions. To my right is
16 Vijay Jain. He's from the Center for Nuclear Waste
17 Regulatory Analysis, part of Southwest Research
18 Institute, and they have done a lot of work in this
19 area.

20 Next one, please.

21 And this presentation will cover the
22 objective of this program, the motivations, a
23 technical approach, some of the preliminary findings,
24 and any other useful information which can be used for
25 ongoing work.

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1 Next one.

2 This program was initiated, the ICET
3 program, with the objectives of clearly to have a sort
4 of analytical tool whereby we can predict chemical
5 byproducts in any given sump environment.

6 In doing that, obviously it also included
7 a survey of all readily available commercial programs,
8 computer codes, and then also ask the center to
9 recommend a suitable code where we could use
10 prediction of these chemical byproducts.

11 CHAIRMAN WALLIS: These are equilibrium
12 predictions or are they kinetic?

13 MR. B.P. JAIN: They are mostly
14 equilibrium predictions.

15 Like any other code, we were also
16 interested in knowing what the limitations of these
17 codes were and what the code can and cannot do. So
18 those were the primary objectives of this study.

19 Next one, please.

20 And the program right away, obviously we
21 tested only five environments in the ICET program, and
22 the results as presented today, they showed that a
23 change in insulation or buffering agent, temperature
24 can greatly affect the type of chemical product or the
25 concentration you could get.

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1 So, again, the motivation was to be able
2 to predict, if we could, what these potential products
3 were in a given environment. The bottom line, as we
4 go over the details, but the bottom line is that
5 computer codes can predict better if those models are
6 properly benchmarked and calculated with the test
7 results from the data observed in the tests. That's
8 basically the bottom line.

9 Vijay will go over some of the program
10 directions and technical approaches.

11 MR. VIJAY JAIN: Good morning. Thanks,
12 B.P.

13 We adopted a phased approach in looking
14 into the speciation modeling. We started our work by
15 looking at the thermodynamic models using the inputs
16 that were based on the values that we obtained from
17 the literature, especially for corrosion, and we used
18 the exposed surface area in containment water
19 composition from the ICET test plan.

20 Again, the literature was very sparse in
21 the actual corrosion data for the specific containment
22 environment, specifically looking at 2,800 ppm boron.
23 So we started with a review of what's in the
24 literature, and then we followed the pre-test, pre-
25 ICET modeling that was based upon the input values

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1 that were tabulated based upon the experimental
2 results. We conducted independent standardized tests
3 to get the corrosion rates for metals, for insulation,
4 and concrete.

5 We also did some experiments, a
6 standardized test using aluminum and Nukon because
7 some of the literature indicates that aluminum has a
8 strong suppressive effect on Nukon release rates.

9 So we combined those experimental data,
10 developed a new set of input values, and did our
11 simulations, and finally, we benchmarked the
12 simulation based upon the observations we saw from
13 that ICET test.

14 So in this particular representation I'll
15 focus on the pre-ICET and the post ICET thermodynamic
16 simulations. There are lots of commercial codes in
17 the market. Some of them are listed here, such as
18 EQ3/6, geochemistry workbench, PHREEQC. These three
19 codes are typically used in geochemical, geochemistry
20 industry where they look at the weathering phenomena,
21 rock interactions with streams and so on.

22 The codes like Stream Analyzer and
23 environmental simulation programs, they are developed
24 by OLI systems and they are more geared toward the
25 chemical process industry.

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1 In this particular analysis, we adopted to
2 use the Stream Analyzer for our analysis because the
3 reality is it's more of a chemical process that the
4 water, steam comes in, interacts with different
5 components, and produces the byproducts.

6 Furthermore, Stream Analyzer is a very
7 powerful simulation tool. It covers a wide range of
8 pressure and pressure conditions. It can handle
9 concentrated solutions, and its thermodynamic database
10 is 250 solid species, along with many of the organic
11 species we need to model the organic phases.

12 Well, there's some assumptions that went
13 into doing this type of modeling. As you know, the
14 thermodynamic simulations are basically equilibrium
15 simulations. We assume all reactions achieve
16 equilibrium extently (phonetic). We exclude any
17 consideration of reaction kinetics, but in our case,
18 some of the reaction kinetics was partly included by
19 the user of experimental corrosion rates. So at
20 different times we used the corrosion rates to
21 calculate the amount of byproducts that were
22 generated, and we used those as input values for
23 simulations.

24 Again, the reactive materials as far as
25 those limited to ICET simulations or ICET tests and

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1 excluded paints and organics, and we also excluded
2 uptake of (unintelligible) CO₂ in this particular set
3 of slides that I'm going to show, but we do have a
4 future plan to look at CO₂ uptake into the solution.

5 Well, the way we do this simulation is we
6 select the containment water composition which has
7 2,800 ppm boric acid concentration or boron
8 concentration. We select a buffering agent, and then
9 we calculate the corrosion amount as a function of
10 time based upon corrosion rate of different
11 components.

12 I have about ten backup slides that
13 provide the pictures of the samples we use for
14 testing. It also provides the corrosion rate
15 measurements of different debris, metals, insulation.
16 Basically we used corrosion rates for zinc, copper,
17 aluminum, and carbon steel.

18 Depending upon what type of simulation we
19 were doing, we either chose Nukon or we used a mixture
20 of Nukon and calcium silicate, and we included
21 concrete.

22 DR. BANERJEE: These corrosion rates that
23 you estimated, were they corrosion rates change with
24 velocities and all of these types of things? How did
25 you choose these rates to use?

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1 MR. VIJAY JAIN: We didn't really include
2 any effect of velocity. These corrosion rates were
3 using electrochemical techniques, linear polarization,
4 and potential dynamic polarization methods, and
5 therefore fairly conservative rates.

6 DR. BANERJEE: They'll be high enough or
7 would they be too low if you expose. For example,
8 you've got this jet sitting places, right, and
9 dissolving stuff, that sort of thing happening. Now,
10 how do you take that into account here? You've got
11 water, steam water jet sitting in various components,
12 right?

13 MR. VIJAY JAIN: One of the ways that is
14 accounted for is exposed surface area. Corrosion
15 rates are milligrams per meter squared per power R
16 (phonetic). So if the impingement of the jet produces
17 debris of a certain specific area, you include that
18 specific area and on your specific area you will have
19 -- the corroded amount will be higher.

20 DR. BANERJEE: So there is no flow induced
21 effect, corrosion or aluminum?

22 MR. TREGONING: There was no account of
23 any erosion of metallic or nonmetallic components due
24 to the impingement of the LOCA jet.

25 DR. BANERJEE: No, that came off as

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1 erosion. They produced fines, right?

2 MR. TREGONING: Yeah, that wasn't
3 considered. I mean, that certain is source term,
4 although you have to remember that's a relatively
5 localized event compared to the rest of the
6 containment materials which are either exposed to
7 either submerged within the containment pool or
8 located in regions which are affected by the
9 containment spray.

10 So we didn't specifically look at the
11 erosion of, again, anything which might be in the way
12 of the jet.

13 MEMBER KRESS: Well, I suspect what you
14 have is liquid flowing by the surfaces , and the
15 corrosion rate is the function of mass transfer in the
16 liquid phase plus some sort of reaction going on near
17 the surface with the competing movement of materials,
18 corrosion products.

19 So what I think I hear you saying it's the
20 chemical corrosion rate itself that controls this and
21 not the mass transfer in the water so that you have
22 some sort of a way of having measured these corrosion
23 rates where the flow of the water just didn't matter.

24 DR. BANERJEE: If the assumption is that
25 it is reaction controlled --

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1 MEMBER KRESS: Reaction controlled.
2 That's what I'm interpreting.

3 DR. BANERJEE: Whether it's true or not is
4 another issue.

5 MEMBER KRESS: That's true, yeah.

6 MEMBER DENNING: Well, there are two
7 different things. I mean, right now we're just
8 looking at ICET and the ability to predict ICET. The
9 second question is given that you have validated this
10 kind of methodology, how do you apply it to the real
11 system?

12 MR. VIJAY JAIN: The corrosion for Nukon
13 and calcium silicate, we opted to select the forward
14 reaction rate, and these forward reaction rates are
15 way conservative, as you know. As a function of time,
16 the insulation material becomes passive and formation
17 of second (unintelligible) phases, the rate tends to
18 decrease with time.

19 For modeling purposes we assume the
20 forward reaction rate which is the initial portion of
21 the corrosion rate measurements for insulation
22 materials and also for concrete.

23 So the next few slides provide the
24 assimilation results using measured corrosion rate.

25 This slide shows the amount of predicted

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1 solid phases at 60 degrees, at 90 degrees, and at 110
2 degrees. Sixty degrees and 90 degrees, the
3 simulations were conducted at one atmospheric pressure
4 and 110 degree Centigrade, it was conducted at three
5 atmospheric pressure.

6 What you see here is the solid phases are
7 dominated by the solid circles which represents sodium
8 aluminum silicate and solid triangles which represents
9 calcium silicate, calcium and magnesium silicate.
10 These constituents, almost 99 percent of the solid
11 phases that are formed in the system containing and a
12 simulation that contains insulation, all the metals,
13 and concrete.

14 DR. BANERJEE: Is there a time associated
15 with this?

16 MR. VIJAY JAIN: These were all done for
17 half an hour.

18 I show here the conclusion from this were
19 greater amounts of various silicates were predicted to
20 form with increasing temperature action here, but not
21 significantly, not even a factor of two. Calpression
22 (phonetic) indicate that 99 percent of the solid
23 phases predicted in pressurized system would be
24 similar to the phases predicted in nonpressurized
25 system at lower temperature.

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1 Finally, the corrosion products from
2 insulation and aluminum are the major contributor to
3 the secondary solid phases. The contribution from
4 zinc and iron were very limited, and it doesn't even
5 account for one percent of the solid phases that were
6 formed in the system.

7 DR. BANERJEE: So what is corroding here?

8 MR. VIJAY JAIN: In this case you are
9 corroding Nukon fiber, and you are corroding
10 significant amount of aluminum, which is forming
11 sodium aluminum silicate. Calcium magnesium comes
12 from both fiber and some from concrete.

13 DR. BANERJEE: So copper is coming from
14 where?

15 MR. VIJAY JAIN: Copper is one of the
16 inputs coming from the heat exchanger pipes and some
17 wiring, I presume.

18 MR. TREGONING: I think cooler fan blades
19 is the predominant contributor. Maybe John Gisglom
20 (phonetic) would want to comment on that.

21 MR. GISGLOM: John Gisglom, EPRI.

22 It's the basic material --

23 PARTICIPANT: John, I think you have to
24 get up to the microphone.

25 MR. GISGLOM: The copper that we accounted

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1 for in ICET was the copper mainly in the heat
2 exchanger tubes and fins for the containment fan
3 cooler units.

4 DR. BANERJEE: Thank you.

5 And the calcium magnesium silicate?

6 MR. VIJAY JAIN: Calcium could come either
7 from concrete or come from Nukon fiber.

8 CHAIRMAN WALLIS: Excuse me. This cooper,
9 the fan cooler units are not submerged in the sump.
10 So why do they come into this? I mean, maybe there's
11 an atmosphere of steam up there, but that's not the
12 same as having them in the sump itself, is it?

13 MR. TREGONING: John can elaborate, I
14 think.

15 MR. GISGLOM: They would be exposed to
16 containment spray for the initial period, and there
17 are also a very minor amount of copper that would be
18 in the sump itself, and that's reflected in the ICET
19 series where there was significantly more copper in
20 the nonsubmerged region than in submerged region.
21 There's a small heat exchanger near the bottom of the
22 sump, and that's what's reflected.

23 PARTICIPANT: Okay. Thank you.

24 DR. BANERJEE: I have a test plan here
25 that talks about 25 percent submerged copper and 75

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1 percent nonsubmerged and instrument air lines were
2 also part of that copper.

3 So to go back, the calcium magnesium
4 silicate is the concrete and what else?

5 MR. VIJAY JAIN: And insulation, Nukon
6 insulation.

7 DR. BANERJEE: Nukon, and just the main
8 other constituent that dissolved was the sodium
9 aluminum that dissolved was the sodium aluminum
10 silicate, and where did that come from?

11 MR. VIJAY JAIN: Aluminum comes from
12 aluminum, metal scaffolding present in the containment
13 building, and silica comes basically from Nukon fiber
14 dissolution, and they combined to form sodium aluminum
15 silicates.

16 The next slide shows the predicted amount
17 of solid phases as a function of time at 60 degrees
18 Centigrade, and what you see here is, again, you see
19 the same results. You see the solid phases are
20 dominated by sodium aluminum silicate and calcium
21 aluminum silicate, but at longer time to start seeing
22 participation of silica because silica tends to exceed
23 its solubility limit, and also some formation of
24 calcium silicate.

25 Again, these are originating from the

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1 byproducts of Nukon insulation, concrete, and
2 aluminum.

3 DR. BANERJEE: So what temperature this
4 is?

5 MR. VIJAY JAIN: These are at 60 degrees
6 Centigrade in a pH 10 environment, which will flex the
7 ICET Test No. 1.

8 DR. BANERJEE: So the first set of results
9 are essentially the 60 degrees in your previous slide.

10 MR. VIJAY JAIN: Our previous slide was --

11 DR. BANERJEE: Half an hour you said.

12 MR. VIJAY JAIN: -- half an hour for 60
13 degrees, 90 degrees, and 110 degrees.

14 DR. BANERJEE: All right, but if you take
15 that 60 degree vertical set of data there, that is
16 your first set on the left.

17 MR. VIJAY JAIN: Yeah, sure.

18 DR. BANERJEE: And this is what is coming
19 together.

20 MR. VIJAY JAIN: Coming together, yes.

21 MR. TREGONING: I'm going to suggest just
22 for point of clarification all of these first sets of
23 results are pre-ICET simulations. So they don't
24 include benchmarking with respect to the observations
25 that we're seeing in the ICET test. So I'd suggest

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1 that we move relatively quickly through these and get
2 to the ones that we feel are more pertinent with
3 respect to the ICET test.

4 Some of these silicates, while they were
5 predicted initially in the speciation modeling, were
6 not observed in the ICET tank. So no point in
7 necessarily fixating on them.

8 CHAIRMAN WALLIS: Most of these lines have
9 a slope of one?

10 MR. VIJAY JAIN: I'm not too sure if --

11 CHAIRMAN WALLIS: I think it looks like it
12 anyway.

13 MR. VIJAY JAIN: These are on the log
14 scales of --

15 CHAIRMAN WALLIS: Yeah, but if you do, it
16 looks like a slope of one if you take the log scale.
17 So it's a uniform rate of dissolution.

18 MR. VIJAY JAIN: For metals we assume,
19 yes, it is because the user forward the action rate
20 for insulation.

21 MR. TREGONING: Yeah, that's an
22 assumption, a modeling assumption.

23 MR. VIJAY JAIN: So those are the results
24 we obtained before we had ICET test results, and we
25 went and examined ICET test results. We basically

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1 found that silicate phases were not observed in ICET
2 environments.

3 Many precipitation and dissolution
4 reactions are kinetically controlled at pressure
5 temperature and time conditions of the ICET
6 experiments, and some of them are very sluggish.

7 Silicates are the most thermodynamically,
8 most stable phases, but kinetically they are very
9 sluggish. Some of the silicate phases only formed the
10 type of pressure and may take several years to form.
11 Some of the glassy pressure (phonetic) indicates that
12 some of the silicate phases depending upon the glass
13 composition can form at 95 degrees Centigrade or a
14 period of one to two months.

15 So in the future simulations, what we did
16 is we suppressed the formation of silicates from the
17 remodeling based on the observations we had from ICET
18 test.

19 MEMBER KRESS: How did you do that
20 physically with the model? Do you give it a different
21 GIBs (phonetic) per energy or something?

22 MR. VIJAY JAIN: No. What we do is
23 basically the input asks you what phases you wanted to
24 put your input values to.

25 MEMBER KRESS: I see. You just said it

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1 wasn't there.

2 MR. VIJAY JAIN: Yeah, basically it says
3 if it doesn't exist. The first test we did, we didn't
4 take off anything because we just liked to get
5 observations that we would observe from the most
6 stable phases.

7 The second thing that we observed or last
8 observed was aluminum hydroxide phase, which is AlOH_3 ,
9 was not observed to form in ICET environments.
10 Rather, aluminum oxyhydroxide, which is AlOOH , was
11 observed.

12 So we suppressed the formation of aluminum
13 hydroxide while allowing the formation of aluminum
14 oxyhydroxide phase.

15 MEMBER KRESS: Now, you had to do that in
16 a different way, that suppression.

17 MR. VIJAY JAIN: No, the same thing.
18 There are ten aluminum phases. I say don't
19 equilibrate my inputs with aluminum hydroxides, but do
20 it for the rest of the things.

21 MEMBER KRESS: You can just tell the code.

22 MR. VIJAY JAIN: Good.

23 DR. BANERJEE: So there is no way to dial
24 in a kinetic --

25 MR. VIJAY JAIN: The only way the kinetic

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1 information is built in is through the reaction rates
2 of the different components.

3 MR. TREGONING: In these codes.

4 DR. BANERJEE: In these codes there's no
5 way to dial it in though.

6 MR. VIJAY JAIN: There is one code called
7 EQ3 equals six where you can do some kinetic studies,
8 but we didn't use that code to start with.

9 MEMBER KRESS: The Canadians have a code
10 called FAST, F-A-S-T, the committee, but it's not in
11 the liquid phase. It's in the gas phase.

12 MR. VIJAY JAIN: Well, again, when you
13 start going into kinetic phases, you have to look at
14 formation of flocculent, gel formation. Everything
15 needs to be incorporated, and I presume to do all of
16 those things will require so many exemptions that you
17 won't have credibility of that data coming out from
18 kinetic analysis. Extremely difficult to do kinetic
19 modeling for these types of environments.

20 MR. TREGONING: Unless potentially you
21 build your own model from --

22 MR. VIJAY JAIN: Even then you have to
23 make assumptions at what rate the colloids are formed
24 and gel formation takes place and how they grow, how
25 they precipitate out.

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1 As Bruce indicated, there were five ICET
2 tests, and in this particular presentation, I'm going
3 to focus on the results from the ICET test number one,
4 and have provided the results to ICET test number
5 three as the back-up slides. If we have time, we can
6 go back and look at the back-up slides.

7 Basically we did simulations for all five
8 tests in this particular study.

9 This slide shows the first ICET simulation
10 result based upon ICET test conditions, which also
11 includes the phases that we observed not to form in
12 ICET environments. The slide shows the release of
13 silica into the solution, silica, aluminum and
14 calcium. These are three key elements that are formed
15 that were observed in the ICET conditions.

16 The slide also shows the pH dependence as
17 a function of time. It shows the amount of silica
18 released as a function of time, up to 30 days, calcium
19 and aluminum.

20 You'll see here for up to 15 days the
21 prediction for calcium and aluminum are right on mark.
22 Given the complexity of the systems and the simulation
23 assumptions, it shows extremely good correlation for
24 calcium and aluminum for 360 days or 15 days.

25 We see a high release of silica in our

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1 simulation, and that's because we assume all of the
2 latent debris, which is concrete order to be dissolved
3 at time zero, which is a fairly conservative
4 assumption, which provides additional source of
5 silica, and you see a high amount of silica in our
6 predicted values.

7 We believe that the higher predicted
8 values for aluminum and calcium are related to the
9 fact that as a function of time the surfaces may
10 become passive, may become less reactive, which is,
11 again, a kinetic form, a kinetic issue which is not
12 incorporated in our models.

13 It shows a fairly good prediction for pH,
14 and this slide basically summarizes what I just said.
15 The model predicts high silica concentration because
16 concrete particles were assumed to dissolve instantly.

17 Silica concentration was well below the
18 saturation concentration in pH 10 of the pH 10
19 containment water, and that because aluminum clearly
20 inhibits the release of silicon into the solution.

21 CHAIRMAN WALLIS: These are dissolved into
22 the water? I thought the aluminum was in particulate
23 form, some of it, colloidal.

24 MR. B.P. JAIN: It could be. Some of it
25 could be.

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1 MR. VIJAY JAIN: Could be colloidal, but
2 it still --

3 CHAIRMAN WALLIS: Could be colloidal.

4 DR. BANERJEE: It could be still present
5 in the solution. Again, that test assumption we are
6 assuming that it could be colloidal. It has not been
7 proven it's colloidal. It could be just an ionic
8 form.

9 MR. CARUSO: Were all of the metal samples
10 pure metal or were they alloys?

11 MR. VIJAY JAIN: Well, I think I received
12 these samples from the ICET test. So whatever they
13 used, I think copper was copper metal. Aluminum had
14 -- I think John can answer that question better than
15 me.

16 MR. TREGONING: It depended. I mean,
17 there were steel samples. There were copper samples.
18 I think Bruce is right, industrial metals. So even
19 the copper and aluminum samples had some impurities in
20 them. At least the copper and aluminum were nominally
21 pure.

22 John, do you want to elaborate?

23 MR. GISGLOM: They were industrial metals.
24 The copper was copper. It wasn't 90-10 or something
25 like that. It was --

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1 MR. CARUSO: But I mean, aluminum, you
2 have silica aluminum. I mean you go buy aluminum
3 alloys to use, and it's usually some silica aluminum
4 alloys. Does that have any effect?

5 MR. TREGONING: These weren't aluminum
6 alloys, right? I mean, this was, again, industrial
7 grade, pure --

8 MR. GISGLOM: It was basically industrial
9 grade aluminum. It wasn't --

10 MR. TREGONING: There's impurities
11 certainly.

12 MR. GISGLOM: There certainly are some
13 minor amounts of impurities in the metal, but it
14 wasn't pure aluminum. It was aluminum, basically
15 industrial grade alloy.

16 MR. VIJAY JAIN: Continuing, the model
17 predicts high concentration for aluminum and calcium
18 at 20 days or 720 hours, and we believe it is
19 attributed to the reduced reactivity of the surfaces
20 with time. It could be for formation of passive foam
21 or secondary phases that form on the surface that are
22 released into the solution.

23 The model also predicts formation of solid
24 phases. We see formation of ferrous hydroxide at 148
25 hours, and we see the formation of zinc hydroxide at

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1 32 hours. Again, these are fairly small quantities
2 that were observed in the simulations.

3 MEMBER DENNING: And is there any way to
4 compare those against solid phases suspended in the
5 tests?

6 MR. VIJAY JAIN: I presume these phases
7 may be mostly adhering to the metal surfaces, and I
8 haven't seen any information from the ICET test that
9 indicates some. There were some coating on the metal
10 surfaces in ICET tests. I'm not too sure it has been
11 characterized yet or not.

12 MR. TREGONING: If there's coatings, and
13 again, at the risk of overstepping, Bruce might
14 correct me here, but I believe in some cases in the
15 sediment you could identify or isolate particulate
16 that may have been either zinc or iron in nature, but
17 again, it was within the sediment which we've already
18 discussed was a very heterogeneous mix.

19 Certainly if we observed it, it was a
20 relatively or very small percentage of the sediment.
21 So, Bruce, if you want to elaborate.

22 MR. LETELLIER: We did attempt to examine
23 the surface products that were formed, but we didn't
24 have easy access to a shallow angle EDS equipment that
25 would be needed to separate the substrate from the

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1 surface deposits.

2 So while we could visually examine a
3 surface for what appeared to be clean metal versus
4 corroded metal, it was difficult to separate them for
5 quantitative assessment.

6 I do agree with Vijay that a lot of those
7 forms are deposited on the surface rather than
8 suspended or precipitated out of solution.

9 MEMBER KRESS: On your previous slide, you
10 speculate that the silicon prediction was higher
11 because you let the concrete particles dissolve
12 instantly. Why wouldn't that give you the same effect
13 on the calcium?

14 MR. VIJAY JAIN: Well, it should, but
15 again, the amount of silica that you're seeing is ten
16 ppm compared to calcium that increases on five ppm for
17 silica and about ten to 20 ppm for calcium.

18 MEMBER KRESS: Not a lot.

19 MR. VIJAY JAIN: Maybe some of that effect
20 might have been lost in the increased concentration of
21 calcium because calcium comes from other sources also.

22 MEMBER KRESS: Yes. That may be it.

23 MR. VIJAY JAIN: This provides a summary
24 of our simulation results. For ICET No. 1, we saw a
25 good correlation with major elements in solution up to

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1 ten in 60 hours. Simulation predicts high
2 concentration in solution at 722 hours, as I
3 indicated, could be attributed to the passivation of
4 the surfaces.

5 ICET No. 2, we saw a good correlation with
6 major element except calcium, up to 360 hours.
7 Simulation predicts calcium to be precipitated as
8 phosphate similar to the one that Bruce talked about
9 for ICET Test 3, but in ICET Test 2 where there was a
10 limited observation of calcium phosphate on the
11 fibers.

12 In Test No. 3, we saw a good correlation
13 with major elements. Again, we didn't accept calcium,
14 up to 360 hours. Assimilation predicts high
15 concentration of calcium in solution after 96 hours,
16 and it was significantly higher compared to what was
17 observed in ICET Test No. 3.

18 For Test No. 4, prediction did not
19 correlate with ICET results because the simulation
20 inputs were based on separate corrosion experiments
21 for CalSil, insulation, and aluminum. As Bruce
22 indicated, there was a strong synergetic effect
23 between CalSil and aluminum. In our standardized test
24 that we did in the lab, we did a combination of Nukon
25 and aluminum together, but we did not do it for CalSil

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1 and aluminum.

2 So partly our results don't predict ICET
3 No. 4 environment is because we have assumed very high
4 rates for CalSil and aluminum without any synergetic
5 effects.

6 A prediction for ICET Test No. 4 did not
7 correlate for ICET results because simulation inputs
8 were based upon either corrosion measurement at pH
9 seven or ten, and we had no corrosion measurements
10 done independently for pH of 8.2.

11 And we know that at pH of ten, least from
12 Nukon and suppressed aluminum, but pH seven there is
13 no aluminum released. It's almost passive, but Nukon
14 releases at a very fast rate.

15 DR. BANERJEE: Let me understand these a
16 little bit. These are the results of your simulations
17 done with the code using some corrosion rate.

18 MR. VIJAY JAIN: Measured corrosion.

19 DR. BANERJEE: Measured corrosion rates,
20 and those were measured in your lab.

21 MR. VIJAY JAIN: Yes.

22 DR. BANERJEE: Okay, and how were those
23 corrosion rates? They were just coupons exposed?

24 MR. VIJAY JAIN: Yeah, they basically used
25 -- these are slides. The first backup slide shows the

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1 size of equipment we used.

2 DR. BANERJEE: Okay

3 MR. VIJAY JAIN: And for Nukon we used the
4 same ratio of volume to mass that was used in ICET.
5 We preserved the surface area to what's in issue.

6 DR. BANERJEE: You're trying to bridge
7 your coupon experiments to the ICET experiments using
8 your code as a bridging tool somehow. I mean, one can
9 look at the small scale experiments that were done,
10 and you're trying to say something about the large
11 scale.

12 MR. VIJAY JAIN: Yeah, those were used to
13 get the corrosion rates that were input to the
14 simulations, and the output for the simulations were
15 then compared with the ICET results.

16 MEMBER KRESS: How do you incorporate
17 those corrosion rates? Do you take the corrosion rate
18 and predict at a given time how much would have been -
19 -

20 MR. VIJAY JAIN: Exactly.

21 MEMBER KRESS: And then you input that as
22 an equilibrium amount at that time.

23 MR. VIJAY JAIN: Exactly.

24 MEMBER KRESS: Okay.

25 MR. VIJAY JAIN: There is a slide which I

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1 would like to show you, a backup slide, Slide No. --
2 here. Let me see which slide it is -- 29. This slide
3 basically provides --

4 MR. B.P. JAIN: Twenty-nine?

5 MR. VIJAY JAIN: Yeah, 29 shows how well
6 our lab results compare with the ICET results, which
7 provides confidence. No, this is not the one.

8 MR. B.P. JAIN: That's 29.

9 MR. VIJAY JAIN: That's the one, Slide No.
10 26. Sorry about that.

11 This slide shows the key element, silica
12 aluminum and calcium, what we saw in our lab tests and
13 the amounts of these elements observed in ICET tests.
14 These lab experiments correlate, given the complexity
15 of the systems, given that ICET had so many other
16 things. These experiments show how well the little
17 lab experiments correlate with the observed behavior
18 in ICET for silica, aluminum, and calcium.

19 So this provided me confidence that the
20 numbers that I'm using which drive corrosion rates are
21 very well represented of what was observed in ICET
22 tests.

23 DR. BANERJEE: Now, the difference between
24 Slide 26 and 14 is due to what? These on 26 are just
25 your coupons. It doesn't have any --

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1 MR. VIJAY JAIN: Simulation results. It
2 doesn't have any simulation results.

3 DR. BANERJEE: No simulation results.

4 MR. VIJAY JAIN: Slide 14 has ICET results
5 and simulation results.

6 DR. BANERJEE: But those simulation
7 results in 14 were not informed with your corrosion
8 rate data from your lab? I'm trying to understand the
9 difference between --

10 MR. VIJAY JAIN: There are three sets of
11 data. It has the observed corrosion behavior in the
12 lab test, predicted simulation results, and ICET
13 results, and all three indicate a very good
14 correlation with each other.

15 CHAIRMAN WALLIS: Well, 14 is comparison
16 with theory, I understand. Twenty-six is comparison
17 between two experiments, isn't it?

18 MR. VIJAY JAIN: Well, one experiment is
19 the lab.

20 CHAIRMAN WALLIS: Yeah, one is the Uricks
21 (phonetic) test and the other is the ICET test.

22 MR. VIJAY JAIN: Yeah, and my lab
23 experiments only had Nukon and aluminum. It didn't
24 have anything else.

25 CHAIRMAN WALLIS: So 26 is experiment

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1 versus experiment, and 14 is theory versus experiment.

2 DR. BANERJEE: But was 14 informed with
3 corrosion rate data or not?

4 MR. VIJAY JAIN: Yeah, the corrosion rate
5 data was obtained, what you see in slide 26, based on
6 that, and translated as an input value for simulations
7 to predict what are the solid phases that will form.

8 So the lab experiments cannot give you a
9 prediction of the solid phases of byproducts that are
10 going to form. You have to simulate and indicate what
11 are the solid phases you're going to see as a function
12 of time.

13 MEMBER KRESS: You could interpret the
14 results on 26 as being the change in the mass of your
15 coupons.

16 MR. VIJAY JAIN: Yeah.

17 MEMBER KRESS: So, you know, you say
18 that's all in there somewhere. You don't know what
19 form it's in.

20 MR. VIJAY JAIN: But, for example,
21 aluminum. The amount of aluminum we measured in the
22 solution correlates very well with the amount of
23 weight loss, indicating there is no aluminum
24 precipitation at 60 degrees Centigrade, and that's why
25 we say that there's no --

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1 MEMBER KRESS: But that may be a
2 difference between the two slides.

3 DR. BANERJEE: So if you take, say, the
4 aluminum in Slide 26, which is a measurement --

5 MR. VIJAY JAIN: Yeah.

6 DR. BANERJEE: -- and you take the
7 aluminum in Slide 14, which is a simulation, but to
8 drive that simulation you took the corrosion rate data
9 from Slide 26, right? That's what I'm confused about.

10 When you say that you obtain --

11 MR. VIJAY JAIN: But there are two things.
12 We did two measurements. We measured all the metals
13 using electrochemical metals. We measured the
14 solution chemistry with Nukon insulation and aluminum
15 together. The corrosion rates that were used for
16 simulation were based upon electrochemical metals. So
17 it was not based upon --

18 DR. BANERJEE: On these coupon tests.

19 MR. VIJAY JAIN: -- the combination of
20 insulation and aluminum together, but the two
21 correlate very well. If I plot the aluminum released
22 into the solution and based upon the corrosion rate
23 they predict almost similar --

24 DR. BANERJEE: So if I understand it, you
25 have two sets of corrosion rate data. One is the data

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1 you're showing on Slide 26.

2 MR. VIJAY JAIN: Yes.

3 DR. BANERJEE: Another set goes into the
4 calculations you show on Slide 14.

5 MR. VIJAY JAIN: That's true.

6 DR. BANERJEE: Where is that corrosion
7 rate data that goes into Slide 14?

8 MR. VIJAY JAIN: That's shown on Slide --
9 it's in the backup slide -- Slide No. 24, which should
10 be easy to get from here. So you see here these are
11 electrochemical tests. It gives you the corrosion
12 rate of aluminum at 60 degrees, at 90 degrees, and at
13 110 degrees.

14 So basically you take this corrosion rate,
15 which is given in grams per meter square per hour and
16 just put the exposed surface area and time you're
17 going to simulate and give you total amount that
18 you're playing with in that simulation.

19 MEMBER KRESS: Now, this I understand is
20 the initial slope in --

21 MR. VIJAY JAIN: For electrochemistry
22 there's only one. What you do is basically you do a
23 linear localization where you put a small voltage
24 across the sample and see the current density, and
25 from current density you use the failures law to get

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1 the corrosion rate.

2 MR. TREGONING: But, again, you apply the
3 constant corrosion rate, and there's a difference as
4 well, within the simulations, and if you look at the
5 experimental data, corrosion is certainly evolving as
6 a function of time.

7 MR. VIJAY JAIN: Yeah, and again, these
8 simulations don't take into account any passivity that
9 happens as a function of time, which is, I presume, a
10 kinetic issue which needs to be incorporated.

11 MEMBER KRESS: I guess what Sanjoy, I
12 think, was getting at -- at least I would have got it
13 -- was you're not using sort of data to predict the
14 theory which is then used to predict the data. It
15 looks like that.

16 MR. TREGONING: It's not circular like
17 that.

18 CHAIRMAN WALLIS: No, it's not quite as
19 circular. It's an independent measurement of
20 corrosion rates.

21 MR. VIJAY JAIN: Right. Independent and
22 initial measurement.

23 CHAIRMAN WALLIS: Right, but it's a
24 different kind of measurement, which is useful.

25 MR. VIJAY JAIN: These are all

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1 standardized tests for metals and for Nukon fiber we
2 have to tweak it a little bit, but it's a standardized
3 test used for glasses which I adopted for fibers.

4 CHAIRMAN WALLIS: So now you can predict
5 what happens in a sump.

6 (Laughter.)

7 DR. BANERJEE: With a little coupon,
8 right?

9 MEMBER DENNING: Now, one thing I don't
10 understand though is, of course, what you've done is
11 you've focused on what's in solution, and I realize
12 one has to start there, but as far as us understanding
13 what's happening in the sump, we have to know what
14 comes out of solution.

15 MR. VIJAY JAIN: And that's what was shown
16 on Slide 15, where I showed that the model solution
17 predicts hydroxides of iron and zinc, and if you look
18 at the call for aluminum, you see a linear change
19 indicating that 100 percent is in solution till 15
20 days. So there was no solid precipitation occurring
21 for aluminum in the solution.

22 So I have to get back to Slide 15, I
23 guess, where I was.

24 MEMBER DENNING: But we don't have much in
25 the way of validation of that. I mean, that's really

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1 the hard part of the problem.

2 MR. VIJAY JAIN: You mean the validation
3 of the solid phases?

4 MEMBER DENNING: The validation of solid
5 phases, right, and part of it is it's not part of this
6 equilibrium process.

7 MR. VIJAY JAIN: Well, I guess I think --

8 MEMBER DENNING: I mean, it is someplace.
9 You know, some place it's a solid, but we don't know
10 whether it's suspended or whether it's on the surface.

11 MR. VIJAY JAIN: That's true.

12 DR. BANERJEE: But in your coupon
13 experiments, you could look at -- I mean, you could do
14 those little coupon experiments and see what the solid
15 phases were, too, right?

16 MR. VIJAY JAIN: Yeah, I could have done
17 it, hindsight, yes, but of course, I did it when we
18 did it.

19 MEMBER DENNING: All right, but you could
20 have done it at some point.

21 MR. VIJAY JAIN: Yes, it could have given
22 at least some insights to it, but that was done much
23 before we had ICET results.

24 MR. TREGONING: I think the important
25 point to make is that, you know, the best simulations

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1 were ones that were informed in an educated way with
2 respect to experimental observations that were made in
3 the ICET tank, and that's a very important point.

4 MEMBER DENNING: In fact, it was necessary
5 if you were going to use equilibrium thermodynamics.

6 MR. TREGONING: That was a necessary step.
7 That's certainly true.

8 DR. BANERJEE: So you couldn't have taken
9 your coupon tests and found out the same thing.

10 MR. TREGONING: Well, the pre-ICET
11 simulations was the closest to doing exactly that, and
12 you saw what the results were.

13 DR. BANERJEE: Yeah, but they were using
14 electrochemical data.

15 MR. TREGONING: It wouldn't have mattered.
16 I mean, what you saw there was the species that were
17 predicted. You might have gotten different amounts
18 with different corrosion rates, but those species
19 would have -- and, Vijay, correct me -- at least still
20 dominated.

21 MR. VIJAY JAIN: Because silicates are the
22 most stable phases. Any time you run a thermodynamic
23 code, if you have silica aluminum and sodium and
24 calcium, it will predict silicate --

25 DR. BANERJEE: All I'm saying is that if

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1 you wanted to study kinetics, you could study the
2 kinetics on a small scale and find out the same thing,
3 that silicates perform slowly.

4 MR. VIJAY JAIN: Yeah, and in fact, my
5 background is in glass science, and I've studied --

6 DR. BANERJEE: You don't have to do these
7 huge tests.

8 MR. VIJAY JAIN: My background is in glass
9 science, and I've studied to corrosion of glasses for
10 the last 20 years, and if you look at it, you do form
11 silicates, but not in ICET conditions. It takes high
12 temperatures and longer times to form those silicate
13 phases of the surface of glasses.

14 MR. TREGONING: The value of the ICET,
15 there have been a number and even predecessors to
16 ICET, a number of separate effects types of tests
17 looking at single or maybe even dual effects, but this
18 is really unique in the sense that it was the first
19 time that we tried to put all of these things that may
20 have interaction and synergistic effects together, and
21 one of the things we've noticed in ICET certainly is
22 that in many cases the synergistic effects can be
23 important.

24 DR. BANERJEE: Like which ones?

25 MR. TREGONING: You have passivation

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1 issues, effect of aluminum. Even the effect of
2 aluminum on silicate dissolution from Nukon, I mean,
3 that was something that initially we had predictions
4 that we expected about an order of magnitude more
5 silicon than we actually observed in the ICET tank,
6 and that was something we really had to go back,
7 scratch our head a bit to try to figure it out.

8 Some good characterization work at LANL
9 had indicated some of the forms are potential reasons
10 for that, and the Vijay went off in his lab and just
11 did some small scale experiments when he tried to look
12 at dissolution of Nukon in the presence of aluminum.

13 That simple synergistic effect has a huge
14 effect on the types of products, the amount of silicon
15 that we saw in the test, and that's just one example.

16 MR. VIJAY JAIN: It shows right here in
17 this slide two types of tests, Nukon fiberglass in the
18 containment solution and Nukon fiberglass in aluminum,
19 but pH seven as a function of time, you don't see any
20 difference, any at all of aluminum in the corrosion of
21 Nukon. In fact, the mass released from Nukon mass
22 gets dissolved.

23 But at pH ten, what you see here is the
24 Nukon glass shows a fairly high release rate, but
25 after you add aluminum to it the dissolution of fiber

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1 goes down by an order of magnitude.

2 CHAIRMAN WALLIS: I'm trying to translate
3 this into amount of silicon in the sump. You've got
4 these strange units. I understand what they are, but
5 how do they relate to what's happening?

6 MR. VIJAY JAIN: This is milligrams of
7 Nukon fiber released by meter surface.

8 CHAIRMAN WALLIS: So meter squared of
9 surface.

10 MR. VIJAY JAIN: Surface area of the
11 fiber.

12 CHAIRMAN WALLIS: Right. How do I
13 translate that into --

14 MR. VIJAY JAIN: The ICET test gives how
15 much surface area of Nukon is there. You can multiply
16 it and it will give you --

17 CHAIRMAN WALLIS: I know I can, but you
18 can't tell me right away.

19 MR. TREGONING: I think Bruce is going to
20 look at the silicon floc, but I think in ICET 1 we
21 were on the order of ten to 15 milligrams per liter.
22 So that's roughly --

23 CHAIRMAN WALLIS: Silicon in solution?

24 MR. TREGONING: Yeah, ten kilograms or so.

25 And we were predicting from this on the order of 80 to

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1 100 milligrams per liter. So again, about an order of
2 magnitude higher.

3 CHAIRMAN WALLIS: So how much on the sump?

4 MR. TREGONING: Yeah.

5 CHAIRMAN WALLIS: How many kilograms in
6 the sump?

7 MR. TREGONING: Somewhere between maybe
8 ten in actuality kilograms versus 100 predicted. I
9 think I'm -- am I close there?

10 MR. LETELLIER: Those levels are right.

11 MR. TREGONING: Okay. Thank you.

12 MR. VIJAY JAIN: So these are the things
13 that we have to be very careful in assessing the
14 specific effect in one. Some of the synergetic
15 effects that happen especially with aluminum on
16 insulations.

17 MEMBER KRESS: So now we have to throw in
18 paint chips and coatings.

19 MR. TREGONING: This is a relatively
20 simple one. It's just two input materials.

21 CHAIRMAN WALLIS: There's nothing that's
22 likely to act as a catalyst for any of these reactions
23 that's hanging around in the containment?

24 MR. VIJAY JAIN: Well, at least if you
25 look at ICET 1 environment, the large studies that

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1 were done with aluminum and Nikon basically represents
2 what you observed in ICET, large scale test which had
3 everything else in it, indicating that other
4 components are not really playing any catalytic role
5 in enhancing or --

6 CHAIRMAN WALLIS: If anything, they
7 inhibit. They don't catalyze. They inhibit the
8 reaction, but there's nothing to promote the reaction.

9 MR. TREGONING: Yeah, at the risk of
10 spinning off here, we've asked all of these very same
11 questions to our peer reviewers, and we've had a lot
12 of initial discussions. We've done a lot of
13 brainstorming just within the group, but then also
14 with the peer reviewers to try to determine.

15 You know, ICET was unique. We tried to
16 account for a lot of things within the ICET test. We
17 obviously didn't account for everything, nor could we
18 ever account for everything. So we're trying to
19 identify possible contributions to either things that
20 we didn't study or the effect of relatively small
21 amounts of materials like organics and things like
22 that, how they might have resulted in different
23 observations.

24 So these are all incredibly valid
25 questions that we're certainly pursuing at least in a

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1 brainstorming sense, but it does take a bit of
2 discussion and a bit of analysis just to try to get
3 your arms around.

4 CHAIRMAN WALLIS: But there doesn't seem
5 to be any basis for assuming that there's some sort of
6 a catalyst which promotes reactions.

7 MEMBER KRESS: Now, how about educating
8 me? I was under the impression that catalysis was a
9 kinetic condition and you would not see catalysis with
10 an equilibrium code.

11 MR. VIJAY JAIN: That's right. The codes
12 wouldn't predicted it.

13 MEMBER KRESS: Wouldn't predict it. I
14 mean, wouldn't see anything.

15 CHAIRMAN WALLIS: The codes wouldn't
16 predict it.

17 MEMBER KRESS: No.

18 MR. TREGONING: The thermodynamic.

19 CHAIRMAN WALLIS: So you have to do the
20 test, right?.

21 MEMBER KRESS: Or do a kinetics code.

22 CHAIRMAN WALLIS: So what's the bottom
23 line of all of this?

24 MR. VIJAY JAIN: Well, there was a
25 question asked on the Nukon fiber. Just make sure

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1 that the CM photograph of the Nikon fiber.

2 These are about seven to ten microns in
3 diameter, and each of these fibers is about a
4 centimeter to two centimeters in length. So these are
5 fairly small pieces that are bonded together with the
6 organic polymer, and during impingement, these are
7 very high strength fibers, I mean, small. You can't
8 really break that easily. So you might not see too
9 much of fragmentation of the fiber size itself.

10 Well, in summary, the chemical evolution
11 of the sump environment was the aggregate assumption
12 of temperature, pressure, and time. The calculation
13 indicated that the phases predicted in a pressurized
14 system would be similar to the failures predicted in
15 the nonpressurized system at a lower temperature.

16 It also indicate that in solution and
17 aluminum are the major contributors to the corrosion
18 products.

19 We benchmarked the thermodynamic
20 simulation to ICET. The ICET data indicated lack of
21 formation of silicates and aluminum hydroxide in the
22 containment water in a 20-day test at 60 degrees
23 centigrade. We revised our thermodynamic simulations
24 and indicated that provided a good correlation with
25 Test No. 1, 2, and 3 up to 360 hours.

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1 Modeling results. The calculations tend
2 to diverge after 360 hours, and I attribute it to
3 selection of initial dissolution rate, which might
4 decrease as a function of time and reduction in the
5 surface reactivity with time due to the formation of
6 passive layers or second phases on the surfaces.

7 Experimental data indicates a strong
8 synergetic effects between in solution and aluminum.
9 A combination of -- this is the bottom line -- of
10 ICET, lab tests, and simulation provided sites into
11 reactor specific chemical effects. By itself one
12 cannot really do the job. If you look in what we are
13 doing together, it could provide some specific
14 insights.

15 Well, the plan for the upcoming program.
16 We will continue the modeling based upon ICET results.
17 We would like our future program to include the effect
18 of CO₂ which might additionally form some calcium
19 carbonate.

20 We will again examine the ICET results and
21 try to incorporate them. Similarly, the gradual
22 evolution of ICET containment chemistry instead of
23 having discrete times, we'll try to have a continuous
24 time dependence and see what type of information we
25 get, and who would like to use PHREEQC for future

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1 investigation.

2 PHREEQC is a jucamental (phonetic) code
3 that can incorporate the effect of CO₂ and other
4 gases. So it might benchmark that particular effect,
5 and the argument is to develop a generalized modeling
6 approach for other reactor specific conditions. So
7 hopefully a combination of the work that's going on.

8 CHAIRMAN WALLIS: Can you give us some
9 blind predictions of what's being done somewhere at
10 Argonne or somewhere? You make a prediction ahead of
11 time and see if it works out?

12 MR. VIJAY JAIN: The pre-ICET was a blind
13 prediction.

14 MR. TREGONING: And we did exactly that.

15 DR. BANERJEE: And you also can get, of
16 course, what's happening in the solid phase, the
17 precipitates.

18 MR. VIJAY JAIN: That's right, from
19 simulations, again, that need to be somehow ratified.

20 DR. BANERJEE: Yes, but it's not easy to
21 verify those in the ICET test because there was such
22 a multiplicity of stuff, but maybe in smaller or
23 different tests you could validate that at some point.

24 CHAIRMAN WALLIS: Well, industry is doing
25 all sorts of small scale tests, aren't they?

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1 DR. BANERJEE: Right.

2 CHAIRMAN WALLIS: You have great
3 opportunity to.

4 DR. BANERJEE: Do you have access to that
5 that they talked about yesterday?

6 MR. VIJAY JAIN: I got the presentation.
7 I didn't get a chance really.

8 MR. TREGONING: We haven't seen the test
9 report. We had access to the test plan prior to
10 testing, and we observed that. This was discussed
11 yesterday. We observed some of the testing. We
12 expect, I think, you know, maybe any week now that at
13 least for informational purposes we'll get an advanced
14 look at the --

15 CHAIRMAN WALLIS: Yeah, I would think they
16 would consult with you because these tools might be
17 useful to them.

18 DR. BANERJEE: So your initial approach,
19 anyway, is to look at the equilibrium thermodynamics
20 using measured corrosion rates to the use of kinetic
21 effect.

22 MR. VIJAY JAIN: That's right.

23 DR. BANERJEE: Now, when you do look at
24 some of these, is it possible then to use kinetics to
25 a limited extent to do more ab initio things than this

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1 stuff? I mean use some combination of kinetics codes
2 in a careful manner so that you don't need so many
3 constants. Combine it with some dynamics codes.

4 MR. VIJAY JAIN: And some of these
5 kinetics codes will also require input of some rate of
6 corrosion so that the rates of corrosion have to be
7 developed.

8 DR. BANERJEE: But to sort of try to get
9 this on a sound, scientific basis to minimize the
10 amount of stuff you have to do.

11 MEMBER KRESS: Well, I think you might use
12 the kinetics code to check your assumption of how fast
13 you reach equilibrium and then that would validate
14 your use of the equilibrium code. You're still going
15 to have the dissolution rates in, either one.

16 MEMBER DENNING: Dr. Shack, could you
17 comment? I saw you dying to do that, and I know you -
18 -

19 MEMBER SHACK: No, I'm not going to say
20 anything.

21 MR. VIJAY JAIN: You can tell us
22 privately.

23 MEMBER SHACK: Well, I mean, you just need
24 the kinetics data. It's not as though the kinetics
25 code is sitting out there waiting for you to use it.

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1 MEMBER KRESS: You don't have reaction
2 rate coefficients.

3 MR. VIJAY JAIN: Yeah, we don't have that
4 information.

5 MEMBER KRESS: And you may have to put in
6 about 100 reactions or more.

7 DR. BANERJEE: Oh, that many?

8 MEMBER KRESS: Yeah, with this many.

9 DR. BANERJEE: It looks like combustion
10 then

11 MR. TREGONING: So, m again, it's a
12 plausible path forward, but again, it's certainly non-
13 trivial, to say the least.

14 DR. BANERJEE: But even combustion, I
15 mean, you can usually take these 80 or 90 reactions
16 and boil them down to eight or nine.

17 MR. VIJAY JAIN: Yeah. If you really
18 look, I mean, what's boiling down here is the effect
19 of aluminum and insulation. To me if I have to really
20 go and do a plant specific, I would look at those two
21 parameters very closely. I know that based upon
22 corrosion rates of cooper, zinc, and carbon steel,
23 they are very low in amount and doesn't seem to have
24 any significant effect on what's observed in ICET test
25 and lab studies and simulations.

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1 DR. BANERJEE: So you're saying there are
2 only a few reactions.

3 MR. VIJAY JAIN: Yeah, it could limit down
4 to a few reactions that contribute. You see, we're
5 making a risk informed judgment. You will say that
6 aluminum and solution are the key players in the
7 evolution of the containment water and the byproducts
8 in the system.

9 And the final slide is some information we
10 published NUREG 6873 that has basically nine
11 predictions which are probably not valid after ICET
12 information came in.

13 MR. TREGONING: That's the pre-ICET work.

14 MR. VIJAY JAIN: Pre-ICET work.

15 CHAIRMAN WALLIS: So this actually is
16 fairly encouraging, that you can actually make these
17 predictions and with some further work you might be
18 able to make some more, and they might actually be
19 useful to industry and the NRC.

20 MR. TREGONING: Potentially, although,
21 again, I'm a bit of a cynic here. I don't want to be
22 overly optimistic that we're going to be able to
23 develop some model that's going to be able to predict
24 all of the various effects that we're really concerned
25 about.

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1 Will we possibly have a tool that will
2 provide some additional insights, as Dr. Banerjee has
3 been --

4 CHAIRMAN WALLIS: It's encouraging. I
5 mean, he has had some successes. It hasn't been
6 invalidated and all of that, and --

7 DR. BANERJEE: And what makes it credible
8 is had some failures. Failures are very good. When
9 things work, you always worry about it, that somebody
10 is fitting the data with something.

11 CHAIRMAN WALLIS: That's why you ask some
12 of your questions.

13 Are we ready to take a break now for
14 lunch?

15 MR. VIJAY JAIN: I'm done.

16 CHAIRMAN WALLIS: Thank you very much.

17 MR. VIJAY JAIN: Thank you.

18 CHAIRMAN WALLIS: We'll take a break. The
19 easiest thing to remember would be 1:30. Shall we go
20 to 1:30 then?

21 We'll go to 1:30.

22 (Whereupon, at 12:25 a.m., the meeting was
23 recessed for lunch, to reconvene at 1:30 p.m., the
24 same day.)

25

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A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

(1:30 p.m.)

13. CHEMICAL EFFECTS HEAD LOSS TESTING:

OVERVIEW, TECHNICAL PROGRAM, AND RESULTS

CHAIRMAN WALLIS: This is another one of those presentations we have been looking forward to: chemical effects head loss testing at Argonne National Lab. Who is going to start? Bill, are you going to open up for us?

MS. TORRES: I'm going to start.

CHAIRMAN WALLIS: Please go ahead.

MS. TORRES: Good afternoon. My name is Paulette Torres. And I represent the Office of Nuclear Regulatory Research Division of Engineering. I am the project manager of the chemical effect head loss testing. And this is my first time addressing the CRS. Right next to me is Dr. Shack, who represents Argonne National Lab. And he will be presenting right after me.

The chemical effects head loss testing is a complementary research activity designed to evaluate head loss associated with chemical byproducts which form integrated chemical effect test environments, also referred as ICET.

The reason for this project is that we

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1 have little information on head loss associated with
2 chemical byproducts and that we need to understand how
3 chemical byproducts formed in plant-specific
4 environments can affect head loss formation.

5 The NRC and the nuclear industry developed
6 the ICET program. The ICET program simulated the
7 chemical environment present inside a containment
8 water cooler after a loss of coolant accident.

9 Chemical byproducts were formed in the
10 environment tested. However, the head loss associated
11 with chemical byproducts was not evaluated in the ICET
12 program. This testing program at Argonne National
13 Laboratory is investigating the head loss associated
14 with chemical effects products.

15 From a regulatory perspective, the
16 research underway at Argonne National Lab is assigned
17 to help resolve general safety issue 191 resolution.
18 To support this goal, the work conducted at Argonne
19 provides information to help the staff review their
20 chemical effects part, licensee submittals, in
21 response to general letter 2004-02 and to inform the
22 auditing process.

23 CHAIRMAN WALLIS: The treatise?

24 MS. TORRES: The what?

25 CHAIRMAN WALLIS: I don't understand this.

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1 Something is wrong with this sentence. Did Bill Shack
2 write that sentence?

3 (Laughter.)

4 MS. TORRES: No.

5 MR. TREGONING: I don't think we can
6 finger Bill for that one. Treatment, don't you think?

7 CHAIRMAN WALLIS: Well, I'm trying to
8 figure out what it is trying to say.

9 MR. TREGONING: Treatment.

10 CHAIRMAN WALLIS: This means treatment is
11 where it should be? Okay.

12 MR. TREGONING: See, Bill, I told you.

13 MS. TORRES: Our chemical effect head loss
14 testing program investigated the potential head loss
15 associated with chemical byproducts of
16 trisodiumphosphate in environments containing the soft
17 calculation.

18 We also did dissolution and saline tests.
19 The dissolution tests were intended to identify the
20 dissolved calcium concentrations produced in simulated
21 containment pool conditions. And the settling tests
22 were performed to assess the settling tests of calcium
23 phosphate precipitate.

24 CHAIRMAN WALLIS: The last sentence is
25 wonderful, too, "Measure the expected settling rate."

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1 I mean, Bill, you're doing very well here.

2 MS. TORRES: Benchmark testing without
3 chemical products is currently ongoing at Argonne.
4 And it's scheduled to be completed in February. The
5 result of this benchmark testing will be used to
6 ensure consistency in testing methods among the
7 research labs.

8 Tests to examine the head loss from
9 chemical byproducts in sodium hydroxide buffered
10 environments and sodium tetraborate environments are
11 scheduled to commence immediately after the benchmark
12 tests. All testing in Argonne is scheduled to be
13 completed by April 2006.

14 MEMBER DENNING: Can I ask the function of
15 -- you said used to -- I can't remember the exact
16 words, but there's something like consistency among
17 the different laboratories. What were your words
18 there? I didn't quite understand.

19 MEMBER KRESS: They're just seeing if Bill
20 Shack knows how to make measurements.

21 MS. TORRES: The best way to say it is
22 Argonne along with Pacific National Laboratory. They
23 are doing also benchmark testing.

24 MEMBER DENNING: Yes, but there is a
25 methodology that is supposed to give consistency

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1 treatment of the calculation of --

2 MS. TORRES: There is a procedure
3 established between the two labs and the NRC.

4 MR. TREGONING: In anomaly, the test
5 programs are different in that the Argonne work is
6 evaluating primarily chemical effects contributions to
7 head loss wall. The PNNL work is looking at standard
8 insulation materials.

9 However, we have a certain number of
10 replicate tests that are anomaly-identical that will
11 be performed at both laboratories. These will be
12 cases with standard insulation to bring no chemical
13 effect.

14 The purpose of those tests is to do dual
15 benchmarking to make sure that the measurements that
16 we get are not loop-specific for the most part or if
17 they are, we want to understand possibly some of the
18 either operator variabilities or things that may occur
19 that could lead to differences. So it's just a way
20 for us to try to assess some of the independent ways
21 of running these tests, some of the variability that
22 might result from that.

23 MEMBER DENNING: Would you be developing
24 correlations that would be used to calculate head
25 loss?

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1 MR. TREGONING: One of the objectives of
2 the PNNL work is to supply data to develop
3 correlations. You're going to hear about that this
4 afternoon. Initially the Argonne objective is not to
5 develop data to be used for correlations. However,
6 it's certainly available if and when we reach that
7 state where we're ready to try to develop some
8 correlations based on certain chemical products.

9 CHAIRMAN WALLIS: This is one of my gripes
10 always, that when you do research, you should really
11 make a prediction of what you expect to find before
12 you do the test. Then you learn more.

13 If you just stack up all kinds of data and
14 then a year later someone tries to explain it, that's
15 a very ineffective way to proceed. You should
16 actually develop your understanding in terms of theory
17 while you examine the data as soon as you can. Then
18 you make much more progress.

19 MR. TREGONING: Right.

20 CHAIRMAN WALLIS: Then you can sort of see
21 anomalous things, you know, unexpected things and all
22 of that.

23 MR. TREGONING: At the risk of stealing
24 too much thunder from this afternoon, I mean, the 6224
25 correlations and some of the insights that we gave for

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1 those were applied and developed as --

2 CHAIRMAN WALLIS: Yes, they were. That's
3 right. That makes sense.

4 MR. TREGONING: Certainly agree with your
5 point there.

6 MS. TORRES: I am turning over the
7 discussion to Dr. Shack, who will be discussing test
8 results.

9 CHAIRMAN WALLIS: Thank you.

10 MEMBER SHACK: And, again, I will be
11 presenting work that's really done by my colleagues at
12 Argonne. The principal investigator who designed the
13 loop facility and was leading our effort was John Oras
14 until he broke his leg in two places or broke two
15 bones in his leg.

16 Ken Kasza is now following up on the
17 thermal hydraulics work. And John Hee Park and Ken
18 Natesan are really handling the chemistry studies that
19 support the work that we're doing here.

20 The measurements we're making are done in
21 a fairly conventional test loop. We, you know, build
22 up a bed on a horizontal screen. And, again, this is
23 not really meant to replicate a situation in a plant.
24 It's meant to measure the head loss associated with a
25 bed of certain characteristics so that one should

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1 recognize that this is really the development of a
2 head loss characterization, rather than trying to
3 represent what really happens in a sump screen design.

4 CHAIRMAN WALLIS: How do you put the stuff
5 in?

6 MEMBER SHACK: We put the stuff in
7 basically here. We just open this up and pour it in.

8 CHAIRMAN WALLIS: So you open the top?

9 MEMBER SHACK: We open at the top and pour
10 it in.

11 CHAIRMAN WALLIS: While the stuff is
12 flowing around or what?

13 MEMBER SHACK: While the stuff is flowing
14 around. When I discuss the actual tests, we'll talk
15 a little bit more about how we treat the material
16 before we put it in.

17 CHAIRMAN WALLIS: It seems to make a
18 difference how you put the stuff in, the sump tests.

19 MEMBER SHACK: Yes. It can. One of the
20 things I should point out, again, the tests that we
21 have done to date have been with the perforated plate,
22 rather than a screen.

23 The perforated plate that we have been
24 using has staggered 3/16th-inch holes and a 51 percent
25 flow area. The sump screens or the perforated plates

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1 that people seem to be using for fabricating the new
2 strainers, have somewhat smaller holes, one-eighth
3 inch, and somewhat smaller flow area. And we're
4 switching to that perforated plate for our further
5 testing. And we're using that for our benchmark
6 testing.

7 As mentioned, the tests to date have been
8 done with a horizontal screen, but we can also run
9 with a vertical screen if that were desirable.

10 The loop can operate up to 180 degrees F.
11 when we're running with a LEXAN test section, which we
12 can do with some chemistries. For other chemistries,
13 we have to use a clear PVC test section. In that
14 case, we're limited to 140 degrees F.

15 CHAIRMAN WALLIS: What is the size of the
16 piping in the rest of the loop? It's six inches in
17 the test section. What is it when you get down to the
18 --

19 MEMBER SHACK: It goes down to two inches
20 so that we can essentially reduce the possibility that
21 we're going to have debris --

22 CHAIRMAN WALLIS: So the velocity there is
23 about one foot a second, right?

24 MEMBER SHACK: It goes up.

25 CHAIRMAN WALLIS: So why does it take so

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1 long to go around the loop?

2 MEMBER SHACK: It's a big loop.

3 CHAIRMAN WALLIS: It must be.

4 MEMBER SHACK: Well, wait until you see
5 the PNNL loop.

6 (Laughter.)

7 MEMBER SHACK: They've got a taller
8 building than we do. You know, when we are doing
9 these things, there is always this question of how
10 much do we put in.

11 CHAIRMAN WALLIS: But if it's a big loop,
12 what sort of typical dimensions? Is it for five feet
13 tall or something?

14 MEMBER SHACK: Oh, no, no, no. Twenty
15 feet tall.

16 CHAIRMAN WALLIS: This is 20 feet tall,
17 this thing?

18 MEMBER SHACK: Yes.

19 CHAIRMAN WALLIS: Oh, great gods.

20 MEMBER KRESS: Are we looking at --

21 CHAIRMAN WALLIS: Why is it so huge? Your
22 test section is just a small part of it, then.

23 MEMBER SHACK: Well, there was a great
24 desire since some concerns have been raised about
25 earlier loop testing that there wasn't enough space

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1 after the elbows to develop a fully developed flow.
2 And so the tendency was to essentially make the loop
3 bigger, have more L/Ds before you got to the test
4 section.

5 CHAIRMAN WALLIS: Which means that
6 anything that gets through the screen has to take all
7 of these four minutes before it comes around again.

8 MEMBER SHACK: Comes around again.

9 CHAIRMAN WALLIS: Okay.

10 MEMBER KRESS: Are we looking at top down
11 or the side in this?

12 MEMBER SHACK: This is the side. You
13 know, it's a vertical test loop at the moment.

14 MEMBER KRESS: So when you want to do
15 horizontal tests, you put an elbow in there and --

16 MEMBER SHACK: We put a hair pin. You
17 take this section out. And you put a hair pin in that
18 goes over here, comes down and around. And then you
19 put your test section in up here.

20 CHAIRMAN WALLIS: Because you want to keep
21 things long.

22 MEMBER SHACK: We want to keep things
23 long. We keep things long.

24 DR. BANERJEE: What is the total length
25 again?

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1 MEMBER SHACK: I actually don't know. I'm
2 guessing 20 feet by 20 feet, but I might -- you know,
3 it's something on that order/

4 DR. BANERJEE: So it's trying to switch
5 right there.

6 MEMBER SHACK: Right.

7 CHAIRMAN WALLIS: At one foot a second.

8 MEMBER SHACK: Those are rough figures.
9 Don't hold me to it.

10 CHAIRMAN WALLIS: To get a four-minute
11 time, you're going to have an awful long pipe.

12 MEMBER SHACK: It's three and a half
13 minutes, to be precise, but I rounded it off to four
14 for the presentation.

15 CHAIRMAN WALLIS: Okay. Well --

16 DR. BANERJEE: One foot per second
17 roughly, right?

18 MEMBER SHACK: Yes.

19 DR. BANERJEE: Except in narrow bits?

20 MEMBER SHACK: Right.

21 CHAIRMAN WALLIS: Except in the fat bits.

22 MEMBER SHACK: Now, again, coming back
23 again, one of the decisions we make is what we put in
24 the loop and how much that we've put into the loop.
25 We have tried to essentially say that the head loss,

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1 whatever is going on is going to be characterized by
2 the massive chemical products and debris per unit area
3 of the screen.

4 So if you're making comparisons between
5 our loop and the Los Alamos loop and the PNNL loop, in
6 our loop, one gram of debris is really 47.6 grams per
7 meter of debris.

8 DR. BANERJEE: What is the difference
9 compared to the Los Alamos, original Los Alamos?

10 MEMBER SHACK: It is taller. We can also
11 control temperature. You know, our tests are
12 basically plus or minus a tenth of a degree typically
13 when we're running the tests. I believe they have no
14 real temperature control there. So that they had pump
15 heat and some variability.

16 We also, again, have more L/D. You know,
17 theirs was a much smaller loop, a larger diameter. So
18 their L/Ds were quite different.

19 CHAIRMAN WALLIS: Well, just to go back to
20 this, if you have a loop which is so long and has a
21 velocity of one foot a second, then you're making
22 these precipitates in a long reactor before they come
23 around to the --

24 MEMBER SHACK: Our precipitates form very
25 quickly. Yes. Let me discuss exactly how the

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1 precipitates come in and arrive at the screen in a
2 little bit because that is a variable that we are
3 interested in. That becomes an important variable
4 that is really very different from the three minutes
5 in our loop. It's not a characteristic time that we
6 want to look at.

7 Much of our testing today just focused on
8 the ICET-3 test conditions. And the bullet says it's
9 plants which use sodium triphosphate for pH control
10 after an accident. Well, the other important element
11 is that they have cal-sil insulation.

12 And the ICET-3 test we found -- and,
13 again, the ICET-3 was actually one you could probably
14 predict without the integral test. You know, cal-sil,
15 calcium silicate, will dissolve when you put it in hot
16 water. And you combine calcium with phosphate, and
17 you will get a calcium phosphate precipitate.

18 CHAIRMAN WALLIS: So it is really STP, not
19 TSP that you keep talking about in all these slides.
20 It's STP.

21 MEMBER SHACK: Yes, sodium triphosphate.

22 CHAIRMAN WALLIS: It's not trisodium
23 phosphate.

24 MEMBER SHACK: Trisodium phosphate. I'm
25 sorry.

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1 CHAIRMAN WALLIS: Well, which one is it?

2 MEMBER SHACK: Trisodium.

3 CHAIRMAN WALLIS: Oh, okay. Oh, okay.

4 The dissolved calcium, again, we focus on cal-sil, but
5 you could get calcium from other sources, even from
6 the NUKON, from concrete. Again, when you have the
7 cal-sil, you have an overwhelming source of calcium.
8 It's a plentiful supply. The critical parameter for
9 the production of the precipitate is the massive
10 cal-sil per unit volume of sump fluid.

11 Plants are now estimated to be somewhere
12 around 1.5 grams per liter if you look at the amount
13 of cal-sil that ends up in the sump and the volume of
14 the sump.

15 The ICET-3 loading was 19 grams per liter,
16 which looks like a tremendous difference, but you have
17 to recognize that for cal-sil loadings greater than 2
18 grams per liter, you basically run out of phosphate.
19 So that the amount of phosphate, the calcium
20 phosphate, they generated in ICET-3 was not as
21 un-prototypical as it seems when you look at the sheer
22 mass of cal-sil that was present.

23 The one thing that will go on is we will
24 get precipitate formation here that will proceed until
25 either we use all the phosphate or we use up all the

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1 calcium. The kinetics of the process will depend on
2 the chemistry, particularly on the rate of the TSP
3 addition.

4 Most of the time in the plants will be
5 essentially calcium-limited. That is, there is an
6 ample supply of phosphates around, but the amount of
7 dissolved calcium that you have is limited by the
8 amount of calcium silicate that you have.

9 Our initial head loss test was just
10 essentially to replicate the conditions in ICET-3.
11 Then we did a second test that was more parametric to
12 look at a range of chemical product loadings.

13 Again, the baseline environment here
14 always is 2,800 ppm of boron as boric acid, lithium
15 hydroxide. Typically there are about four grams per
16 liter of the phosphate material. And the temperature
17 was 54 degrees C.

18 The screen loading, again, if I put in the
19 55 pounds of cal-sil scaled to my test loop size that
20 they use in ICET-3, I wouldn't have to look for
21 chemical effects because nothing would move.

22 So we have picked loadings per unit area
23 that seem relatively representative of what we might
24 expect to find in plants. That is, these loadings
25 range up and down from plant to plant and from

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1 scenario to scenario in the plant, but we're somewhere
2 in a reasonable range.

3 This particular one uses 15 grams of
4 cal-sil and 15 grams of NUKON. We build the bed at .1
5 feet per second. And the intent in the test is
6 typically to build a bed at .1 feet per second. And
7 then we'll get a stable bed. And at that point, we'll
8 do some velocity cycling, typically down.

9 Our understanding is that the .1 feet per
10 second is sort of an upward bound for the actual
11 velocities that we might be interested in. So we
12 typically are interested in looking at lower
13 velocities

14 CHAIRMAN WALLIS: Can you build a bed
15 which is made of NUKON, then after --

16 MEMBER SHACK: That varies from test to
17 test. In most of the tests, we mixed the NUKON and
18 the cal-sil together. And I should mention that our
19 NUKON is preprocessed.

20 You know, we start out with the leaf
21 shredder kind of NUKON. Then that's processed in a
22 blender. And our blender comes from Wal-Mart. And we
23 use the ice crush setting for 30 seconds. The PNNL
24 people have --

25 MEMBER DENNING: Prebaked?

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1 MEMBER SHACK: Prebaked. The PNNL people
2 have worked out a test to sort of characterize to some
3 extent the processing that goes on at the NUKON. They
4 look at sort of the retained water that comes out of
5 the NUKON. And they have sort of systematically
6 looked at that.

7 We get a bed that is reasonably uniform.
8 And so we have stuck with this one preparation
9 procedure. Again, it comes out with a fairly finely
10 disbursed amount of NUKON. The cal-sil we again -- we
11 crush the cal-sil, the mortar and pestle, to a fairly
12 fine grade.

13 What we do in most of our tests is then
14 presoak the cal-sil/NUKON mixture for 30 minutes.
15 This sort of represents what happens in your waiting
16 in a reactor for a certain amount of time before you
17 start recirculation. So before this stuff arrives at
18 the screen, it has had a certain amount of time to
19 dissolve. And I'll talk about that --

20 CHAIRMAN WALLIS: So you have got this 15
21 grams of one and 15 grams of the other. You just pour
22 it on top of the pipe. And then it somehow finds its
23 way to the screen?

24 MEMBER SHACK: Yes. We mix them together.
25 We make a slurry of 15 grams of cal-sil and 15 grams

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1 of --

2 CHAIRMAN WALLIS: Then you establish the
3 bed for a long time, don't you?

4 MEMBER SHACK: It depends. The fiber beds
5 -- well, it also depends on what you mean by
6 "establish."

7 CHAIRMAN WALLIS: You say "establish."

8 MEMBER SHACK: Yes.

9 CHAIRMAN WALLIS: We want to know what you
10 mean.

11 MEMBER SHACK: My standards aren't as high
12 as PNNL's. So for a NUKON bed, I can establish the
13 bed with a fairly few recircs. And our benchmark
14 tests we're running for 20 --

15 CHAIRMAN WALLIS: PNNL, one of you guys
16 takes hours to recirc.

17 MEMBER SHACK: Yes. In fact, if you look
18 at the cal-sil beds, it takes a long time to get an
19 established cal-sil bed.

20 CHAIRMAN WALLIS: It's a mystery, isn't
21 it?

22 MEMBER SHACK: No. It's just the
23 filtration keeps increasing. And you keep taking out
24 finer and finer amounts of cal-sil.

25 CHAIRMAN WALLIS: There's always the

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1 debate about whether that is what is happening or
2 something else because from the turbidity measurements
3 they did at Los Alamos, you conclude that all the
4 cal-sil is taken out pretty early on.

5 MEMBER SHACK: No. I mean, you can see
6 the cal-sil in the loop for a long time. It remains
7 milky, yes. The NUKON disappears to the eye very
8 quickly. You can argue over how long it takes to get
9 the last few percent of it out, but the cal-sil was
10 there for a long time.

11 CHAIRMAN WALLIS: So how can you correlate
12 anything if you don't know how much cal-sil there is
13 in the bed?

14 MEMBER SHACK: We know how much we're
15 adding and how much the potential is. In this
16 particular first test, the way we did the test, we
17 wanted to essentially look at the ICET-3 condition,
18 where when they did ICET-3, they added the cal-sil.
19 And they waited for four hours before they added the
20 TSP.

21 CHAIRMAN WALLIS: Now, you have ICET-3, 4.
22 Is it ICET-3 point what when you say "first test"?

23 MEMBER SHACK: ICET-3-1.

24 CHAIRMAN WALLIS: 3-1?

25 MEMBER SHACK: Because I don't think --

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1 CHAIRMAN WALLIS: It doesn't appear in the
2 quick look report.

3 MEMBER SHACK: No. That's in the first
4 quick look report.

5 CHAIRMAN WALLIS: Okay. This other one,
6 the one from last year.

7 MEMBER SHACK: The one from last year. So
8 in this test, we established the bed. Then we added
9 calcium chloride to give us the amount of dissolved
10 calcium that we estimated was in ICET-3.

11 CHAIRMAN WALLIS: Along with establishing
12 the bed, you didn't take very long to make this bed
13 compend with PNNL?

14 MEMBER SHACK: Mostly because we sort of
15 thought when we added the calcium phosphate, that it
16 was going to overwhelm everything and we wouldn't be
17 worried about small changes.

18 DR. BANERJEE: So you establish the bed
19 first and then --

20 MEMBER SHACK: First. Then we added the
21 calcium as calcium chloride. We had TSP in the loop.
22 And so we immediately performed a precipitate, which
23 built up on the bed. And we had a very high head loss
24 essentially. The first recirculation, we essentially
25 took the loop to its capability, about five or six

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1 psi.

2 MR. TREGONING: Just a point of
3 clarification. The establishment of the debris bed
4 initially and then adding calcium chloride was really
5 limited to these first two tests here and then a few
6 tests later on. But there are really a multitude of
7 ways in which the bed was established with different
8 amounts of particulate cal-sil, NUKON, and calcium
9 phosphate.

10 CHAIRMAN WALLIS: So you did various
11 things, it seems to me.

12 MR. TREGONING: Yes.

13 CHAIRMAN WALLIS: You run it for about
14 three-quarters of an hour. And then you increased the
15 velocity if I'm looking at the right -- are you going
16 to show us these traces?

17 MEMBER SHACK: Well, we will when we get
18 to the test. You know, replicating ICET-3 was one,
19 the first test. You know, when we get to the tests
20 that we think are more representative, we will look at
21 those traces in a little more detail.

22 The next test that we ran again had the
23 same kind of prebuilt bed, a mixture of NUKON and
24 cal-sil. But, instead of adding the 200 ppm of
25 calcium, dissolved calcium, that we expected from the

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1 ICET-3 test, we started out adding 10, 25, and 50 ppm
2 of dissolved cal-sil or dissolved calcium, which,
3 again, formed a calcium phosphate precipitate.

4 And, again, we had measurable increases in
5 head loss with as little as ten ppm calcium.
6 Twenty-five ppm gave us much larger ones. And, again,
7 50 and above gave us very large head losses with these
8 debris beds.

9 Again, the results from these initial
10 tests, we had increased head loss for all the
11 dissolved calcium concentrations down to ten ppm. We
12 did see in one test an interesting phenomenon where
13 the calcium phosphate agglomerated. And it comes down
14 as a white milky substance.

15 At a very, very low velocity, the particle
16 sort of agglomerated into rather large snowflake kinds
17 of things. So, instead of a fine milky precipitate,
18 we had sort of isolated large snowflakes in a
19 relatively clear solution.

20 DR. BANERJEE: Why did that happen? Any
21 clues?

22 MEMBER SHACK: No because we don't seem to
23 be able to reproduce that. We don't call it an
24 anomalous result, but we expected that to happen every
25 time. Because it happened when we had a very low

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1 velocity, we expected to find that happen every time
2 we dealt with a very low velocity thing. And it
3 doesn't seem to. I don't know. It seems to happen
4 sometimes and it doesn't happen other times.

5 CHAIRMAN WALLIS: It may depend on what is
6 happening in the rest of the loop.

7 MEMBER SHACK: It is not clear I guess is
8 the only thing I can say.

9 DR. BANERJEE: Has it happened more than
10 once?

11 MEMBER SHACK: It was most dramatic in
12 this one test. And we again see a tendency towards
13 agglomeration in the slower velocities but nothing as
14 dramatic as it was in the first test, where we again
15 -- I think there's a photo in the quick look report.
16 I mean, it really is very large snowflakes in what
17 looks like to be a fairly clear solution; whereas, in
18 almost all the other cases, there's a real milkiness
19 to the solution.

20 MEMBER DENNING: Are they truly
21 agglomerated or are they growing crystalline?

22 MEMBER SHACK: It is hard to say. They
23 look to me like agglomerates, but it's hard to say.

24 MR. TREGONING: There were some unique
25 things about that test, though, that we haven't tried

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1 to demonstrate. I mean, we had deposited and filtered
2 out a significant percentage of product on the bed.

3 And, really, we didn't drop back to lower
4 velocities in that test until we had reached a point
5 where we were starting to ingest air into the pump.
6 So then the flow rate was cut back. So it's hard to
7 even ascertain how much product was really in the
8 loop. And the product could have had very different
9 particulate sizes than standard calcium phosphate that
10 hadn't been prefiltered in any way.

11 So there were some unique things. I'm not
12 using the word "anomalous." There were some unique
13 things about that test that may partially explain some
14 of the --

15 CHAIRMAN WALLIS: There seems to be a snow
16 of precipitate, both in test 1 and test 2.

17 MEMBER SHACK: Well, yes. The snow in
18 test 1 is completely, you know --

19 CHAIRMAN WALLIS: It looks more like a
20 pile of down or something.

21 MEMBER SHACK: Right, yes. You know, the
22 200 ppm just gives you an enormous amount of calcium
23 phosphate, but that --

24 CHAIRMAN WALLIS: So the snow here you are
25 talking about is in test 2?

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1 MEMBER SHACK: Is test 2. Now, the
2 interesting --

3 CHAIRMAN WALLIS: Figure 9 is the snow,
4 isn't it, flocculent precipitates?

5 MEMBER SHACK: I don't know the figure
6 numbers, I'm afraid.

7 DR. BANERJEE: Figure 9 has the flocculent
8 precipitates.

9 MEMBER SHACK: Okay. The important thing
10 is that when we go off and we look at dissolution
11 tests with -- and, again, it's at that time we were
12 looking at fairly higher loads of calcium silicate, 6
13 to 25 grams per liter. We can form the 220 ppm fairly
14 quickly, 30 minutes in an initial acidic environment.
15 And, again, we expect the calcium to keep dissolving
16 until we -- to continue.

17 Now, we wanted to go on to look at
18 additional head loss tests for the ICET-3 environment.

19 CHAIRMAN WALLIS: Are you going to show us
20 any data?

21 MEMBER SHACK: Yes.

22 CHAIRMAN WALLIS: All these words --

23 MEMBER SHACK: It's coming. It's coming.

24 DR. BANERJEE: Most of the precipitate,
25 the floc seems to be forming in the region away from

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1 the bed itself.

2 MEMBER SHACK: It is forming, you know,
3 essentially as rapidly as we are adding them through.

4 DR. BANERJEE: Right.

5 MEMBER SHACK: I mean, the reaction time
6 for calcium and phosphate is instantaneous. So it's
7 forming essentially as soon as we add it to the loop.
8 And then it's just carried on down to the bed.

9 CHAIRMAN WALLIS: Well, I guess you are
10 going to get to the data. We're going to talk about
11 it --

12 MEMBER SHACK: Yes, we are going to get to
13 the data.

14 CHAIRMAN WALLIS: So we can anticipate it.
15 You put it in in pieces in test two. You put in a
16 little bit and then some more and then some more.

17 MEMBER SHACK: Yes. That was just so we
18 could get one test to cover a range of calcium
19 additions. You know, you can argue whether that is a
20 realistic way to do it, but we were just trying to get
21 some sort of feel for what kind of levels of calcium
22 it was needed to get, you know, a measurable chemical
23 effect.

24 When we started to do a little bit more
25 systematic look at this, you know, there are a number

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1 of important variables here. And one of them is the
2 degree of calycle dissolution that occurs prior to the
3 debris bed formation.

4 If we get dissolution before the debris
5 bed forms, then we have a debris bed that forms from
6 NUKON, from calcium silicate, and calcium phosphate
7 all mixed together.

8 If, in fact, we form the bed before we
9 have much dissolution. Then the transformation to the
10 calcium phosphate occurs within the bed. And you
11 could argue --

12 CHAIRMAN WALLIS: This is where it makes
13 a difference what is in the rest of the loop because
14 if you put the stuff in just above the bed, then it
15 will go through and doesn't come up short until it
16 goes all the way around the loop and comes back. By
17 that time, it has probably made some calcium
18 phosphate.

19 DR. BANERJEE: No. He is saying the
20 reaction is instantaneous.

21 MEMBER SHACK: Yes, once you get to the
22 solution. You're limited by the dissolution rate of
23 the calcium silicate, not the formation rate of the
24 calcium phosphate.

25 CHAIRMAN WALLIS: You think if you put it

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1 in your plans, by the time it gets to the bed, it's
2 already precipitated?

3 MEMBER SHACK: Oh, yes. It is calcium
4 phosphate long before it ever gets to the bed if
5 there's this flow of calcium. The calcium silicate
6 arrives at the bed and then proceeds to dissolve.

7 CHAIRMAN WALLIS: So why does it keep on
8 building up for minutes after that, then?

9 MEMBER SHACK: Because we don't have all
10 the calcium silicate dissolved when we add it to the
11 bed. We are adding a mixture of calcium silicate and
12 partially dissolved calcium silicate.

13 CHAIRMAN WALLIS: So when it says "10 ppm
14 calcium," that means calcium in what form?

15 MEMBER SHACK: Yes. In that particular
16 test, we were adding dissolved calcium. So we were
17 controlling that in the test.

18 CHAIRMAN WALLIS: It still keeps building
19 up over time after that. It doesn't instantly --

20 MEMBER SHACK: Because we are going to
21 dissolve calcium silicate.

22 DR. BANERJEE: So if I understand the
23 model, it is like, or at least your thinking, it is
24 that as you precipitate calcium phosphate, normal
25 calcium silicate dissolves and if you have an excess

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1 of --

2 MEMBER SHACK: Phosphate.

3 DR. BANERJEE: -- phosphate, it will
4 continue to --

5 CHAIRMAN WALLIS: Okay. Well, I guess we
6 have to look at your data --

7 MEMBER SHACK: Yes.

8 CHAIRMAN WALLIS: -- because it looks as
9 if nothing much happens for 20 minutes, although you
10 have added cal-sil, until you suddenly put in this
11 dissolved stuff. And then it really goes off.

12 MEMBER SHACK: Hopefully we'll get to
13 that.

14 MR. TREGONING: It depends dramatically on
15 the test --

16 MEMBER SHACK: Test, yes.

17 MR. TREGONING: -- and the way in which
18 the debris was prepared.

19 MEMBER SHACK: But the important thing
20 here is we want to look at the degree of dissolution
21 that occurs to the --

22 MR. TREGONING: Which we think we
23 understand pretty well. Sorry. I didn't mean to
24 leave you hanging.

25 MEMBER SHACK: And this degree will depend

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1 on how long it basically takes to get to the bed. So
2 you've got the time to start recirculation, which is
3 typically 30 minutes.

4 You've got a transport time, which will
5 depend -- you know, it's variable depending on where
6 the accident occurs and how things are moving within
7 the bed, and the rate of TSP dissolution. That is, we
8 can alter that or at least it certainly seems
9 conceivable that that would have an effect.

10 DR. BANERJEE: But you are adding
11 dissolved TSP or TSP --

12 MEMBER SHACK: We are adding dissolved
13 TSP, but we are simulating essentially how long the
14 TSP takes to --

15 DR. BANERJEE: Comes from that basket.

16 MEMBER SHACK: Comes from the basket. So
17 that's a variable for us, is that rate that we're
18 adding the TSP.

19 CHAIRMAN WALLIS: So you are adding TSP at
20 some steady rate as well. And it doesn't say on the
21 graph when the TSP gets in there.

22 MEMBER SHACK: Because on some tests, it's
23 instantaneous. Let me go through it test by test, and
24 I'll try to --

25 CHAIRMAN WALLIS: Okay. You explain it.

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1 Okay. It's just I've got more data than you are going
2 to show.

3 MEMBER SHACK: Well, I am going to show
4 enough data that we ought to keep us busy. Of course,
5 the NUKON and the cal-sil screen loading is another
6 critical factor.

7 CHAIRMAN WALLIS: So you're not to explain
8 test 2?

9 MEMBER SHACK: I want to go on to real
10 tests. Tests 1 and 2 were --

11 CHAIRMAN WALLIS: Just too --

12 MEMBER SHACK: Those were scoping tests to
13 give us an idea.

14 CHAIRMAN WALLIS: It gives very
15 interesting results.

16 DR. BANERJEE: What was wrong with them?

17 CHAIRMAN WALLIS: What was wrong with
18 them, right? It couldn't be explained.

19 MR. TREGONING: Nothing was wrong with
20 them.

21 MEMBER SHACK: Nothing was wrong with
22 them.

23 DR. BANERJEE: They look valuable.

24 CHAIRMAN WALLIS: They look very valuable,
25 yes.

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1 MEMBER SHACK: They were valuable in
2 indicating that you could get large head loss with
3 small amounts of dissolved calcium.

4 CHAIRMAN WALLIS: But it also showed the
5 way things build up with time after you do something,
6 which is very interesting.

7 MEMBER SHACK: We can come back to those
8 tests. I think the other tests are more interesting
9 if I could get to them.

10 DR. BANERJEE: Why are they interesting?

11 MEMBER SHACK: I will explain that when I
12 get to them if I ever get to them.

13 Now, just to look over our test procedure,
14 what we have done is to conduct baseline tests with no
15 TSP to assess the effect. Again, we get head loss.
16 with cal-sil and NUKON. That happens.

17 So we get that amount of head loss. We
18 want to see the change in head loss that occurs when
19 we have the chemical effect, which in ICET-3 requires
20 the TSP. So we do the baseline test without the TSP
21 and then the test with the TSP added in some way.

22 As I have mentioned, we typically presoak
23 the cal-sil in NUKON slurries at temperature for 30
24 minutes to simulate the time prior to recirculation.
25 I would argue that this is really a minimum residence

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1 time for dissolution. That is, in the real situation,
2 the cal-sil will be in the loop for something greater
3 than 20 minutes before it actually arrives to the
4 screen. So it's sort of a minimum time.

5 We have also essentially used calcium
6 chloride additions to represent the sort of limiting
7 case of complete. You know, rather than wait for the
8 calcium silicate to dissolve, we have just taken the
9 equivalent amount of dissolved calcium and added it by
10 getting calcium chloride.

11 So when we do the test with the NUKON bed
12 and the calcium chloride, we're looking at a test
13 where you have a very long residence time in the sump
14 before you build the bed. And that's a limiting case
15 for us.

16 DR. BANERJEE: So you have a nice table in
17 your report --

18 MEMBER SHACK: Right.

19 DR. BANERJEE: -- which summarizes all of
20 these things?

21 MEMBER SHACK: Right, which tries to put
22 those together. Again, we have looked at various
23 additions of the TSP to represent. Because that is
24 another uncertainty, we don't have a good grasp of
25 exactly how rapidly the TSP gets added. We wanted to

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1 see how large that effect was.

2 Okay. Now we're off to data. The rest
3 set of data we wanted to look at, the very faint one is
4 my baseline test here, which is really ICET-3-11.
5 It's this number 11 test.

6 So this is 15 grams of cal-sil, 15 grams
7 of NUKON, no TSP. And I'll get this again. It takes
8 me roughly at least an hour to get to some sort of
9 steady state condition or pseudo steady state
10 condition for the bed as it builds up. I get a
11 pressure loss of about a psi.

12 CHAIRMAN WALLIS: Now, in the tests at
13 LANL, sometimes it took a long time to equilibrate and
14 the pressure drop was building up with time.
15 Sometimes it didn't.

16 MEMBER SHACK: Well, the NUKON tests build
17 up very rapidly. With the cal-sil, it's much slower.

18 CHAIRMAN WALLIS: The NUKON, I think we
19 understand that.

20 MEMBER SHACK: Right.

21 CHAIRMAN WALLIS: But with cal-sil, it
22 seems to take different amounts of time to come to
23 equilibrium if it ever comes to equilibrium.

24 MEMBER SHACK: Well, in our experience
25 with our cal-sil tests, we have never found one that

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1 came rapidly up.

2 CHAIRMAN WALLIS: No. It's a question of
3 is it 10 minutes to a 50 or a 100?

4 MEMBER SHACK: No. It's more like is it
5 60 minutes --

6 CHAIRMAN WALLIS: Right.

7 MEMBER SHACK: -- or is it 200 minutes?

8 MR. TREGONING: That is not quite true.
9 The initial mixtures of debris, we initially looked at
10 different concentrations of debris. The first test in
11 there in the report had seven grams of NUKON and 25
12 grams of cal-sil. If you look at those, there is some
13 very rapid head loss that occurs in those tests.

14 Now, did it equilibrate? I would argue
15 probably not. But I think those results are somewhat
16 analogous to what we have seen in prior LANL studies
17 as well as subsequent PNNL studies as well.

18 DR. BANERJEE: This is ICET-3-25 you're
19 talking about, baseline?

20 MR. TREGONING: This would have been --

21 DR. BANERJEE: Seven, 25 cal-sil, 25?

22 MEMBER SHACK: We will come back to the 7
23 and 25. I wanted to go --

24 MR. TREGONING: Sorry.

25 MEMBER SHACK: There the head loss with

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1 the 25 grams of cal-sil was so large we couldn't
2 really discern a chemical effect. We were already --
3 we died from the physical debris. I wanted to go to
4 a test condition, at least initially, where we could
5 see a dramatic effect of the chemical effect.

6 DR. BANERJEE: So you're showing a presoak
7 effect versus a no presoak?

8 MEMBER SHACK: No, no. Again, test 11 is
9 a no chemical effect. This is purely physical debris.
10 It's just cal-sil and a NUKON, no TSP. I don't form
11 any calcium phosphate. I get one psi pressure drop.

12 If I take essentially the same conditions,
13 the physical debris loading, same pretreatment of the
14 cal-sil and NUKON except that now I have added TSP and
15 I add the TSP, I put half of the TSP in during the
16 presoak of 30 minutes and I add the remainder of the
17 TSP over the 30 minutes after the presoak is added to
18 the loop, I guess, of course, now a much, much larger
19 head loss.

20 CHAIRMAN WALLIS: So it goes up in steps
21 if it has something to do with the residence time in
22 the loop? Is that what is going on there?

23 MEMBER SHACK: Well, I suspect that it is
24 building up as I take recirculations around the bed
25 and I'm filtering and I'm filtering and I'm filtering.

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1 DR. BANERJEE: Typical recirculation time
2 is what?

3 MEMBER SHACK: Three and a half to four
4 minutes.

5 MEMBER DENNING: So it is consistent with
6 the steps, --

7 CHAIRMAN WALLIS: So it is reasonably
8 consistent with the steps, right.

9 MEMBER DENNING: -- although it could be
10 --

11 MEMBER SHACK: This is a test where I have
12 added the TSP during the presoak.

13 CHAIRMAN WALLIS: Which is that test?

14 MEMBER SHACK: That's test 10.

15 DR. BANERJEE: Half during presoak, half
16 --

17 MEMBER SHACK: Half.

18 DR. BANERJEE: -- metered in after?

19 MEMBER SHACK: Now, you know, the half
20 presoak, half afterwards, I could have forgotten the
21 half afterwards because I had all the phosphate I
22 needed to do the job already, but, you know, we're
23 just sort of -- it sort of looks nice to be
24 semi-prototypical-looking.

25 DR. BANERJEE: But more complex to

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1 interpret, right?

2 MEMBER SHACK: The next interesting test
3 to look at now is test number 6, where we have
4 essentially added -- again, here is my baseline test
5 with no TSP. And, again, it's the same baseline test
6 that I had up here. But in this test, I didn't add
7 the TSP to the presoak.

8 CHAIRMAN WALLIS: When did you add it?

9 DR. BANERJEE: Which number is that?

10 MEMBER SHACK: Test 6.

11 DR. BANERJEE: I thought you added 18
12 initially.

13 MEMBER SHACK: That's to the loop, but not
14 to the presoak. Now --

15 CHAIRMAN WALLIS: So there is TSP in this?

16 MEMBER SHACK: There is TSP.

17 CHAIRMAN WALLIS: Why is there no effect
18 until 35 minutes?

19 MEMBER SHACK: I'll explain that. One of
20 the things that's, again, unprototypical about our
21 situation is that -- and we'll discuss this when we
22 come to the dissolution test -- typically adding TSP
23 slows the dissolution rate if you have got low
24 concentrations of cal-sil because, again, the cal-sil
25 dissolves more rapidly in an acidic environment.

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1 If you have the cal-sil and you add the
2 TSP, you get a more neutral environment. You slow the
3 dissolution of the cal-sil. That's not true in
4 concentrated cal-sil solutions because what happens in
5 those cases, you add the cal-sil. It begins to
6 dissolve. And you essentially now saturate the
7 solution with dissolved calcium.

8 You come to an equilibration of the
9 calcium-calcium silicate dissolution at that
10 condition. You can increase the dissolved calcium in
11 that test by adding TSP. So you take the calcium out
12 of solution, and you allow more calcium to dissolve.

13 DR. BANERJEE: In this test 6, you had a
14 presoak, right?

15 MEMBER SHACK: We had a presoak, but we
16 didn't add any TSP, which means that --

17 DR. BANERJEE: During the presoak?

18 MEMBER SHACK: During the presoak.

19 DR. BANERJEE: Right.

20 MEMBER SHACK: So in the presoak, we got
21 up to 200 ppm dissolved cal-sil because the
22 concentration in our presoak happens to be just about
23 what it is in ICET-3. That's an accident. And so you
24 get the 200 ppm. So when we dilute that into the
25 loop, we're only adding four ppm of dissolved calcium

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1 at that point. And you see very little effect.

2 Now, what happens is that as you're in
3 this loop, calcium continues to dissolve. Most of the
4 cal-sil or much of the cal-sil has been trapped in the
5 bed. Other of it is circulating around. But it is
6 dissolving. It's combining with the calcium
7 phosphate.

8 CHAIRMAN WALLIS: TSP came in at the
9 beginning?

10 MEMBER SHACK: TSP came in at the
11 beginning, but if there's no dissolved calcium, it
12 doesn't --

13 CHAIRMAN WALLIS: It doesn't say so. It
14 would be useful if it said "TSP" at that arrow or
15 something so that we can --

16 MEMBER SHACK: Okay. I can --

17 DR. BANERJEE: TSP is there.
18 One-sixteenth of the --

19 MEMBER SHACK: One-eighth.

20 DR. BANERJEE: One-eighth, yes, is already
21 there.

22 MEMBER SHACK: But, again, since I have
23 very little dissolved calcium, it doesn't make any
24 difference. But, again, as I begin to dissolve the
25 calcium, I build up my head loss. And essentially I

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1 get up eventually to a very high head loss, again
2 given enough time.

3 MR. CARUSO: Let me just say this again.
4 We add all the TSP and one shot at times zero.

5 MEMBER SHACK: No, no, no. I had
6 one-eighth --

7 MR. CARUSO: You had one-eighth there.

8 MEMBER SHACK: -- in there. And then I
9 added the rest of it over time.

10 DR. BANERJEE: Over how long? Over how
11 long?

12 MEMBER SHACK: Essentially a half an hour.

13 CHAIRMAN WALLIS: When did you stop?

14 MEMBER SHACK: When I ran out of TSP.

15 CHAIRMAN WALLIS: So that should be shown
16 on graph 2 or something --

17 MEMBER SHACK: Yes, yes.

18 CHAIRMAN WALLIS: -- so we can tell what's
19 going on.

20 MS. TORRES: I think it was in test 6.
21 Wasn't it metered into seven-eighths over an hour?

22 MEMBER SHACK: It may have been over an
23 hour. Again, since you're calcium-limited here, it
24 almost doesn't matter which rate you add the -- I
25 could have dumped all the phosphate in at T equals

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1 zero and it wouldn't have made a dime's worth of
2 difference to what is going on here. I have to wait
3 until the calcium dissolves.

4 DR. BANERJEE: I am trying to understand
5 the mechanism. I guess Graham is, too. So let's go
6 over it step by step. If you presoak the stuff
7 without TSP, some of the calcium and the cal-sil goes
8 into solution at that point.

9 MEMBER SHACK: At 200 ppm roughly.

10 DR. BANERJEE: Two hundred ppm. But since
11 there is no TSP there, it has nothing to react
12 against.

13 MEMBER SHACK: Right.

14 DR. BANERJEE: So no precipitators form,
15 nothing.

16 MEMBER SHACK: Nothing. The dissolution
17 stops.

18 DR. BANERJEE: At that point, it stops.

19 MEMBER SHACK: It stops.

20 DR. BANERJEE: Now you start adding TSP.

21 MEMBER SHACK: I know. Now I pour this
22 into the loop.

23 DR. BANERJEE: The loop. And you add TSP.

24 MEMBER SHACK: Adding TSP.

25 DR. BANERJEE: So forget the one-eighth

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1 that you added.

2 MEMBER SHACK: Right.

3 DR. BANERJEE: So as you do that, you
4 start to precipitate our --

5 MEMBER SHACK: I start to dissolve
6 calcium.

7 DR. BANERJEE: But you must make room for
8 it so it's reacting, right?

9 MEMBER SHACK: Right. Well, my dissolved
10 calcium level once I've poured the presoak into the
11 loop is four ppm. It's going to start dissolving and
12 immediately react with the phosphate.

13 DR. BANERJEE: Okay. Because you're
14 diluting it?

15 MEMBER SHACK: Because I'm diluting it.

16 DR. BANERJEE: So it starts to dissolve,
17 --

18 MEMBER SHACK: Right.

19 DR. BANERJEE: -- starts to react with the
20 phosphate.

21 MEMBER SHACK: And eventually I see a
22 buildup in the pressure.

23 DR. BANERJEE: So does it get to sort of
24 the equilibrium level of around 200, the calcium, or
25 what happens to the calcium levels?

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1 MEMBER SHACK: No. The calcium all
2 disappears because there's more than enough phosphate
3 to take out all the calcium.

4 DR. BANERJEE: It eats it?

5 MEMBER SHACK: The phosphate just eats it
6 all up.

7 DR. BANERJEE: So the rate-determining
8 step becomes the dissolution of the cal-sil.

9 MEMBER SHACK: Dissolution of the cal-sil.

10 MR. CARUSO: Until the phosphate is
11 exhausted?

12 MEMBER SHACK: Well, in the real world, it
13 appears that you're almost always calcium-limited,
14 rather than phosphate-limited. In ICET-3, you were
15 phosphate-limited.

16 DR. BANERJEE: So it is not a very complex
17 mechanism.

18 MEMBER SHACK: The important thing here is
19 how fast it can all happen. You know, people talk
20 about having margins for head loss. It's one thing if
21 you're building up chemical effects over 30 days. You
22 know, we're talking about chemical effects that occur
23 over an hour, you know, 30 minutes.

24 DR. BANERJEE: So it's basically dictated
25 by dissolution kinetics.

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1 MEMBER SHACK: Dissolution kinetics.

2 DR. BANERJEE: Which depends on the fluid
3 mechanics probably of the dissolution, right?

4 MEMBER SHACK: Well, I would argue, you
5 know, you're in a fairly quiescent pool.

6 DR. BANERJEE: This thing is in this
7 basket with flows going through it.

8 MEMBER SHACK: Right. Now, the TSP --

9 DR. BANERJEE: It has a plume behind it or
10 something?

11 MR. CARUSO: Are you really in a quiescent
12 pool? I mean, it's raining throughout.

13 MEMBER SHACK: Well, it is raining
14 throughout, yes.

15 MR. CARUSO: Raining pretty healthfully,
16 too.

17 MEMBER SHACK: Whether it is raining or
18 it's quiescent, it doesn't make much -- you know,
19 whether it gets you in 20 minutes or 45 minutes, you
20 know, I'm not going to argue over that. The answer is
21 it happens fairly quickly. I think that's the
22 important point here. You know, I'm not going to
23 argue over prototypically exactly what time it is, but
24 it's not 30 days.

25 DR. BANERJEE: So you're saying it's

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1 phosphate-limited, this whole thing?

2 MEMBER SHACK: It is calcium-limited.

3 DR. BANERJEE: Isn't there a lot of
4 calcium around?

5 MEMBER SHACK: No, no, no. The calcium
6 primarily comes from the cal-sil insulation. Now, we
7 could argue how much calcium is in the concrete, how
8 much you could get out of the NUKON itself, but the
9 cal-sil is the primary source of the calcium. So it
10 is really cal-sil-limited.

11 DR. BANERJEE: So there is excess
12 triphosphate.

13 MEMBER SHACK: Excess triphosphate.

14 CHAIRMAN WALLIS: So this cal-sil is
15 mostly trapped in the bed, isn't it? So the reaction
16 is taking place in the bed?

17 MEMBER SHACK: Well, there are cal-sil
18 fines that are recirculating. There is cal-sil
19 trapped in the bed. Exactly what fraction is in the
20 bed and what fraction is recirculating, which portion
21 is dissolving is not clear.

22 DR. BANERJEE: You didn't take any samples
23 and do this sort of thing that these guys did?

24 MEMBER SHACK: No. We probably should
25 have been doing that, but we didn't.

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1 Just to come on again, we did some
2 replicate tests. And, again, this is a replicate test
3 now of the one with the TSP addition, where we're
4 adding the half TSP to the presoak. And so we get,
5 you know, a little difference, but we get high head
6 losses of about the same magnitude in each case. And,
7 you know, it happens fairly quickly, a little more
8 quickly.

9 CHAIRMAN WALLIS: Now, this argument that
10 the buildup with time is all due to continually
11 filtering out more cal-sil I think needs to be sorted
12 out, whether that's true or whether it's due to the
13 changes in the structure of the bed, which is another
14 explanation, which seems to be consistent with some of
15 the observations from previous tests.

16 MEMBER SHACK: I mean, if you look visibly
17 at the turbidity, it's decreasing as the test --

18 CHAIRMAN WALLIS: Well, one way you could
19 do it easily -- well, I don't know if you could do it
20 easily -- is to simply take out the fluid and put in
21 clean fluid.

22 MR. TREGONING: The PNNL people are going
23 to be doing things like that.

24 CHAIRMAN WALLIS: Doing that kind of
25 thing. Okay.

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1 MR. TREGONING: Well, I think the PNNL
2 results will show you some differences between
3 continual filtering due to accumulation of debris --

4 CHAIRMAN WALLIS: See, this continual
5 filtering, why is it in this bottom test, jump up in
6 steps like that? If you look at what happened after
7 you increase the flow, it goes up in another step like
8 that.

9 MEMBER SHACK: Okay. You know, just to
10 replicate this test, we're coming down here to the no
11 TSP test. So this is a pure physical debris test.
12 Again, I would argue that as I decrease velocity,
13 these beds remain fairly stable. That is, you know,
14 there are undoubtedly changes. And we measure changes
15 in the bed depth as we decrease the velocity, the
16 pressure drop decreases, and there is a kind of an
17 elastic expansion of the bed.

18 When you increase the velocity, you get a
19 sort of a non-linear effect. And so you compress the
20 bed. It now becomes a more effective filtration
21 mechanism. And so you trap more. And you're trapping
22 more within the bed.

23 So you not only get the immediate jump-up
24 of the elastic or of the compression, you get a
25 continual buildup due to the more effective filtering

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1 you get of the cal-sil that's still in the --

2 DR. BANERJEE: But the bed permeability
3 doesn't go linearly within Darcy's law.

4 MEMBER SHACK: No.

5 DR. BANERJEE: So, in fact, that's what
6 you're seeing that effect, that even though the
7 porosity mentioned and the permeability won't. That's
8 why I think you get the higher pressure drop.

9 MEMBER SHACK: So you get this buildup
10 here that's continuing on. Now, again, so we have
11 shown, at least under some conditions, you get a very
12 dramatic contribution of the calcium phosphate to the
13 head loss. That is, you're getting a much higher head
14 loss --

15 CHAIRMAN WALLIS: Bill, now, I have found
16 this now. To go back to the figure 13 you showed us,
17 which is --

18 MEMBER SHACK: Which slide?

19 CHAIRMAN WALLIS: The one on the bottom
20 there. In your report, you have a corresponding
21 figure, which shows the trajectory of pressure drop
22 and velocity go up.

23 MEMBER SHACK: Yes.

24 CHAIRMAN WALLIS: And then when you
25 decrease the velocity at around 210, right, you

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1 decrease the velocity, what you show in your figure is
2 that you go to decrease the velocity from .1 to .09,
3 .09 something, you hardly decrease it at all and the
4 pressure drop goes down by about 60 percent, which
5 seems very strange. It doesn't show on this figure
6 because you haven't got the --

7 DR. BANERJEE: What is the number?

8 CHAIRMAN WALLIS: This is figure 14. I
9 mean, usually you expect it to go back the way it came
10 up more or less.

11 DR. BANERJEE: It's a hysteresis effect.

12 CHAIRMAN WALLIS: Well, yes, but the
13 hysteresis effect is usually the other way around.

14 DR. BANERJEE: Right.

15 CHAIRMAN WALLIS: Usually it stays up,
16 rather than leaping down? There's something strange
17 about that. If it's --

18 MEMBER SHACK: Partly that could be just
19 the way that we're sampling the data when we make a
20 rapid change here.

21 CHAIRMAN WALLIS: If it's a correct plot.
22 Maybe the plot is misleading in some way.

23 DR. BANERJEE: Well, the top branch has
24 the hysteresis effect that you expect.

25 CHAIRMAN WALLIS: That you expect, right.

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1 And the bottom one is odd, unusual. Maybe it's an
2 artefact of the way you're sampling or something.
3 You're going to sort that one out.

4 MEMBER SHACK: We will sort that one out.

5 CHAIRMAN WALLIS: And then there is
6 something odd, too, in that if you look at the
7 trajectory, after about, you know, we get to 0.14 feet
8 a second or something, it seems to be going up very
9 steeply. Presumably if you kept on that trajectory,
10 it would go up to an even much higher value.

11 So there are a whole lot of questions you
12 get from -- I'm sure you asked yourself these things,
13 too. The more you look at the details, the more you
14 want to do another test.

15 I'm sorry. The audience doesn't
16 understand it because I'm looking at another figure,
17 but if you look at the other figure of how velocity is
18 changed and pressure drops, there are some anomalous
19 things or some odd things about that, the way it
20 works.

21 DR. BANERJEE: But you also show us tests
22 1 and 2 because they have a very interesting --

23 CHAIRMAN WALLIS: He doesn't want to do
24 that, though.

25 MEMBER SHACK: We don't want to do that.

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1 Let's go through all the tests I want to show you
2 first. And then we can come back to those if we have
3 time.

4 DR. BANERJEE: You should not send us the
5 quick look reports.

6 MEMBER SHACK: We did.

7 DR. BANERJEE: You should not.

8 MEMBER SHACK: And, again, what we're
9 looking at here are rests where we have had now the
10 same 15 grams of NUKON, but we changed the cal-sil
11 from 5 grams to 10 grams, 15 grams.

12 CHAIRMAN WALLIS: Of course, your numbers
13 of grams don't correlate with the Los Alamos tests
14 precisely, do they?

15 MEMBER SHACK: No. We have different --

16 CHAIRMAN WALLIS: Right.

17 MEMBER SHACK: What you need to compare
18 are screen loadings because we have different
19 diameters.

20 CHAIRMAN WALLIS: You have the same
21 diameter, don't you, almost essentially the same
22 diameter?

23 MEMBER SHACK: No. Theirs is almost a
24 foot.

25 CHAIRMAN WALLIS: Is there a big

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1 difference there?

2 MEMBER SHACK: Oh, yes. This is a very
3 significant --

4 CHAIRMAN WALLIS: I thought we had a
5 six-inch one, too.

6 MEMBER SHACK: No, no.

7 CHAIRMAN WALLIS: It was PNNL that has the
8 six?

9 MEMBER SHACK: PNNL. We're close.
10 There's a big difference between ours and the --

11 CHAIRMAN WALLIS: I was confused, then.
12 Okay.

13 MEMBER SHACK: Again, with these loadings,
14 we see a relatively -- you know, almost no measurable
15 effect of --

16 CHAIRMAN WALLIS: But you don't have a
17 plot showing how your data compare with somebody
18 else's?

19 MEMBER SHACK: We're running the benchmark
20 tests now. We were supposed to run the benchmark
21 tests a long time ago. We ran the first ICET-3 test.
22 It turns out the results were so interesting everybody
23 wanted to keep testing chemical effects. And we never
24 got around to the benchmark testing for a while.

25 DR. BANERJEE: So 3-11 does not qualify as

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1 a benchmark, then?

2 MEMBER SHACK: Well, I should say that if
3 we go back and we look at our pure no TSP test and to
4 the velocities -- we have built better, comparable
5 ones with PNNL. We actually compare pretty well.

6 You know, we didn't run those as benchmark
7 tests. You know, they build their bed. And then they
8 go off and do their velocity cycling. And we go off
9 and add our chemicals. But if you just looked at the
10 initial portions where we could compare them, I would
11 say that we are comparing fairly well.

12 So I think that the benchmark tests will
13 demonstrate that we get comparable results, but that
14 at the moment we have no systematic comparison of
15 those.

16 DR. BANERJEE: Did you do a premixed --

17 MEMBER SHACK: Yes. Again, you know, if
18 we're comparing premixed with premixed, obviously if
19 we compare different addition histories, you'll get
20 different results. But, again, when we're actually
21 trying to match tests where the conditions are
22 expected to give us the same results, we get it.

23 Again, my point here only is that our
24 relative contribution of the calcium phosphate depends
25 strongly on the debris loading. These are the tests

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1 that --

2 CHAIRMAN WALLIS: Although on the bottom
3 figure there, you haven't really reached an
4 equilibrium because your velocity is continuing to
5 decrease, I understand.

6 MEMBER SHACK: Yes. Well, we can't --

7 CHAIRMAN WALLIS: Velocity number 10 is
8 drifting down. If you kept it constant, one might
9 hypothesize that the red curve would keep on going up.

10 MEMBER SHACK: Right. But when we --

11 CHAIRMAN WALLIS: Pump more than five psi?
12 Is that it?

13 MEMBER SHACK: Right. You know, we're
14 pushing the loop to its --

15 DR. BANERJEE: It's acanthotic.

16 CHAIRMAN WALLIS: But it hasn't reached an
17 equilibrium, essentially. It's still drifting down.

18 MEMBER SHACK: Yes. If we push the
19 velocity back up and if we pressurize the loop and
20 push the velocity back up, we would get more head
21 loss. But that wasn't what we were really trying to
22 demonstrate there. All we wanted to do was
23 demonstrate that the calcium phosphate was giving you
24 a greater increase to the velocity.

25 CHAIRMAN WALLIS: But if someone were

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1 looking at this and saying they have reached
2 equilibrium, that would not be a right conclusion.

3 MEMBER SHACK: No, that's not. That's not
4 the correct conclusion because we can't maintain
5 velocity in the loop.

6 DR. BANERJEE: Are there still fines being
7 generated at that point, do you think, or are you just
8 taking out entrained fines or is it bed relocation
9 occurring?

10 MEMBER SHACK: Well, all sorts of things
11 are happening at that point. I mean, the pressure is
12 going up. The bed is compressing. The cal-sil is
13 continuing to dissolve.

14 You know, in these chemical tests, almost
15 there's nothing that really is a steady state because
16 the cal-sil is continuing to dissolve in all of this.
17 You know, if we kept running this test for days on
18 end, we would probably still get different results.

19 DR. BANERJEE: But your phosphate is all
20 used up.

21 MEMBER SHACK: No, no, no, no. I have
22 plenty of phosphate. I always have plenty of
23 phosphate.

24 CHAIRMAN WALLIS: Eventually if you
25 dissolved all the cal-sil, you might have some --

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1 MEMBER SHACK: Yes. Eventually it
2 dissolves all the cal-sil.

3 CHAIRMAN WALLIS: It's quite different
4 then.

5 MEMBER SHACK: We can't run the test that
6 long or we haven't run the -- or let's say if you're
7 dead, it doesn't matter what happens after the cal-sil
8 dissolves. If the head loss is already so high --

9 CHAIRMAN WALLIS: If it dissolves, then
10 your bed no longer has cal-sil in it. So something
11 else is going on. What happens to --

12 MEMBER SHACK: Well, you've got calcium
13 phosphate.

14 CHAIRMAN WALLIS: What happens to the sil
15 pod of the cal-sil? The cal goes into the phosphate.
16 What happens to the sil pod?

17 MEMBER SHACK: You're getting the silica
18 levels.

19 CHAIRMAN WALLIS: Isn't silica built up in
20 the bed, then?

21 MEMBER SHACK: No. Most of that stays as
22 a soluble.

23 CHAIRMAN WALLIS: Stays as a soluble.

24 MEMBER SHACK: Yes. You know, we have
25 measurements essentially of the silica in the loop.

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1 And it is going up as the test continues. If we now
2 come to the, again, 7-gram NUKON, 25-gram cal-sil,
3 again, here we added these in steps, which is why you
4 see the debris load.

5 Again, the debris load went up so fast
6 that it's difficult to tell whether there is a
7 chemical effect or not. The debris itself was enough
8 to essentially give you a head loss that essentially
9 exhausted the capability of our loop.

10 CHAIRMAN WALLIS: When does it come down
11 again?

12 MEMBER SHACK: Because we lowered the
13 velocity.

14 CHAIRMAN WALLIS: Yes, but you didn't
15 lower it that much.

16 MR. TREGONING: We lowered it from .1 to
17 about .5.

18 CHAIRMAN WALLIS: Yes, but -- well, maybe
19 that's enough to do it. Maybe that's enough to do it,
20 --

21 MEMBER SHACK: Now, what we did, again --

22 CHAIRMAN WALLIS: -- although before you
23 had it down to even lower velocity. And the head was
24 --

25 MEMBER SHACK: It was sort of going up.

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1 CHAIRMAN WALLIS: So there's something odd
2 there.

3 MEMBER SHACK: Well, yes. I can't
4 remember. We may have perforated the bed under the
5 pressure load. All sorts of things begin to happen
6 when you get up to very high pressure loads. And so
7 you blow through, and the pressure drops. I don't
8 remember exactly what happened in that test.

9 If we run the test without any NUKON at
10 all, just the 25 grams of cal-sil on the perforated
11 plate, again, we don't get complete coverage. It
12 doesn't really bridge it effectively. You know, it
13 seems that it takes a certain amount of fiber to get
14 -- so we get some elevation in head loss, but we have
15 enough essentially flow through to keep the head
16 losses fairly low.

17 CHAIRMAN WALLIS: With a little more
18 cal-sil, you might --

19 MEMBER SHACK: With a little more cal-sil
20 or just a little bit of NUKON, yes, things would
21 probably go up much more dramatically.

22 CHAIRMAN WALLIS: Now, this is still going
23 up after four hours? Slightly.

24 MEMBER SHACK: Yes.

25 CHAIRMAN WALLIS: Not much.

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1 MEMBER SHACK: Not much. Okay. This is
2 a test now where we kept the cal-sil --

3 CHAIRMAN WALLIS: Let's take the
4 perforated bed, where it would be rather difficult to
5 reproduce. You might do another experiment and be
6 somewhat different.

7 MEMBER SHACK: It may well come out, too.
8 If we take the -- now, a test where we have 10 grams
9 of cal-sil and 5 grams of NUKON, you remember the 15
10 grams of NUKON and 10 grams of cal-sil gave us
11 virtually no chemical effect. And we've got a
12 relatively low head loss.

13 Again, here it is with the 15/10. The
14 5/10 now gives us the very high head loss. Again, the
15 saturated head, this bed is only three millimeters
16 thick. This is an 11-millimeter bed. But the head
17 loss is far greater in the thin bed.

18 So, again, for a given cal-sil loading, we
19 get a highly non-linear, non-monotonic function of the
20 fiber loading. That is, if we have no fibers at all,
21 we get a relatively low head loss.

22 With a little bit of fiber, we jump the
23 head loss up. With additional fiber, it can come back
24 down again. And if we keep adding fiber, of course,
25 it will continue to go on back up. So it's, again --

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1 DR. BANERJEE: Why did it stop sort of I
2 or is that an optical illusion? Look at the other
3 line.

4 MEMBER SHACK: This one? Do you mean this
5 one?

6 DR. BANERJEE: I may be mixing up the
7 velocity --

8 MEMBER SHACK: I think you're mixing the
9 velocity and the --

10 DR. BANERJEE: Yes. So the velocity is
11 going down.

12 MEMBER SHACK: Yes. This one we just
13 couldn't keep the velocity up. It was jumping up so
14 fast the velocity -- we lost control of the loop. The
15 head loss had just gone up.

16 DR. BANERJEE: That was 3-18.

17 MEMBER SHACK: Right.

18 DR. BANERJEE: But that's not in our table
19 here. What happened to that or is it?

20 MEMBER SHACK: Well, that was in the quick
21 look report. We're on from the quick look report.

22 DR. BANERJEE: Oh, we are beyond the quick
23 --

24 MEMBER SHACK: We are beyond the quick
25 look report.

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1 DR. BANERJEE: That's why we don't have
2 this.

3 MEMBER SHACK: We keep testing, right.

4 DR. BANERJEE: So that --

5 MEMBER SHACK: The quick look report was
6 late December.

7 DR. BANERJEE: Okay. So 3-18 now. You
8 have five grams NUKON, ten grams --

9 MEMBER SHACK: Cal-sil.

10 DR. BANERJEE: -- cal-sil.

11 MEMBER SHACK: We have a three-millimeter
12 bed.

13 DR. BANERJEE: And it a presoaked for 30
14 minutes.

15 MEMBER SHACK: Presoaked, same treatment.

16 DR. BANERJEE: And is there trisodium
17 phosphate?

18 MEMBER SHACK: There is trisodium
19 phosphate.

20 DR. BANERJEE: Added during the presoak?

21 MEMBER SHACK: Presoak.

22 DR. BANERJEE: Okay.

23 MEMBER SHACK: So it's a complement,
24 essentially, of the previous test, where you had the
25 15 grams of NUKON and 10 grams of cal-sil. Again, by

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1 reducing the NUKON, we have jumped the pressure loss
2 from here to here.

3 CHAIRMAN WALLIS: And, again, if we jump
4 the pressure drop, then the velocities come way down.

5 MEMBER SHACK: I would suggest if I could
6 maintain the velocity, it would be even more dramatic.

7 CHAIRMAN WALLIS: But the pressure drop
8 per unit velocity is enormously --

9 MEMBER SHACK: Yes.

10 CHAIRMAN WALLIS: What is that curve to
11 the right? That is an interesting one. Is that for
12 the same cal-sil proportions?

13 MEMBER KRESS: He described it.

14 MEMBER SHACK: That is just a schematic.

15 CHAIRMAN WALLIS: A schematic.

16 MEMBER SHACK: No data, just a picture of
17 what happens here. The fact that if you have a given
18 amount of cal-sil --

19 CHAIRMAN WALLIS: A given amount of
20 cal-sil?

21 MEMBER SHACK: A given amount of cal-sil.

22 CHAIRMAN WALLIS: Because it says you were
23 given -- okay. Okay. Now I understand.

24 MEMBER SHACK: Cal-sil loading. It can be
25 a highly non-linear, non-monotonic function. So with

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1 no fibers, it's equivalent to what we saw before. We
2 couldn't form a continuous bed. We would get a very
3 low head loss.

4 We had a small amount of fiber. We're in
5 this sort of a test, where we get a very high head
6 loss. We add more fiber. We're back to this
7 situation. The head loss drops. Of course, if we
8 keep building up the fiber, we're going to keep
9 building up head loss.

10 DR. BANERJEE: Is that partially a
11 function of the rapidity with which cal-sil dissolves
12 so you're not making that gooey stuff to --

13 MEMBER SHACK: No.

14 MR. TREGONING: You see a similar
15 phenomenon even without chemical products.

16 MEMBER SHACK: You know, the chemical
17 products will eventually shift the curve around and
18 change things around.

19 CHAIRMAN WALLIS: It must depend on how
20 you put it in because you could have gotten to the
21 peak and then put some more fibers in. It wouldn't
22 make any difference.

23 MEMBER SHACK: You would get a different
24 curve depending on how you put them in. You know, our
25 tests have all been done so far for homogeneous

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1 additions.

2 CHAIRMAN WALLIS: Well, they put them in
3 at the same time to get that.

4 MEMBER SHACK: Right. And we're still
5 getting that now.

6 CHAIRMAN WALLIS: But if you could make a
7 sandwich, you could get all kinds of --

8 MEMBER SHACK: If you make a sandwich, you
9 can get different ones.

10 DR. BANERJEE: So the hypothesis would be
11 that with this thin bed you are likely to jam up all
12 the pores.

13 CHAIRMAN WALLIS: Exactly. If you have
14 the right proportions of stuff, you can jam up the
15 pores.

16 DR. BANERJEE: Pores, right.

17 MR. TREGONING: And, again, essentially
18 the same mechanisms we saw in LANL experiments two,
19 three years ago at this point.

20 CHAIRMAN WALLIS: Except for theirs
21 sometimes would suddenly happen, rather than --

22 MEMBER SHACK: I mean, the difficult thing
23 is it's hard to know when you're being conservative
24 here. If you overestimate your debris loading, you're
25 not necessarily being conservative. And that makes

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1 life difficult when we don't know that we can --

2 CHAIRMAN WALLIS: You don't know where the
3 real pickiest peak is.

4 MEMBER SHACK: Right. Now, this was again
5 an attempt to look at sort of the -- you know, we
6 looked at one bounding thing where we had very little
7 dissolution of the cal-sil before we formed the bed.
8 And we found that we eventually built up to the
9 pressure loss. It took us time to do that.

10 What I've got here now is a bounding case
11 where, instead of adding cal-sil, I'm adding calcium
12 chloride. So I get a dissolved calcium level that is
13 equivalent to full dissolution of the cal-sil.

14 So this is the other bounding case where
15 I go a very long time in the pool, high dissolution
16 before I form the bed, in which case, again, I get an
17 even more rapid buildup than I do in the case where --

18 DR. BANERJEE: That means you have got
19 your 200 ppm or whatever is that solubility.

20 CHAIRMAN WALLIS: This is all the constant
21 velocity?

22 MEMBER SHACK: This is all the constant,
23 yes. We would like to do the velocity cycling tests
24 except when the pressure drop gets so large we can't
25 control the loop anymore and do those tests.

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1 But, again, what I would argue is that the
2 real behavior is somewhere between these two. This is
3 sort of, at least from my engineering judgment, in our
4 dissolution data sort of the minimum amount of
5 dissolution, I would think, would take place before
6 you formed the bed. This is clearly a bounding amount
7 of dissolution before you form the bed.

8 And so, at least for this particular
9 loading, you have this range of possible behaviors,
10 somewhere in between, depending on, again, the exact
11 details of the --

12 CHAIRMAN WALLIS: Maybe give the same --

13 MEMBER SHACK: Eventually you'll get
14 there. And, again --

15 CHAIRMAN WALLIS: What is the blue dot
16 thing?

17 MEMBER SHACK: The blue dot thing is just
18 -- again, this is --

19 CHAIRMAN WALLIS: You waited all the time
20 before you --

21 MEMBER SHACK: I'm just adding nine ppm of
22 calcium. I'm adding a small amount of calcium. But,
23 again, this is adding the -- I build the five of those
24 first.

25 CHAIRMAN WALLIS: When you eventually put

1 it in, it leaps up to join the other curves.

2 MEMBER SHACK: Yes. And I get there with
3 only essentially 27 ppm of calcium. I'm all the way
4 up here. But, again, I've now added this calcium in
5 a somewhat perhaps non-prototypical manner because
6 I've built the bed. And then I've precipitated the
7 calcium phosphate on top of it.

8 So this you might argue is kind of an
9 arrival time kind of phenomenon.

10 CHAIRMAN WALLIS: There are some tests
11 where you essentially plug the thing up completely,
12 the velocity goes to zero. Aren't there some tests
13 like that?

14 MEMBER SHACK: Oh, yes. Yes. I mean,
15 most of our tests or more of our tests than we planned
16 on seem to end up that way.

17 CHAIRMAN WALLIS: Actually, I don't know
18 if we show them here, but in your reports, there are
19 some places where the velocity seems to go to zero
20 almost.

21 MR. TREGONING: Just a point of reference,
22 I mean, we are talking about 220 ppm of dissolved
23 calcium, but the 15 grams of cal-sil given the volume
24 at a loop equates stoichiometrically to about 45 ppm
25 of equivalent dissolved calcium, so not at the 200 ppm

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1 level, where you can get, again, fairly significant
2 head losses.

3 DR. BANERJEE: One of the things I notice
4 is that in your previous slide, you had 15 grams of
5 NUKON and 10 of calcium silicate for 3-16; 3-18, you
6 had 5 and 10; but now if you go to 15 and 15, as you
7 have in ICET-3-10, your pressure drop goes way back
8 up. So if you keep the NUKON constantly by 15 and you
9 just increase your calcium --

10 MEMBER SHACK: It depends on how you want
11 to -- you know, if you want to keep the NUKON constant
12 and vary the cal-sil or you want to keep the cal-sil
13 constant and vary the NUKON, --

14 DR. BANERJEE: Right.

15 MEMBER SHACK: -- you get to the same
16 place.

17 DR. BANERJEE: Yes. But, you know, if you
18 keep the NUKON constant --

19 MEMBER SHACK: It's the NUKON:cal-sil
20 ratio.

21 DR. BANERJEE: You can get a very high
22 pressure drop, 15.

23 MEMBER SHACK: Yes.

24 DR. BANERJEE: So that loading, fiber
25 loading, which is going down with cal-sil constant,

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1 all you have to do is increase the cal-sil constant
2 and you just shift the --

3 MEMBER SHACK: Yes, yes.

4 DR. BANERJEE: Right? Completely.

5 CHAIRMAN WALLIS: I am looking at all of
6 these very interesting results. And I'm wondering how
7 many more tests you would need in order to really
8 understand what is going on to the point where you
9 could predict something.

10 I'm wondering. I don't know if you want
11 to even hazard an answer to that one.

12 MEMBER SHACK: I think we understand a
13 great deal from these tests already.

14 CHAIRMAN WALLIS: You have learned a lot.

15 MEMBER SHACK: Yes.

16 CHAIRMAN WALLIS: You have not shown us
17 any predictions of anything.

18 MEMBER SHACK: No, no.

19 MR. TREGONING: I think we have a pretty
20 good conceptual model of what is happening in these
21 environments. Actually, making predictions, again --
22 and I touched on this earlier. Given some of the
23 non-linearities of the behavior, that's a much more
24 difficult proposition. There's no doubt about it.

25 CHAIRMAN WALLIS: And some of the lack of

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1 repeatabilities, if it turns out that it makes a big
2 difference how you put something in or something, then
3 you have to --

4 MR. TREGONING: Yes. I wouldn't call that
5 lack of repeatability. That's just a lack in
6 different --

7 CHAIRMAN WALLIS: Well, lengthy. If you
8 haven't controlled something --

9 MR. TREGONING: It's an initial value
10 problem. So you've changed the initial value.

11 CHAIRMAN WALLIS: Well, maybe the way
12 someone put stuff in is different. I mean, did you
13 shake the ingredients in rapidly or it may be just an
14 uncontrolled --

15 MR. TREGONING: No. Certainly, again, I
16 think I might have said it earlier there are some --

17 CHAIRMAN WALLIS: So you have learned a
18 great deal. You have learned a great deal. But you
19 are still some way from having a complete set, which
20 enables you to with confidence predict things.

21 MR. TREGONING: Well, I don't want to
22 minimize the problem. This is one particular chemical
23 interaction we saw in the TSP environment. There are
24 other chemical interactions that are potentially
25 important as well that we don't have as complete --

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1 CHAIRMAN WALLIS: But if you were given a
2 mission to by X date have a prediction tool for this
3 problem, how many more experiments would you need?
4 And what would you do with them?

5 MR. TREGONING: Are you allocating
6 unlimited resources as well or --

7 CHAIRMAN WALLIS: No.

8 MR. TREGONING: -- as well as stipulating
9 the --

10 CHAIRMAN WALLIS: Make an assessment of
11 what it would take to get to the point where you had
12 a predictive tool. And then we'll figure out what it
13 costs.

14 MEMBER DENNING: Relative to what you have
15 spent at Argonne already.

16 CHAIRMAN WALLIS: Would you need ten times
17 as many tests or just twice as many or 100 times as
18 many?

19 MR. TREGONING: The number of tests is
20 just one consideration. I think the initial
21 consideration is trying to evaluate, you know, what
22 sort of capabilities are out there analytically that
23 might be even applicable to try to apply these to this
24 problem.

25 We have done some initial looking, but

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1 it's in a very rudimentary stage at this point. So,
2 you know, step one is understand what is occurring,
3 develop conceptual models, provide information that
4 can be used in an engineering sense, which I think we
5 have been able to demonstrate that we can do that with
6 the type of testing that has been done, not only in
7 Argonne but I think in PNNL and LANL as well.

8 So actually building a model is certainly
9 a separate step. How much that is needed for the
10 engineering resolution of this problem is still
11 unknown to me at this point.

12 MEMBER DENNING: Well, you know, I would
13 like to say that I think it's critical. What we heard
14 yesterday from NRR, which is really a reflection of
15 what the industry plans to do, is an approach that, at
16 least in this head loss area, is very empirical and
17 done in a plant-by-plant basis but very empirical.

18 Without Research's ability to interpret
19 what these various processes are, I just don't see how
20 you're going to be able to come to regulatory
21 decisions with a technical basis.

22 Questions are going to be raised that are
23 not going to be answerable by the very empirical way
24 that the industry plans to go about this particular
25 piece of the process. And if you guys can't provide

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1 some model that enables one to interpret and say what
2 the effects are, I don't think you're going to be --
3 I don't think that NRR's decisions will be defensible.

4 MR. TREGONING: Right. But, again, there
5 is conceptual understanding. And there is actually
6 predictive modeling. And those two can be quite a bit
7 different in terms of the level of effort that is
8 necessary to achieve one versus the other.

9 I would argue that if you did rely on
10 empirical evidence to demonstrate the sufficiency of
11 your modification, if it could be argued on a
12 technical basis that you have done so in a
13 semi-empirical deterministic, yet conservative way,
14 that potentially I could see as a way forward.

15 Now, I am not trying to minimize that.
16 That is not an easy thing to do. And the
17 justification of conservativisms, again, it's an
18 ongoing discussion that the staff has been having with
19 the industry to make sure that, at least in our
20 opinion, we feel like they are appropriately
21 addressing some of these issues.

22 CHAIRMAN WALLIS: Your conceptual
23 understanding isn't really complete until you have
24 started to model it in some way because it may be that
25 what you think is happening in words, when you try to

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1 describe it in terms of numbers, it turns out not to
2 work very well.

3 MR. TREGONING: But, again, models by
4 their very nature have limitations as well. So what
5 we understand in a model may or may not be physical
6 reality versus the limitation model.

7 CHAIRMAN WALLIS: Various scientists
8 through the ages have said until you can start
9 predicting things with numbers, you don't really
10 understand things.

11 MR. TREGONING: We have done a lot of
12 things in an engineering sense without having
13 predictive models.

14 DR. BANERJEE: Yes, but I keep hearing
15 this engineering sense all the time. What does that
16 really mean?

17 MR. TREGONING: Catch word.

18 DR. BANERJEE: Through these ad hoc
19 experiments, you get some numbers, you stick it in,
20 and you hope for the best. But I think that some time
21 later, somebody actually understands it and says,
22 "Look, these numbers are completely wrong because the
23 small, little factor here completely changes that
24 answer."

25 So the model gives you a framework to

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1 phrase your understanding of the physical world.
2 Otherwise you're just talking.

3 MR. TREGONING: I agree, but the model is
4 only as good as it's able to actively represent the --

5 DR. BANERJEE: Yes, can be improved.

6 CHAIRMAN WALLIS: What you should say is
7 yes.

8 MR. TREGONING: Yes.

9 MEMBER DENNING: Well, he says yes. And
10 then he has got to follow up.

11 DR. BANERJEE: I don't understand a
12 credible design not to put it in some sort of a
13 framework of a model. Everybody says you should do
14 it.

15 CHAIRMAN WALLIS: But then you might have
16 to confront a real reality.

17 DR. BANERJEE: A real reality.

18 CHAIRMAN WALLIS: Otherwise you might talk
19 about it forever.

20 MR. LU: This is Shanlai Lu.

21 I think right at the beginning when we
22 talked to the Research to establish the testing
23 program, it wasn't intended to conduct confirmatory
24 analysis.

25 CHAIRMAN WALLIS: To confirm what? You

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1 don't have a model. How can they confirm?

2 MR. LU: Right. To identify major issues;
3 for example, the chemical. This was actually, the TSP
4 issues of it were among the issues surprising us. And
5 so the overall testing program from our perspective,
6 we want to have our own as a confirmatory.

7 And the real burden should be the burden
8 of proof should be on the industry to prove they can
9 handle all kinds of environments. So that is the
10 thing we are looking for.

11 So we want to use these test results as
12 our leverage or position to launch our questions so
13 that we can ask a fair question to industry other than
14 relying on NRC's resources to resolve and develop an
15 entire theory and knowledge from our own limited
16 budget.

17 CHAIRMAN WALLIS: Well, I think that this
18 is the case where the word "confirmatory" is really
19 inappropriate. These guys are doing investigative
20 research. They're finding out new things. They're
21 not confirming anything yet. And that is what you are
22 up against. And it may be it can't be used for
23 confirming anything because there is nothing to
24 confirm.

25 If you have a theory or correlation or

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1 something you're going to use, you're going to say,
2 "Well, we'll confirm it against this," but you can't
3 just confirm based on a lot of qualitative
4 understanding of what has happened.

5 MEMBER SHACK: Can I show you some more
6 interesting empirical --

7 CHAIRMAN WALLIS: Yes, please do. That
8 would be good.

9 MEMBER SHACK: -- off-the-wall
10 experimental results.

11 CHAIRMAN WALLIS: You're going to confirm
12 something for us here?

13 MEMBER SHACK: Okay. The next environment
14 we want to look at is the ICET-1 environment, which
15 seems quite interesting. In the ICET environment, we
16 were able to do the test directly. That is, we didn't
17 have to simulate the product, although we did with the
18 calcium chloride. In fact, it's a relatively easy
19 chemical product to simulate.

20 CHAIRMAN WALLIS: This is one we don't
21 have any quick look reports for or something?

22 MEMBER SHACK: You don't have any quick
23 look reports for this.

24 CHAIRMAN WALLIS: Thank you.

25 MEMBER SHACK: The ICET-1 environment is

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1 really much more complex. I mean, Bruce didn't go
2 into the full description of just how complex it is to
3 sort of understand something that isn't quite crystal
4 and it isn't quite amorphous and we don't really
5 understand the structure very well because, you know,
6 it's the Heisenberg thing. Every time we look at it,
7 we're disturbing it. So we really don't know what it
8 is that was there before we went off and we poked it
9 to look at it.

10 And so we're trying to essentially
11 simulate that. Let me just sort of go on to our first
12 attempts to do that and some of the practical problems
13 that we had in doing it.

14 So, again, these aluminum hydroxide
15 emulsions, colloids seem to be the principal chemical
16 product that cause head loss from the ICET-1
17 environment. We didn't want to take 30 days to
18 dissolve aluminum plates in the solutions. So we got
19 to those concentrations by essentially trying to do it
20 with aluminum nitrate additions but maintaining the pH
21 and temperature conditions of ICET-1.

22 So what we were matching was the pH, the
23 concentration, the temperature, and most of the
24 chemical environment; that is, the borate and
25 complexing. We did essentially add things that

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1 weren't in the ICET-1, the nitrate. But, you know,
2 there's a feeling that that is not likely to lead to
3 complexing that will muck things up, but, again, that
4 is something that we were looking at.

5 We thought we were fairly successful when
6 we did this on a lab scale, when we mixed things up in
7 a beaker, and we sort of let them precipitate out. We
8 get products that look like the ICET-1. We sort of
9 get qualitative behavior that seems like ICET-1. When
10 we measure kinematic viscosity, we get kinematic
11 viscosity that resembles ICET-1. So we were ready to
12 do a loop test.

13 Now, our loop test turned out to be
14 compromised by non-prototypical behavior. When we
15 tried to make our aluminum additions on this loop size
16 scale, we didn't get the nice, clear solution that we
17 were supposed to get until we cooled down in
18 temperature. We sort of produced the snowfall.

19 And the snowfall sort of occurred. You
20 know, we were hitting the average concentrations
21 right. Obviously we had high local concentrations.
22 Perhaps we lowered the local pH with the nitrate
23 addition so that we were getting too high a
24 concentration, too low a pH locally. And we ended up
25 with our snowfall. And, again, you can see the

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1 initial snowfall.

2 Now, that's the bad news.

3 CHAIRMAN WALLIS: It looks like the same
4 one you got in --

5 MEMBER SHACK: Yes. Well, all snow looks
6 alike in your loop test.

7 If we stay at 160 degrees and we just wait
8 a few minutes, the snow redissolves. And we're back
9 to the clear solution. So, although we had the sort
10 of non-prototypical behavior to begin with, we did
11 seem to end up with a solution at 160 F. that was
12 clear. It did have 375 ppm of aluminum. So to that
13 extent, it was like the ICET-1 solution.

14 As we began to cool down, we would get
15 increasing turbidity, again, sort of looking like the
16 ICET-1. And I don't have a picture as we went all the
17 way down to room temperature, but we ended up with a
18 -- you know, it looked like a very large layer of
19 vanilla ice cream on top of the bed when we were all
20 done. So, you know, we got a large amount of
21 precipitate as we cooled down to room temperature.

22 The interesting thing was that if you're
23 looking at the way we got head loss, we started going
24 up in head loss even before we began cooling down the
25 temperature. And you'll notice that we didn't wait

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1 until steady state. And let me just sort of tell you
2 the reason we did that was the dilute was cracking up.
3 So we were running the test here to completion before
4 the loop suddenly split and fell apart.

5 CHAIRMAN WALLIS: You were cracking the
6 plastic?

7 MEMBER SHACK: We were cracking the
8 plastic. So we --

9 CHAIRMAN WALLIS: Which is something that
10 you understand.

11 MEMBER SHACK: Well, it was --

12 CHAIRMAN WALLIS: You understand crack
13 propagation very well, I understand.

14 MEMBER SHACK: It was sort of a controlled
15 gamble. We knew that the LEXAN did not take well to
16 the sodium hydroxide environments, but we thought we
17 were going to do this for a relatively short term.

18 CHAIRMAN WALLIS: Did you get any crazing
19 of it --

20 MEMBER SHACK: No, we didn't get crazing.

21 CHAIRMAN WALLIS: You get crazing of
22 plexiglass.

23 MEMBER SHACK: We got cracks inches long
24 is what we got when we finally ended up --

25 MEMBER KRESS: Did it leak before it

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1 broke?

2 (Laughter.)

3 MEMBER SHACK: We closed the system down
4 successfully, a little water on the floor. So the
5 test was sort of complete. I mean, in ICET-1, they
6 have a LEXAN or a polycarbonate window that held up
7 fine.

8 We think essentially the forming of the
9 tube has residual stresses that they don't have in the
10 window-type shape. So with the residual stresses and
11 the environment, we had real problems.

12 But, at any rate, you can see that even
13 before we begin to cool down, before there is anything
14 visible going on here, we're getting very substantial
15 increases in head loss.

16 So, again, this correlate -- and, again,
17 it doesn't seem to correspond with what we see in the
18 changes in the kinematic viscosity. You know, Bruce
19 showed some data where he doubled the kinematic
20 viscosity. When we do the measurements, we double the
21 kinematic viscosity. But we're seeing, really, much
22 larger --

23 CHAIRMAN WALLIS: Is this the NUKON on the
24 screen here?

25 MEMBER SHACK: Yes, the NUKON is on the

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1 screen.

2 CHAIRMAN WALLIS: It's already been laid
3 down?

4 MEMBER SHACK: Yes. We can see if we look
5 over here to the temperature thing, what we did was,
6 you know, at room temperature, we introduced the
7 NUKON. That essentially jumps up the head loss.

8 CHAIRMAN WALLIS: Okay.

9 MEMBER SHACK: Now we begin to heap the
10 loop up. And, again, this is all pure water at this
11 point. The viscosity is dropping. And so we get to
12 160 degrees in pure water.

13 You know, we have decreased the head loss
14 because we have decreased the viscosity of the pure
15 water. We now add our aluminum solution. And we're
16 staying at 160 F. And there's no visible precipitate.
17 But the head loss is going up quite dramatically.

18 And as we begin to cool down, again, the
19 head loss just keeps going up as we cool down, as we
20 cool down.

21 CHAIRMAN WALLIS: Why is it not in phase?
22 It looks as if the jumps in pressure are not quite in
23 phase with the --

24 MEMBER SHACK: There is a kind of a lag in
25 the system.

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1 CHAIRMAN WALLIS: There's a lag of
2 something.

3 MEMBER SHACK: There is a lag in the
4 system that it somehow --

5 CHAIRMAN WALLIS: Goes all the way around
6 before it comes back?

7 MEMBER SHACK: Well, no. I don't think
8 it's that. I think it's a chemical equilibrium, you
9 know, that the material is changing, you know, it's
10 agglomerating. It's doing something that we don't
11 quite understand.

12 DR. BANERJEE: Perhaps even just --

13 MEMBER SHACK: Well, I have to go back to
14 the lab notes as to exactly when we could begin to see
15 visible signs. Again, at 160, we're seeing these
16 jumps with nothing visible in the way of precipitate
17 --

18 CHAIRMAN WALLIS: We're talking about in
19 the -- pressure goes in steps, although the
20 temperature --

21 DR. BANERJEE: If they are in the
22 nanometer range, you won't be able to see them.

23 MEMBER SHACK: No. We do see this
24 murkiness as we come down. By the time we get to 110,
25 you can definitely see a difference. And, as I say,

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1 when you get even cooler, you know, you begin to pick
2 up a large visible amount of precipitate, somewhat
3 akin to what Bruce showed from the ICET 1.

4 DR. BANERJEE: You should be able to see
5 light scattering or something.

6 MEMBER SHACK: Yes. Let me show you some
7 things that will be coming up in just a little bit on
8 that, at least some of the particles. Again, the
9 LEXAN components were severely damaged. We had
10 numerous axial and circumferential cracks. In fact,
11 we had a 360-degree crack underneath the screen by the
12 time the weekend was over.

13 The future testing -- and this is going to
14 require a PVC test section, which, unfortunately, will
15 only get to 140 F. But we also have to rethink our
16 way of doing the aluminum additions. We're looking at
17 using sodium aluminate, which will let us not change
18 the pH as we add it. And we will have a better
19 distribution header. But, again, those tests are
20 coming up. We're still --

21 CHAIRMAN WALLIS: You're sort of using
22 polycarbonates.

23 MEMBER SHACK: Well, LEXAN.

24 CHAIRMAN WALLIS: LEXAN.

25 MEMBER SHACK: Yes. Yes. We wanted

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1 something clear. And the two clear plastics that are
2 out there really are clear PVC, which is
3 temperature-limited; and the LEXAN, which gets up to
4 nice high temperatures but just doesn't like the
5 sodium hydroxide in --

6 DR. BANERJEE: You have to do what we do
7 in thermal hydraulics. Use a sapphire window.

8 MEMBER SHACK: We looked at using Pyrex.
9 And, again, it's much heavier, much more awkward. It
10 makes life a lot more difficult. We're going to try
11 to live with the PVC section.

12 But, again, although the test was
13 compromised, as I said, I think the results really
14 indicate that if you have those kind of dissolved
15 aluminum levels that they saw in ICET-1, you can get
16 things that can strongly affect head loss.

17 Well, hopefully it comes out better in
18 your handouts than it does on the screen.

19 CHAIRMAN WALLIS: It comes out the same.

20 MEMBER SHACK: Oh, it does? Okay.

21 MR. CARUSO: It looks like you have a
22 movie attached to that.

23 MEMBER SHACK: No. What I have is a .tif
24 that shows you a time temperature history for a
25 four-loop plant. So you have non0isothermal histories

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1 --

2 CHAIRMAN WALLIS: Oh, okay.

3 MEMBER SHACK: -- for four and three and
4 ice condenser plants because what I wanted to do was
5 to go off and compute dissolution now for a more
6 typical history than an isothermal one. And what this
7 shows is that if you look at the amount of aluminum
8 that's dissolved per unit area over the 30 days, you
9 can see that if you consider the actual histories and
10 the ICET-1 because, as Bruce said, they did these
11 calculations when they picked the ICET-1 environment,
12 the ICET-1 isothermal sort of gives you the right
13 average value, typically speaking, for the 30 days.

14 We also wanted to look at the amount of
15 aluminum that dissolved during the spray time, that
16 first period of time when you're doing the spray
17 because you're at high temperatures.

18 And in a real plant, the amount of
19 aluminum that's exposed to the spray can be very
20 different from the amount of aluminum that's exposed
21 or that's actually submerged for the 30 days. And so
22 you wanted to look at both of those.

23 If you go through the ICET test plan, you
24 get a survey of plants where you get some information
25 on the amount of aluminum in various plants. and we

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1 have plant R here, which I call the six sigma plant.
2 It's got an enormous amount of aluminum. And, you
3 know, we'll just forget about it. It's got its own
4 set of problems.

5 But if you look at the other plants --
6 and, again, I don't know how representative this
7 survey is, but it would indicate that typically these
8 plants, you know, are relatively low in amount of
9 dissolved aluminum compared to ICET-1.

10 This is one test where the attempt to sort
11 of make the average gave you a rather distorted
12 picture of the population. And so we'll be looking at
13 replicating the ICET-1 levels but will also be looking
14 at considerably lower amounts of dissolved aluminum
15 and see what that effect is.

16 Again, in some cases, it may be almost --
17 you know, the one-day total is almost like the 30-day
18 total because the difference you have in the amount of
19 aluminum that's exposed during the spray phase is so
20 much larger than it is during the submerged phase that
21 you pick up almost as much aluminum in the one day as
22 you do in the 30 days. And, again, you have much less
23 margin typically at one day than you do 30 days. But,
24 again, the overall amounts of aluminum are large.

25 And, again, when I do these calculations,

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1 there's a number of assumptions that go in. I
2 probably ought to just review those. I assume that
3 there's no passivation of the aluminum surfaces.

4 CHAIRMAN WALLIS: This aluminum in R is
5 scaffolding or something. It's not part of the
6 essential --

7 MEMBER SHACK: Yes. It is scaffolding or
8 something.

9 CHAIRMAN WALLIS: So it could be removed?

10 MEMBER SHACK: Yes. And I'm assuming it
11 actually has been removed, but I have no idea.

12 CHAIRMAN WALLIS: Right.

13 MR. CARUSO: Don't the ice condenser
14 plants have aluminum? I thought all the baskets were
15 aluminum.

16 CHAIRMAN WALLIS: No.

17 MR. CARUSO: They're stainless? Okay.

18 MEMBER SHACK: Again, to go back, in
19 ICET-1, what I've done here is taken the initial
20 corrosion rate data; that is, the high rate data
21 initially, and just assumed that that is always
22 applicable. You know in ICET-1 that you passivated
23 when you got about this much aluminum loss per unit
24 meter.

25 Now, again, because we don't exactly

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1 understand the conditions under which that passidation
2 would occur, I didn't want to credit any passidation
3 in the calculation here. But, even without that, I
4 still end up with lower aluminum levels.

5 DR. BANERJEE: Is there any aluminum other
6 than the scaffolding and ladders and things? Is there
7 any other --

8 MR. CARUSO: Gradings.

9 DR. BANERJEE: Gradings?

10 MR. CARUSO: Gradings maybe.

11 MEMBER SHACK: Yes. All I know is what I
12 read in the ICET-1 test plan, which came from the
13 plant survey. Again, because the spray corrosions
14 typically take place at a higher pH than normal sump,
15 the actual corrosion rate is higher. So that there is
16 a bump up for the sprays that I've put in here.

17 For some reason, that doesn't seem to
18 happen in ICET-1 where I actually have to -- if I'm
19 going to make the model predict the results, I have to
20 sort of scale down the ICET-1 results. But I've just
21 sort of kept this here for conservatism and not done
22 this.

23 So the model is benchmarked only against
24 the ICET-3 results and the labs tests for corrosion.
25 It's conservative for ICET-1.

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1 MR. TREGONING: You assume that all the
2 spray stuff ends up in solution, where in ICET-1 it
3 doesn't necessarily.

4 MEMBER SHACK: It's a solution.

5 MR. TREGONING: You could dissolve it on
6 the plate, but then it could reform as an oxide.

7 MEMBER SHACK: Oxide, right.

8 MR. TREGONING: That might be one --

9 MEMBER SHACK: That might be. So there is
10 a conservatism there.

11 What I wanted to talk a little bit about,
12 again, were cal-sil dissolution tests. One of the
13 things that we are concerned about is the amount of
14 calcium dissolution that can actually occur. What
15 I've mentioned is that we have tried to match the
16 screen loading of cal-sil for the debris loading and
17 the amount of chemical products. That changes the
18 amount of cal-sil per unit volume, which I would argue
19 could affect the dissolution rates; that is, because
20 we don't scale exactly like a sump in a containment.

21 If we're going to maintain roughly the
22 amount of chemical loading, we typically have somewhat
23 more dilute solutions. And so we could get more
24 dissolution perhaps, more rapid dissolution.

25 We also wanted to look at the effect of pH

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1 on the dissolution rate. And, again, one of the
2 things that sort of simplifies this problem is that if
3 you have concentrated solutions, as soon as you add
4 the cal-sil to this thing, you bump up the pH because
5 the sodium silicate which is in there just raises the
6 pH.

7 So, even without a TSP addition, unless
8 you use hydrochloric -- you know, unless you have some
9 other way of controlling the pH, as soon as you add
10 the cal-sil, you're going to raise the pH to some
11 level, and the TSP only essentially does that.

12 Our initial dissolution tests were at
13 relatively high concentrations. We went back and did
14 some that are more representative concentrations, 0.5
15 and 1.5.

16 We looked at three different histories for
17 the TSP, one where we add the TSP before we add the
18 cal-sil. So that's essentially an instantaneous TSP
19 dissolution. And that's certainly the most
20 conservative.

21 The TSP over four hours essentially is the
22 tech spec requirement. And reviewing the plant
23 submittals, the nominal case seems to be that you
24 typically have the TSP kind of dissolve over roughly
25 a one-hour period, something like that.

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1 Now, what I'm showing here is the
2 normalized calcium level. That is, I sort of have
3 done my -- so I could plot all of the data from the .5
4 and the 1.5 on the same graph, what I have done is
5 normalized the calcium concentration to the amount of
6 calcium I would get if that were fully dissolved,
7 again, according to the thing.

8 So, you know, these should end up as one.
9 What you see, the -- let's look perhaps at the square
10 figures. This filled-in square is the 1.5 gram per
11 liter. And the hollow square is the .5 gram per
12 liter. And in most cases, the --

13 CHAIRMAN WALLIS: That plots start off
14 high at one hour and then come down?

15 MEMBER SHACK: Well, there are some unique
16 test results, shall we say. We never have anomalies.
17 We just have unique results.

18 CHAIRMAN WALLIS: Unique is even more of
19 a -- that claims there's nothing like it at all.

20 MR. TREGONING: I think that is an
21 artefact of how they're determining the dissolved
22 calcium levels in those tests. It's much less
23 accurate early on in the test the way they're
24 inferring what the dissolved calcium levels are.

25 MEMBER SHACK: We can't directly measure

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1 the calcium because we get confounded by the cal-sil
2 that's present. When we do the ICP, it measures
3 everything, whether it's dissolved calcium or cal-sil
4 particulate. So we measure the phosphate. And the
5 missing phosphate is assumed to be taken out as
6 calcium phosphate. And it's really the calcium level.

7 What we see here, at least for the one
8 hour and the four-hour additions, there are sort of
9 relatively small differences between the .5 and the
10 1.5. So the fact that we don't replicate the
11 concentration in the volume doesn't seem to affect the
12 relative concentration rate very much. And, again,
13 those two are the same.

14 Now, if we go with the instantaneous TSP
15 solution, which is the blue stuff, you see it does
16 make a difference. But, again, that's a fairly
17 non-realistic TSP addition rate. And, even in that
18 case, if you go out an hour or so, you'll find that if
19 you have .5 grams per liter cal-sil, you're going to
20 be off to the 75 ppm in a few hours.

21 So the conclusion that we're making here
22 is that, whatever the TSP addition rate, which we
23 don't understand all that well, and whatever the
24 concentration, the variability is the cal-sil
25 concentration, which could be something or other, you

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1 can certainly use this data to estimate when you might
2 get the cal-sil concentrations that are interesting.

3 And you'll remember back we had some
4 cases. If you're adding the cal-sil properly, even
5 for 27 ppm cal-sil, you were getting large pressure
6 drops if you had built the bed first and added it on.

7 So, again, this all comes back to the
8 notion that this is a short-term problem. This is not
9 a chemical effect like the aluminum case, which, you
10 know, could take days to happen. It can happen
11 quickly.

12 Okay.

13 DR. BANERJEE: Are you going to tell us
14 how to measure particles?

15 MEMBER SHACK: Yes. I guess I keep
16 hitting the END button, instead of the NEXT button.

17 In our tests, of course, all the chemical
18 product ends up on the screen. You know, the loop is
19 designed that way. Well, the amounts of cal-sil and
20 NUKON that we're putting on come from essentially the
21 transport calculations that the licensees have done,
22 but we assume all the chemical product is transported
23 there.

24 Some of that will settle out. We did some
25 initial preliminary settling tests just to get some

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1 idea of how fast this could come out of solution.

2 And, again, this is a fairly simple-minded
3 test. We have a settling tower. We mix up a
4 solution. We get a uniform mixture at T equals zero.
5 And then we just let it all settle out.

6 CHAIRMAN WALLIS: If you look at the front
7 at the top, there is also a front moving up from the
8 bottom.

9 MEMBER SHACK: Yes, but we are mostly
10 interested in the one up at the top.

11 CHAIRMAN WALLIS: If you can do that, then
12 you get a better idea of what is happening. And you
13 can predict it maybe better.

14 MEMBER SHACK: Well, I just want to --

15 CHAIRMAN WALLIS: Think about it. It's
16 just like a glass of beer upside down, right?

17 MEMBER SHACK: We tried first with 300 ppm
18 dissolved calcium so we could get lots of stuff and
19 see it. We were trying to make it visible for
20 ourselves.

21 CHAIRMAN WALLIS: There's sort of a
22 settling front there, isn't there?

23 MEMBER SHACK: Yes. Well, in the real
24 world, it's easier to see.

25 CHAIRMAN WALLIS: Clearer. Okay.

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1 MEMBER SHACK: You know, there's clearly
2 a settling front there.

3 CHAIRMAN WALLIS: There are probably some
4 fines that hang around above it.

5 MEMBER SHACK: Well, about half of it is
6 taken out by the front. Half of it remains behind.
7 Yes. We decided that in a -- okay. We did the
8 settling front measurements. And we got essentially
9 a velocity for the settling front that's like four
10 centimeters a minute.

11 We decided at more realistic
12 concentrations, we went back to 75 ppm of calcium.
13 There was really no settling front. This one looked
14 much more like a uniform mixture that just slowly
15 cleared, which, again, in a simple-minded case gives
16 you a kind of an exponential settling model.

17 CHAIRMAN WALLIS: There's no way.

18 MEMBER SHACK: And if I took only two data
19 points, it would fit the exponential perfectly.

20 CHAIRMAN WALLIS: Fit a line, too.

21 MEMBER SHACK: Unfortunately, I took three
22 data points. And so it isn't perfect, but, you know,
23 I estimate a settling rate out of that.

24 DR. BANERJEE: What happens if you take
25 four?

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1 MEMBER SHACK: Well, we did test four
2 where we took five data points, again another big
3 mistake. And we got four of them to go exponential.
4 And we sort of threw out the one.

5 CHAIRMAN WALLIS: Usually these things
6 settle faster when there is less concentration. You
7 seem to get it settling faster when --

8 MEMBER SHACK: I think we get an
9 agglomeration in the high concentration. You know,
10 you couldn't see it there, but those are snowflakes
11 that are kind of smashing together in the high
12 concentrations.

13 CHAIRMAN WALLIS: They don't smash.

14 MEMBER SHACK: So, again, the two tests,
15 I get something like .8 centimeters for minute for a
16 settling velocity out of that, again, as a crude
17 estimate of a first estimate of how this might do.

18 One of the other things if one is actually
19 going to do a model of this that you would like to
20 know is the --

21 CHAIRMAN WALLIS: There is a very
22 interesting one here where it actually goes the other
23 way and it actually leaps up and then comes down
24 again.

25 MEMBER SHACK: Yes. Well, yes, right.

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1 DR. BANERJEE: Well, is it completely
2 quiescent or there are more --

3 MEMBER SHACK: Yes. The settling tower is
4 pretty quiet, yes.

5 DR. BANERJEE: No thermal convention?

6 MEMBER SHACK: There may be some thermal.
7 You know, we see particles going up and down. And
8 that's presumably some sort of thermal thing that
9 helps keep it mixed. But, again, that was only meant
10 to get a rough idea of what the settling might look
11 like for this.

12 The other thing that is interesting is to
13 look back at some of the particle size
14 characterization. And, again, Bruce didn't go in
15 this. At LANL, they did some things. And I think
16 they got like, as I recall, a three-step thing.

17 We see something like the three-step when
18 we do this without deflocculating with the ultrasound.
19 We get an order of magnitude change as we
20 deflocculate. And what we're sort of concerned about
21 here is that, although we haven't really done the TEM,
22 we really think that we have sort of like the
23 nano-sized particles they see at Los Alamos. And
24 they're flocculated together.

25 I don't know how much deflocculation is

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1 appropriate to use. You know, so exactly saying what
2 the particle size is I think a little bit difficult to
3 say.

4 DR. BANERJEE: Are these size particles or
5 --

6 MEMBER SHACK: No. This is in solution,
7 yes.

8 DR. BANERJEE: Okay.

9 CHAIRMAN WALLIS: Flocculation is very
10 dependent upon other chemicals, isn't it?
11 Flocculation is very dependent upon other chemicals in
12 solutions, right?

13 MR. LETELLIER: I am not sure if I can
14 answer your question, Dr. Wallis, but I did want to
15 interject that we took solutions directly from ICET
16 tank 1. And our particle sizes were trimodal in the
17 range of a few nanometers to tens of nanometers. And
18 that's what gave us evidence of colloid formation that
19 --

20 DR. BANERJEE: How could you find few
21 nanometers? What is the technique you use?

22 MR. LETELLIER: I am not familiar with it
23 personally. I think it's a laser interferometry test
24 to actually look for the scattering interference from
25 very small objects.

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1 CHAIRMAN WALLIS: Can you see that with a
2 laser?

3 DR. BANERJEE: The problem is the
4 wavelength is so much longer than --

5 MR. LETELLIER: No, not for the particle
6 sizing. Mark showed the trimodal distributions. Let
7 me look in our July presentation, where we actually
8 presented that information.

9 DR. BANERJEE: Well, you can use
10 interference method, but I would be surprised if you
11 can get down to small colloid size.

12 MEMBER SHACK: Well, we get much larger
13 agglomerations in our tests. And, again --

14 MR. LETELLIER: It is a surrogate. That's
15 --

16 MEMBER SHACK: Yes, it is a surrogate.
17 But it may also depend on how you essentially treat
18 the stuff when you do it. I mean, with our
19 ultrasound, we changed it by an order of magnitude.
20 My guess is if we did some more to it, we could change
21 it around some more.

22 The nice thing about the calcium phosphate
23 was that we changed it by less than a factor of two.
24 And so it's really a particle that kind of sits there.
25 And you can have a little better feel for what its

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1 size was.

2 I think in the colloid to treat it, you're
3 much less certain as to what the actual effective size
4 is, probably because it's just difficult to
5 characterize.

6 Okay. In summary, then, head losses with
7 the chemical products can be greater than with an
8 equivalent amount of cal-sil. And, again, that can be
9 dependent on the new kind of cal-sil ratio that you're
10 dealing with.

11 We get large head losses. I wouldn't say
12 there's no difference, but since we couldn't really
13 measure the maximum head loss, we ran out of capacity
14 of the loop. It would be a little unfair to say.

15 We get large head losses, whether we get
16 significant dissolution prior to the formation of the
17 bed or we get dissolution after the formation of the
18 bed. We can still end up with large head losses. You
19 know, the time scales change a bit to get them large.
20 And, again, the relative contribution does depend
21 strongly on the degree loading and, again, can be
22 highly non-linear, non-monotonic.

23 The cal-sil dissolution rate is not
24 strongly dependent on the TSP dissolution rate or
25 cal-sil concentrations. And so the important thing

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1 here is that if you have the cal-sil, you can probably
2 get enough dissolution relatively quickly, but this is
3 an early time kind of a problem. And, again, you can
4 be 75 ppm for down to 0.5 GPL.

5 And that's it.

6 MEMBER DENNING: Has anybody looked at a
7 pure flocculent bed? And is that a degree bed that
8 one can analyze? The size, from what I'm hearing, is
9 -- well, I'm not sure what the characteristic size is,
10 whether it's in the few micron size versus in the
11 nanometer size, where one is looking at the flow
12 through that pure flocculent bed. Has anybody looked
13 at that to see what correlations would tell you?

14 I mean, it's a regime that's getting into
15 one that's dominated, I guess, by capillary actions.
16 Have you looked at anything like that?

17 CHAIRMAN WALLIS: I think you get all
18 kinds of strange things. You get under nanometer
19 sizes.

20 MEMBER DENNING: Well, if you get it under
21 nanometer --

22 MEMBER SHACK: For the calcium, we're at
23 the micron size.

24 MEMBER DENNING: Yes.

25 MEMBER SHACK: It would seem like if you

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1 truly had a cake of this stuff, that, you know, the
2 kind of models that people use for cake filtration for
3 kaolin would look a lot like this.

4 CHAIRMAN WALLIS: I would worry about its
5 compressibility, too. I mean, if it's very fluffy and
6 calculated and then you start to put something on
7 there but it compresses it, then it's going to get --

8 MEMBER DENNING: Well, my question is, you
9 know, we're looking at, how do you solve this very
10 difficult problem? Well, perhaps one has to look at
11 one limit, which is this problem of just the
12 flocculent itself, and worry about compressibility and
13 all of that good stuff.

14 CHAIRMAN WALLIS: Well, if you flocculate
15 suspensions, you just settle them out. You get a very
16 high void fraction. You get a very low concentration
17 of the stuff in the sediment until it compresses or
18 you squash it or something.

19 DR. BANERJEE: I think the real problem is
20 not fluid dynamics but the squashing because we have
21 done experiments on nanoscales, and Newtonian fluid
22 mechanics holds.

23 So I don't think that there's anything
24 really strange because at this level, unless you're
25 looking at charges and stuff like this, which might

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1 have -- it's all wet. So we're presuming this is
2 saturated forced media. So tension in that sense
3 doesn't come in.

4 There's a compressibility which is going
5 to be really hard for this program, I think.

6 MR. LETELLIER: Some of these products are
7 actually hydrated gels, which may not compress but
8 actually deform so that the shear stresses can
9 actually cause them to extrude into the interstitial
10 gaps. At least that is some preliminary thinking that
11 we have for tackling that problem.

12 CHAIRMAN WALLIS: That's not nice, is it?
13 Now, we don't --

14 MR. LETELLIER: That would complicate
15 life, yes.

16 DR. BANERJEE: And they probably have
17 non-Newtonian behaviors, right?

18 MR. LETELLIER: Perhaps or we have thought
19 about treating this as an effective viscosity effect
20 term, where we modified the flows, some of it.

21 CHAIRMAN WALLIS: None of it is actually
22 filling the pores by extruding. Well, this is very
23 interesting. We have to --

24 MEMBER SHACK: I think that is very -- you
25 know, what you kind of have to decide is how realistic

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1 these estimates, I think, of the aluminum
2 concentration are. You know, if you can demonstrate
3 you're down here, you're in a different regime than
4 you are in ICET-1 at 375

5 CHAIRMAN WALLIS: What are you going to
6 take for a plant, though? I mean, if there might or
7 might not be scaffolding in there, you have to
8 probably legislate that no scaffolding will be left in
9 the containment or --

10 MEMBER DENNING: That could very well be,
11 yes.

12 DR. BANERJEE: Or not aluminum.

13 MR. TREGONING: Some of that is taken into
14 account with these, the plant survey information.

15 MEMBER SHACK: The plant is certainly
16 going to have to demonstrate, I think, that they are
17 going to end up less than -- even based on our one
18 flawed test, it doesn't look promising if you are at
19 these kinds of levels of aluminum. How low you can go
20 is something we have to examine yet, but --

21 DR. BANERJEE: Is the 30-day number a
22 realistic number or -- I mean, there is only one thing
23 that is a big, 5,000. So those are much lower than --

24 MEMBER SHACK: That is not a realistic
25 number. That is the only number I'm sure that is not

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1 realistic.

2 CHAIRMAN WALLIS: I am sure it is no
3 longer true, yes.

4 DR. BANERJEE: But the 375 is quite a bit
5 --

6 CHAIRMAN WALLIS: That is not a plant,
7 though. That is not a reactor.

8 MEMBER SHACK: That is not an ICET-1.

9 DR. BANERJEE: That is why I am asking.
10 Is that a realistic number?

11 MEMBER DENNING: Well, I think that what
12 Bill is saying is if you can demonstrate that is not
13 a realistic number, that the realistic numbers are
14 substantially smaller, then you could very well be in
15 a different regime.

16 MEMBER SHACK: Right.

17 MEMBER DENNING: And then the question is,
18 how clearly can you, then, take it into account?

19 DR. BANERJEE: You still have this
20 colloidal --

21 CHAIRMAN WALLIS: I think we should stop
22 by 3:30 so we can have a few more questions,
23 discussion. This is very interesting, but the agency
24 has to decide how much -- we asked you before -- of
25 this kind of stuff do you need to do before you have

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1 enough evidence to make decisions? This research is
2 broadening all the questions, it seems to me. They're
3 resolving some and maybe raising some other ones.

4 MEMBER DENNING: Let me modify that to say
5 technically defensible decisions because I think that
6 this agency can make decisions. The problem is we
7 want to make sure that they are technically defensible
8 positions, right.

9 CHAIRMAN WALLIS: Well, not just to defend
10 against critics but to defend against nature because
11 if you put in too big a screen and then something
12 happens, you know, there is a consequence.

13 DR. BANERJEE: You might get the problem
14 solved at one end and clog the other end in the
15 reactor.

16 CHAIRMAN WALLIS: Are there any other
17 comments besides praise for the quality of the
18 presentation we need to have at this time? Does NRR
19 want to say anything or keep quiet for the moment?

20 (No response.)

21 CHAIRMAN WALLIS: In that case, we will
22 take a break until a quarter to whatever the next hour
23 is, a quarter to 4:00.

24 (Whereupon, the foregoing matter went off
25 the record at 3:28 p.m. and went back on the record at

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1 3:46 p.m.)

2 CHAIRMAN WALLIS: Please come back to the
3 session. We're looking forward to hearing about tests
4 that are being done at another latitude and longitude,
5 PNNL and I think we're going to be quite interested in
6 these results. I'm waiting to hear, please go ahead.

7 MR. KROTIUK: Just to introduce myself, I
8 am Bill Krotiuk. And I'm with the Office of
9 Regulatory Research. I'm breaking this presentation
10 down into two parts. The first part I will talk about
11 the testing that is being done and then we will have
12 PNNL come in and discuss their testing facilities and
13 data a little bit more. And then after that I will
14 come back and I will talk about modeling efforts.

15 Okay, the initial effort of this -- of the
16 -- let's talk about the testing first. The initial
17 purpose of this was really to do the confirmatory
18 testing with respect to previous testing that was
19 done. The objectives it that -- we have some expanded
20 objectives in the sense that we want to characterize
21 the head loss across a model sump screen to standard
22 insulation debris. So I'm really, at this point,
23 talking specifically about Nukon and CalSil. But we
24 also want to look at sensitivity to debris rated
25 composition, to distribute of the debris in the bed,

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1 temperature and flow conditions. So get a little bit
2 more information. The facility --

3 CHAIRMAN WALLIS: How about time? Some of
4 these things seem to be time dependent?

5 MR. KROTIUK: Yeah, we will address time
6 also, yes.

7 CHAIRMAN WALLIS: Some of these
8 experiments have been run for quite a long time.

9 MR. KROTIUK: Yes, they have, yes. The
10 facility itself with PNNL can expand on a little bit,
11 has temperature measurement and control abilities and
12 the ability to measure the thickness of the bed during
13 the testing itself and post testing, the mast of the
14 actual constituents in the bed, for instance Nukon and
15 CalSil itself.

16 CHAIRMAN WALLIS: We've had a lot of
17 discussion in the past about sort of the structure of
18 the bed and whether there were sandwiches and whether
19 as the Nukon and CalSil went round and round, did it
20 end up on top or on the bottom or something. Is there
21 some way that you can take slices of these sandwiches
22 or something and find out just where the stuff is?

23 MR. KROTIUK: We have demonstrated that
24 capability and I do not have those results yet. We're
25 in the process of looking at those beds.

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1 CHAIRMAN WALLIS: Well, you'd think that
2 you could take these little whatever you want to call
3 them, pancakes.

4 MR. KROTIUK: Right, right.

5 CHAIRMAN WALLIS: You make pancakes,
6 right? Cut them and then you could look at them and
7 see where the Calsil is in there and so on.

8 MR. KROTIUK: Yeah, we intend to do that,
9 yes.

10 CHAIRMAN WALLIS: Okay.

11 MR. KROTIUK: But we have not completed
12 that yet, so you're only going to see some -- we'll
13 talk about just some quick samples of that. We don't
14 have real data on that yet.

15 MR. TREGONING: I think we have some
16 pictures of what those cross-sections look like in the
17 PNNL presentation. So at least conceptually, you'll
18 get an idea.

19 MR. KROTIUK: We want to extend this also
20 in the long-term to coatings, head loss across
21 coatings. So the intent is, is that we will have some
22 coatings testing planned in the future, and
23 ultimately, want to use the data to come up with a
24 calculation and model. And as I indicated before,
25 Pacific Northwest National Laboratories is primarily

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1 doing the testing.

2 The primary motivation to do this is the
3 fact that the past testing has had questions regarding
4 the head loss effects of particulates which is the
5 Calsil, calcium silicate itself, in the presence of
6 the Nukon fibers and we wanted to address the concerns
7 expressed by the ACRS members regarding the forms of
8 equation -- I'm sorry, regarding the testing, the way
9 the testing was previously performed and we'll have
10 some information on that.

11 The activity itself supports the
12 resolution of GL 2004-02 and we ultimately want to
13 supply the NRC with additional head loss data and some
14 insights about variation, exactly what you're talking
15 about, the variations within the bed, how that effects
16 head loss. So we have divided up testing, at least in
17 terms of the insulation testing into two series.
18 There's a Series 1 and a Series 2. The Series 1
19 testing has completed already and the intent of that
20 testing was merely -- was primarily to duplicate
21 previous testing and do some confirmation of
22 measurements.

23 This testing used a metal screen and in
24 this testing the Nukon and CalSil debris was added
25 simultaneously to the loop and we'll go over that a

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1 little bit more but that mimics the testing that was
2 done in the past.

3 I also did some -- had some testing done
4 on the Series 1 where I had an unblocked screen just
5 to get a baseline for a non -- for a screen without
6 any debris on it. On the Series 2 test, we will do
7 testing with a perforated plate to reflect, you know,
8 proposed new designs.

9 CHAIRMAN WALLIS: Have you tried to do
10 tests with Nukon and CalSil are added at different
11 times? It says simultaneously here.

12 MR. KROTIUK: Right.

13 CHAIRMAN WALLIS: But have you done tests
14 where they're added -- I think you've done tests,
15 haven't you --

16 MR. KROTIUK: Yes, we have and we'll --

17 CHAIRMAN WALLIS: You will tell us about
18 those, today?

19 MR. KROTIUK: -- we will tell you about
20 those, yes.

21 The matrix that I've developed really, and
22 I'll just briefly describe it. In the past, it
23 appeared that most of the tests with the CalSil and
24 the Nukon beds were done at a mass ratio of CalSil to
25 Nukon of about a half with some done at .1 -- I'm

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1 sorry, 1 and 2, and what I plan, my matrix will try to
2 get more points between there to get the effect of
3 differing combinations of Calsil and Nukon.

4 And one of the key things that I'm trying
5 to identify in the test itself is what I'm defining
6 now as a particulate saturation condition and I think
7 Rob mentioned this earlier. It's basically the
8 condition whereby the Nukon become saturated with
9 particulates such as CalSil and basically becomes
10 clogged and you get an increase in pressure drop. And
11 we believe that this is what was termed the thin bed
12 effect but could actually happen in beds of any
13 thickness.

14 As you said, a sandwich, you could have a
15 sandwich focally or it could be homogenous.

16 MR. TREGONING: This could be uniform
17 saturation within a Nukon bed or very local saturation
18 over a thin layer potentially.

19 MR. KROTIUK: Yeah, that's what I mean by
20 homogenous, right. And as indicated before, we will
21 address -- we did some sensitivity testing that
22 addressed variations of the CalSil itself or within
23 the Nukon bed.

24 CHAIRMAN WALLIS: I presume that this
25 saturation depends on how much the Nukon is squashed.

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1 Maybe it's in these tests. In some of the tests,
2 you've got a fairly high compression of the Nukon.

3 MR. KROTIUK: Uh-huh.

4 CHAIRMAN WALLIS: And so presumably the
5 pore size available for the CalSil is now smaller.

6 MR. KROTIUK: Yeah, yeah, my matrix will
7 hopefully help me identify that but I don't have the
8 information to address that, really. And as you
9 mentioned earlier, one of the important things, we
10 have seen that the concentration variation can vary by
11 the timing of the addition of Nukon and CalSil.

12 Currently, the status is that the testing
13 is ongoing right now. We hope to have the insulation
14 testing completed by April and we'll do the coating
15 testing after that. I mean, that's sort of depending
16 upon the time availability and funding availability.
17 The NUREG will be -- we'll have a draft NUREG in June
18 and a final NUREG completed in September. That's what
19 our plan is at this point.

20 And at that, I will turn over the
21 presentation to Carl Enderlin from PNNL.

22 MR. TREGONING: So this is a different
23 packet now.

24 CHAIRMAN WALLIS: Yes.

25 MR. KROTIUK: And he will address the

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1 specifics regarding the testing.

2 MR. ENDERLIN: I'm a Mac user, so it may
3 take me a second here to -- okay, just to briefly go
4 over the outline, we're going to talk about test loop
5 capabilities and measurements. If you have questions
6 on this, as I go through it, I have a schematic of the
7 loop at the end, so if we may possibly try to catch
8 your questions while we're talking about that loop.
9 I think pretty much of that will be pretty
10 straightforward. When we get to debris bed
11 parameters, I'm sure that's a place where we'll start
12 to have a lot more questions and begins to maybe
13 introduce more material.

14 Pretest evaluation testing, what that's
15 referring to is what we thought are things we needed
16 to learn before we could run the test. I'll talk
17 briefly about the bench mark tests that are going to
18 be run between ANL and PNNL's loops and the benchmark
19 cases. Then on the examples of test
20 procedures/results, what I'm going to show is an
21 example of the Series 1 test results and talk through
22 how we've done the testing for there. And again, keep
23 in mind when we're going through this that our Series
24 1 tests were to mimic the target values. You'll hear
25 me do comparisons of the test. That's what went into

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1 the loop and that's how we compare those.

2 On the Series 1 --

3 CHAIRMAN WALLIS: Do you have some backup
4 slides for the other tests which you don't have here?

5 MR. ENDERLIN: Excuse me?

6 CHAIRMAN WALLIS: Do you have some backup
7 slides? I notice you --

8 MR. ENDERLIN: I have a significant number
9 of backup slides.

10 CHAIRMAN WALLIS: You have 6G here but you
11 don't have 6I and 6H.

12 MR. ENDERLIN: No, my understanding was
13 that you had the Quick Look Reports.

14 CHAIRMAN WALLIS: We did, but they --

15 MR. ENDERLIN: And I have some additional
16 backup slides, but --

17 CHAIRMAN WALLIS: So we would be able, if
18 we wished to, to discuss those other tests.

19 MR. ENDERLIN: Yes.

20 CHAIRMAN WALLIS: Okay.

21 MR. ENDERLIN: Again, the Series 1 test,
22 I'll show examples of data and then from those field
23 your questions, and we can talk about the other ones.
24 When we talk about the Series 1 test, this
25 presentation is not completely put in a chronological

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1 order. After doing the Series 1 test, we're smarter
2 and we've gone back to do some more pretest evaluation
3 testing. What's important to understand is, we didn't
4 use all of our loop capabilities to do the Series 1
5 test, as we attempted to follow the LANL test
6 procedure and for the Series 2, well, we'll use
7 perforated screen and some things will be different.
8 We'll also change the test procedure some and I will
9 try to explain that as we go through before that.

10 On post-test measurement evaluation, those
11 are things after we retrieve the bed, are things that
12 we do to analyze and those will include the
13 sectioning. I can show you an example of that, some
14 trying to assess what the composition was in the bed,
15 taking dimensions of the bed. And I'll talk a little
16 bit more as we go through there, but that post-
17 measurement, some of the things you may be asking to
18 analyze the bed, I've kind of saved for the end just
19 to try to show what we do after we retrieve the bed.
20 And then last, we have a few slides just to talk about
21 issues or things that need to be cited, finalized
22 before we finalize the Series 2 test matrix.

23 Okay, test loop capabilities, we have --
24 we consider ourselves to have two loops. We have a
25 bench top loop which actually consists of a number of

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1 loops. One main loop that we take data in that we'll
2 talk about. The other loops were there to help us
3 design the large scale loop, including one of the
4 important things that we had was to do a mass balance.
5 What went into the loop, what's on the screen and what
6 we retrieve. We were trying to also take care of
7 issues to make sure that one test does not effect
8 downstream tests by having material deposited within
9 the loop.

10 This bench top look provides rapid means
11 of investigation, so we can get answers quicker than
12 we can look at trends, but especially some of the
13 first data there, I'm not going to consider it as
14 pedigreed. As we've gone on, all that instrumentation
15 has been calibrated, so you're going to see some plots
16 up here which I'm going to show you relative trends
17 but I've taken the values off, just so we don't
18 confuse actual magnitude of value versus that that's
19 been determined in the large scale.

20 I will say that as the test program has
21 gone on, we've gotten pretty good comparison but we
22 have not yet done a true bench marking of bench scale
23 to large scale. Again, it was used to assess how we
24 are going to prepare the material and introduce it,
25 repeatability issues, design questions to build a

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1 large scale loop, in handling the material and
2 retrieving it. And again, we look at some trends as
3 they come up, just do to the fact we can do it
4 quicker.

5 Limitations, the pressure ports in the
6 bench top are not in ideal locations. Limited ability
7 to degas the water. So as we get up to higher
8 pressure drops, no matter what we've done I can't put
9 an over-pressurization on the loop to drive the gas
10 into solution and I don't have any temperature control
11 other than running a tube through some cool water and
12 putting a fan on it, so the temperature rise in the
13 loop is greater.

14 The large scale loop is a 6-inch diameter
15 test section. It has a uniform cross section and the
16 screen extends into the pipe wall just slightly. I've
17 gotten an example of a screen assembly and I'll pass
18 this around. What we've done here is to make sure we
19 have no bowing or stretching of the screen. We've put
20 it in a welded collar and that welded collar matches
21 up to the wall of the pipe so if you look in there,
22 there's a little bit of debris that can get into the
23 seam. The gaskets are custom cut and I'll talk about
24 that later but throughout the loop to try to keep any
25 hang-up.

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1 What we've also done is we pre-test the
2 screens by putting a uniform load across them because
3 in our first tests we've run up to 700 inches and we
4 want to make sure we pre-stretch the screen and we
5 then characterize after we pre-stretch it again to
6 determine what kind of deflection we may be getting
7 just due to the loading on the screen, so we're really
8 making bed height measurements and not bowing the
9 screen.

10 This is the perforated plate they're going
11 to and it will be put in a screen assembly. I don't
12 have one just because they were just fabricating the
13 parts, but I brought this to show you the difference
14 in the flow areas and the shape of it. I'll pass
15 those around.

16 CHAIRMAN WALLIS: So you can get something
17 like 30 psi or more across this screen?

18 MR. ENDERLIN: I could actually get
19 greater.

20 CHAIRMAN WALLIS: Your capabilities are
21 considerably higher than Argon?

22 DR. CHAMBERS: Yeah, I have a range of
23 pressure transmitters and I have a high one that I can
24 rerange.

25 CHAIRMAN WALLIS: So this is one reason

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1 that you're measuring higher values than LANL is that
2 you could.

3 MR. ENDERLIN: Yeah, there's a lot of
4 differences between those tests, but, yes.

5 CHAIRMAN WALLIS: They had to stop when
6 they got up to a certain value.

7 MR. ENDERLIN: I'm not sure if LANL ever
8 reached their highest pressure capability. The screen
9 is fixed in transparent polycarbonate section which
10 I'll show a photo of here. The screen assembly is,
11 again, as I've explained, there to reduce deflection
12 and bowing. And our straight section of piping
13 upstream is 20 L/D and we're in excess of 10 L/D
14 downstream and that's to allow us to take pressure
15 measurements, the same as we would for any component
16 testing and have fully developed flow as we approach
17 the screen.

18 Again, before I go on with this, we've
19 been tasked and our understanding is the task is to
20 obtain data for doing the correlation. So while we're
21 trying to bound our test within what might exist in
22 utilities, we're trying to make sure that we're in a
23 very well controlled environment and not necessary
24 mimic a LOCA.

25 This is pictures of the transparent test

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1 section. The collar is exactly where the screen
2 rests, is in the same ID as the schedule 40 pipe, so
3 there is no transition other than what little seam
4 exists between the gasket and the pipe wall, both at
5 the screen assembly and where this transparent section
6 interfaces with the -- with the actual flange pipe.

7 So the screen sits in the middle of this
8 and what it allows us to do is to retrieve our test
9 section and take it for post analysis without
10 disturbing the bed. We have shown when we pull it out
11 of here in some of the manual height measurements that
12 no matter what, you'll create just a little bit of
13 unroundness or effect the sides of this just because
14 the stuff has been compressed against the walls of the
15 pipe. So as we pull this out, we can take from the
16 top detailed bed measurements of basically the bed in
17 a dry state and I'll show you some additional methods
18 we take in situ.

19 MR. CARUSO: Do both of these units have
20 the same nominal opening size?

21 MR. ENDERLIN: They're exactly -- they've
22 been machined --

23 MR. CARUSO: These two units.

24 MR. ENDERLIN: Oh, they have the same
25 nominal OD but that's because the collar -- we're

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1 going to put the other --

2 MR. CARUSO: No, I'm talking about the
3 whole size.

4 MR. ENDERLIN: No, I can tell you exactly.
5 The one you're holding in your -- the perforated
6 plate, is 40 percent flurry and I believe the other
7 one is a little bit over 50. I have that data and can
8 answer it if you --

9 MR. CARUSO: Is there a hole size
10 associated with these?

11 MR. ENDERLIN: With which?

12 MR. CARUSO: Both of them. Is it the same
13 nominal hole size?

14 MR. ENDERLIN: No, oh, no.

15 MR. CARUSO: No.

16 MR. KROTIUK: The perf plate is a eighth
17 of an inch.

18 MR. CARUSO: Eighth of an inch, and this
19 is --

20 MR. ENDERLIN: It's five mesh screens, so
21 every five mesh wires is one inch. Go from center to
22 center five, so it's about a fifth of an inch from
23 center to center on the wire. I'd have to look to
24 tell you exactly what the gauge of the wire is. It's
25 been awhile since I --

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1 MR. CARUSO: Okay.

2 MR. ENDERLIN: That's been detailed.

3 MR. KROTIUK: Yeah, we have that
4 information, but not offhand.

5 MR. ENDERLIN: Okay, this is just showing
6 you an example which I've passed around just because
7 everybody else in the audience wasn't going to have
8 ahold of those. Large scale loop capabilities, again,
9 I'm not going to explain them all and the way we take
10 all the measurements. Briefly, we're recording
11 everything onto a personal computer using Daisy Lab.
12 And we're -- the one thing I don't think I mentioned
13 in the overheads now is we take our velocity using
14 mass flow rates, using Coriolis meters. So we're
15 taking into account the density and mass flow and that
16 allows us in our bench top to keep track of when we
17 start to see any change due to gas coming out of
18 solution.

19 For our pressure drop measurements, we
20 have an array. The idea is when we're below 150,
21 we've always got at least two pressure transmitters on
22 and it helps us watch if we're getting any difficulty.
23 The zero to 2770, I mean, that's 100 psi. We've
24 scaled that right now to 0750, so when you were asking
25 what our total capability is, we can rearrange those.

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1 The zero to five is mainly used for the screen and may
2 be used if we go to even less material.

3 Multiple pressure ports, the
4 specifications or function requirements when we built
5 the loop were quite different than what we're seeing
6 in testing now. So we have these two-inch increments
7 that --

8 CHAIRMAN WALLIS: Let me ask you, either
9 you or Argonne or both of you had consideration
10 fluctuations on flow rate or in pressure drop or
11 something at this -- although things were supposed to
12 be steady, there were fluctuations. Why is that?

13 MR. ENDERLIN: Okay, one reason is --
14 several reasons you may see that. If someone does not
15 have where you get fully developed flow -- these are
16 things I've learned from reading your books as we say
17 -- so but as you go downstream 10 L/Ds that's -- ASME
18 standard is 2 L/Ds upstream, 10 L/Ds for doing valve
19 and component. That's to allow the flow to fully
20 develop. Okay, there will be some transition zone as
21 the flow begins to develop leaving the bed. So as you
22 change velocities, you can get that transition zone to
23 change, that's one thing.

24 The second thing it will create is if you
25 calculate the Reynold's number which some of these

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1 tests are being done, if you're in the range of
2 transition flow, then you know, just any slight
3 vibration in the building, the heating system going
4 on, someone leaning on the pipe, you can begin to see
5 high variations. We have not seen that high a
6 variation in most of our tests in a large scale.

7 Downstairs we'll start to see it as we
8 start to get some gas accumulation at the higher
9 velocities and higher pressure drops and we begin to
10 see some shedding of air bubbles or build-up on the
11 debris bed. So there are a number of things that can
12 explain based on fluid dynamics for that variability
13 other than just the instrumentation.

14 CHAIRMAN WALLIS: Well, I don't know, I
15 don't have it right here, but there seems to be in
16 some tests, quite a considerable fluctuation on flow
17 rate. I think it was your tests.

18 MR. ENDERLIN: Yeah, I don't know if we
19 reported any of those.

20 CHAIRMAN WALLIS: Just go on. We'll take
21 that up later.

22 MR. ENDERLIN: Okay.

23 MR. TREGONING: Were these non-planned
24 fluctuations?

25 CHAIRMAN WALLIS: No, they were supposed

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1 to be steady flow and the flow was fluctuating. It
2 was either Argonne or yours but I don't have the right
3 piece of paper here, so I can't tell you.

4 MR. ENDERLIN: If you find that and just
5 reference the Quick Look Report.

6 CHAIRMAN WALLIS: Right, that's right.

7 MR. ENDERLIN: Okay, in situ debris height
8 measurements, we have a method now, optical
9 triangulation that was not in place for most of the
10 Series 1 test. We have visual observations of test
11 section walls, so those are in situ and we refer to
12 the visual as manual measurements just for referencing
13 them. So you've got optical triangulation, which I'll
14 explain later but basically we take a photo and do
15 post-processing. Visual observations are looking
16 basically at the effects of the wall. We really can't
17 see the center of the bed with any accuracy.

18 And then we take manual measurements;
19 while it's still in the test section, we take detailed
20 post-bed measurements. And I'll say right now as I'm
21 going to compare that you are going to see some
22 significant differences between optical triangulation
23 which you can do the center of the bed, and the manual
24 measurements. Okay, this is just to emphasize our
25 operating conditions. We can pressurize the loop to

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1 150 psi. We don't need that. That's just standard
2 code for building, for most of the piping systems.
3 It's 150, 250 and you move up, so we're at 150 and
4 we're able -- we use a Argonne cover gas with an
5 expansion tank that allows us to pressurize the system
6 after we form the bed to put the stuff -- the gas into
7 solution, anything that may come out as we go to
8 higher pressure drops. The cover gas system using
9 Argonne was just to help after we degas water to help
10 reduce additional gas absorption.

11 Temperature control is 60 to 185 degrees
12 F. The 185-degree limit is basically our
13 polycarbonate test section. We've put it under
14 testing but just -- it really begins to creep as you
15 begin to go up to 200. And the main reason for the
16 temperature control is we can alter the fluid
17 properties, density and viscosity. Velocity range is
18 .02 to two feet per second with the current pump. We
19 can go lower but we have to put in a different mass
20 flow meter and a different pump to get control on the
21 flow. The velocity is controlled mainly using a VFD on
22 the pump but we do have a pinch valve that we have to
23 throttle and we use just a neoprene pinch valve so
24 there's nothing to hold up and catch material.

25 Filtration system was added. It will be

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1 more apparent when I show some of the flow history of
2 why we have it, but a big question we had when we
3 started this test is when I take a data point being
4 able to report to the NRC what the mass was on the
5 screen at that time, which is one way to do it, versus
6 wanting to look at accumulation of the masses. We
7 increase the velocity.

8 So what the filtration system allows us to
9 do when its full capabilities are there, is that we
10 can run -- say the bed is completely -- this is all
11 the material we want retained on it, and at that point
12 we can then filter out anything that's in solution.
13 Then we can start running back to an open loop system
14 with no filtration or we have the ability to now go to
15 a second set of filters that says, "Okay, let's begin
16 to capture material that may be leaving the bed", and
17 then through that we can begin to characterize for
18 example, if we got to CalSil saturation or something,
19 that as you go up in velocity, is the bed losing mass.

20 So as we look at these ramp ups and ramp
21 downs other than bed heights which we're now showing
22 are changing, how do we know exactly what the mass is
23 there? And again, that's mainly for the purpose of
24 trying to create ideal conditions for doing the
25 correlation. And again, I believe you mentioned about

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1 reducing uncertainty. This is a way that we'd talk
2 about reducing uncertainty, is that there's more
3 parameters you can control or if you know, uncertainty
4 in the mass initially is what I dumped in and what I
5 retrieved, I have an uncertainty that it's anywhere in
6 between some minimum bed height to higher. If I can
7 begin to know exactly what's on the bed, it's a way of
8 reducing uncertainty.

9 CHAIRMAN WALLIS: Do you, in your backup
10 slides, have a plot of the output of the pressure
11 transducer?

12 MR. ENDERLIN: No, not with me, I don't.
13 You're talking about pressure transducer as a function
14 of time?

15 CHAIRMAN WALLIS: To see how fluctuating
16 it was, yes.

17 MR. ENDERLIN: Our fluctuations, again for
18 what we'll call the pressure transducer that we're
19 using, on a -- it's sampling at, I think, 10 hertz and
20 recording at 1 hertz. Our fluctuation is at steady
21 state or less than two percent change.

22 CHAIRMAN WALLIS: Okay, so it's not you.
23 Somebody in what I was reviewing had a fluctuation of
24 50 percent or so. I was really surprised. I can't
25 tell you who --

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1 MALE PARTICIPANT: Your pictures don't
2 show any transducer results.

3 MR. ENDERLIN: No, not at that moment.
4 That wasn't a request to put in them at the moment.
5 If that's a suggestion from the ACR, I'd be more than
6 happy to find out what other things you think should
7 be in the Quick Looks. And what we've actually done
8 to those Quick Looks is you have the latest copies, as
9 we've -- like bed height measurements or determine
10 another parameter, we go back and try to add it and
11 update the whole suite of Quick Look Reports.

12 DR. BANERJEE: Are these flush mounted
13 transducers or how are they mounted?

14 MR. ENDERLIN: No, they're delta P
15 transmitters and so what we're using is as we go up to
16 higher temperature, they're below the entire test loop
17 and so what happens is they're flushed. We have a
18 thermal couple down at the manifold. The assumption
19 is that all loops will heat up the same, they're not
20 next to anything. And then they're basically a tubing
21 running up to the pressure port and there's two ports
22 on either side of the loop, to help evaluate against
23 clogging and stuff.

24 DR. BANERJEE: So the little vortex that
25 forms doesn't clog with --

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1 MR. ENDERLIN: No, we -- when we first
2 started testing, it's not debris, it was some
3 constructions things they'd left in we had to go clean
4 out but we actually take those apart and we check them
5 to make sure that we're not getting plugged. Two, we
6 have a cross valving at the transducer, so
7 periodically during testing we make sure we check our
8 zero. And that's our other way to make sure that our
9 --

10 DR. BANERJEE: You don't have any purge or
11 anything?

12 MR. ENDERLIN: No, we do. We purge into
13 the loop to keep from drawing material in. So we
14 periodically purge and the only thing we do there is
15 we try to prevent that once test is going where you
16 have to take a little bit because that purging will
17 change the temperature from collate correction when we
18 go to hotter temperatures. So now, I do want to
19 stress that the temperature difference between that
20 thermal couple and the Series 1 test was minimal. It
21 wasn't a lot. But the Quick Look Reports, as they
22 stand now, have not had temperature correction done,
23 okay, between the temperature in the loop and what we
24 have.

25 So as you go on in ramp ups and you look

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1 at those, there is a slight temperature gain and we
2 are correcting for it. We just -- in those Quick Look
3 Reports, it hasn't been done yet.

4 DR. BANERJEE: Where?

5 MR. ENDERLIN: If your loop is, let's say,
6 warmer than the temperature of the water from the
7 transmitter up to the port, the pressure port, I have
8 to do a temperature correction. That has not been
9 done in the Quick Looks yet.

10 DR. BANERJEE: But it's a small amount,
11 right?

12 MR. ENDERLIN: It's a small amount in
13 these tests. I just want you to know that you start
14 to see slight changes. As we go back and review,
15 there may be one or two real high pressure drop we ran
16 for awhile where things began to heat up a little
17 more.

18 Okay, debris hold-up, again, these are
19 things we learned from down in our test loop and I'll
20 show you again one of the problems we had, but
21 initially we were having a real problem with what went
22 in, getting it all the way out and not finding it on
23 the walls, nor visually seeing it. You know, what
24 we've seen is that the CalSil -- you can filter it
25 out, it's still the size I can filter, but visually,

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1 I can't determine, I have no instruments from a visual
2 standpoint other than maybe a laser attenuation or
3 you'll see some -- dilution is -- we have high
4 dilution in ours and that was one thing that's
5 different between the ANL loop, when we start talking
6 recirculations, time at flow versus recirculation, our
7 loop takes about twice as long to recirculate, the
8 same velocity.

9 Okay, so things that we wanted to make
10 sure that we didn't lose our debris and cut down on,
11 certainly we want to retrieve the mass, is welded
12 fittings versus just flange, custom cut flanges, pinch
13 valve for throttling the flow and where we have these
14 other legs of pipes that we go off the filtering.
15 We've try to minimize the dead legs on those so that
16 we don't have a long length of pipe that may be
17 accumulating debris. We do have it so we can take the
18 loop apart and inspect it, but it would get very
19 costly if we were trying to do our cleaning procedure
20 between every loop. So we've taken a look a feel we
21 have something that's controllable now.

22 I would say that in a couple, the first
23 series tests there wasn't a little construction debris
24 or something in there. We were still working out our
25 system at that time. And I think that's been stated

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1 in the reports where it's an issue.

2 Okay, so this just gives a quick schematic
3 of the loop. The thing that we're going to talk about
4 next that I haven't talked about is our debris
5 injection system which I think is different than the
6 other labs are using at the moment or was used
7 previously. It's a vertical test section. This is
8 just showing we've got multiple ports. The data in
9 there, I think it states in the Quick Look Reports,
10 while the standard is 2L/Ds upstream, we've been
11 taking -- most of the data has been reported at 10
12 L/Ds. Just we get a stabler reading and if you take
13 the average, we can't detect the difference that the
14 velocities were at in -- you know, what is that four
15 feet of pipe or so.

16 We've got a chiller unit pump and then
17 down here we're just representing -- this filter
18 system is actually three parallel pass; a bypass loop,
19 a single filtration for filtering out material at the
20 end of what you call bed formation, and then another
21 loop that shows filtration for the purpose of while
22 you're testing. It's just represented on here by a Y
23 strainer. It was just our concept that we needed some
24 form of filtration. So this is where this deviates
25 from that.

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1 Okay, the debris injection system, it's a
2 closed system so what we're going to do is we're going
3 to load material in and then we can control the flow
4 rate at which this goes into the loop. So we're
5 monitoring at what rate we feed into the system. What
6 we also did in the bench scales, we were trying to
7 determine the critical velocities for settling and
8 resuspension to help design our loop and know what
9 flow rates we being to get in problems when we
10 recirculate.

11 CHAIRMAN WALLIS: So you introduce a
12 slurry, debris is already mixed up with some water.

13 MR. ENDERLIN: Yeah, I'll talk about --
14 the preparation method no the bench top is very
15 similar to what ANL and Argonne did -- LANL did and
16 the initial -- which I'll talk about next, the debris
17 preparation --

18 CHAIRMAN WALLIS: Did you have it in a
19 beaker or something, you just pour it in?

20 MR. ENDERLIN: Well, I'll explain that
21 here. So the preparation method is going to be the
22 same using the pass. Now we create this concentrated
23 slurry, if you will, in the blender. Okay, then we
24 have these 160-inch lines which we pour the water into
25 the line and then there's actually a small residual

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1 air bubble that won't leave the system that we use and
2 we agitate the line. So we have two lines that will
3 become more apparent in the next drawing, but two
4 lines that we can put the Nukon in one CalSil in the
5 other. That was the reason it was created, so we
6 could introduce constituents separately without having
7 them be effected in the concentrated slurry.

8 We put it in there and then we agitate
9 that through the whole hose. Visual inspection is
10 what we're relying on, that it's been mixed and we're
11 relying on results in the bench top look that this has
12 been able to create repeatable beds.

13 CHAIRMAN WALLIS: So it's pretty well
14 mixed --

15 MR. ENDERLIN: In it's highly dilute --

16 CHAIRMAN WALLIS: -- when it goes in. It
17 hasn't had a chance to settle out and --

18 MR. ENDERLIN: No, and the concentrated
19 slurry. One reason is the concentrated slurry, from
20 the time we mix it, it's agitated -- it doesn't allow
21 to set. You put it in the blender, you mix it and it
22 immediately it's being agitated continuously, goes
23 into the hose and then the hose is agitated with a
24 significant amount of manual agitation and we just
25 have -- that's what interns are great for, we have

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1 them sitting there and we keep it moving until it's
2 time to go. So, you know, at the most I would say
3 we've never had stuff in the injection line for more
4 than 10 to 15 minutes before we start to introduce it
5 into the loop.

6 The dilution rates I put in there just
7 because, you know, those are an issue to us if you
8 were trying to inject the concentrated slurry and had
9 things beginning to clump. Those come from what Bruce
10 at LANL said, they started with as kind of a guideline
11 which is the -- I think we took off the other numbers.
12 It was what, 140 grams in five gallons? Is Bruce
13 here?

14 CHAIRMAN WALLIS: It looks like a lot of
15 water compared with the --

16 MR. ENDERLIN: Yeah, so that was his
17 guideline, that you're always more dilute than that
18 and that was the guideline for the Series 1 test and
19 our initial -- again, our initial development was
20 picking up on what LANL had learned to date. There's
21 nothing else more critical than that, than someone
22 showing that worked, and so we set it as a guideline.
23 We were able to develop a system that worked to it.

24 Again, throttling valves are upstream of
25 the mass flow. We originally wanted to record the

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1 mass flow rate into the system but using the Coriolis
2 meters, even with very dilute fiber in the smaller
3 Coriolises this material will plug. That's just an
4 observation, but you know, a three-inch Coriolis, for
5 example, does not have three-inch ports. Okay, so
6 when you talk about a one-inch Coriolis, they're like
7 three-eighths -- two parallel three-eighths inch parts
8 through there and those will see the effects of the
9 fiber.

10 DR. BANERJEE: But these are not these
11 through-flow ends that --

12 MR. ENDERLIN: No, they're d-tube style
13 micro-motion Coriolises. They're not straight tube
14 like N --

15 DR. BANERJEE: Yeah, they're d-tubes,
16 right?

17 MR. ENDERLIN: Yeah.

18 DR. BANERJEE: But they aren't full flow.

19 MR. ENDERLIN: No, they're parallel d-tube
20 models. No, they're not full port, when they say a
21 two-inch, it's two -- you know, when you say a two-
22 inch one, I think it's two seven-eighths ones or, you
23 know, it matters what year they created. The models
24 are slowly getting better now. They've gone to the
25 straight tube. So those throttling valves, if we were

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1 to report or you were to see values of water flow or
2 velocity, that is prior -- the density there is still
3 measuring just the straight water upstream of the
4 material being injected. And a little more clarified
5 show the picture of it.

6 So the big throttling valve is not used to
7 control the velocity in the loop as we do additional
8 velocity. It's there for bed formation to creates a
9 pressure drop so that we can drive fluid into the
10 injection loop lines. Currently, the injection loop
11 lines we put it in at, I think, .8 meters per second.
12 And again, if we wanted to change dilution or reduce
13 dilution, we can change the length of those lines.

14 We've got three micro-motions. This is
15 positioned -- technically, this is downstream, our
16 micro-motion. This is just a schematic from when
17 originally we were putting the loop together. This
18 micro-motion now exists downstream of the screen.
19 Okay, and the reason for this is it sees the mass flow
20 rate immediately after the injection. The other
21 micro-motions are there basically so we can control
22 and repeat the water velocity going through the
23 injection lines.

24 Okay, now we'll probably get into more
25 questions here. What we're talking about here are

1 debris bed parameters. And these are things when we
2 started to do our pretesting of what our goals were.
3 Again, one of the questions when we see -- when we
4 started to see the initial data that had been done and
5 read some of the past work, the question was, is this
6 really randomness in the debris beds or is it just
7 different initial conditions? You know, I bring back
8 to some of the things, is flipping a coin really
9 random? If you could model it if you know exactly the
10 initial conditions, you can begin to guess a lot more
11 of -- or predict, I don't want to say guess here. We
12 want to predict a lot more of -- with better certainty
13 whether it's going to show up heads or tails.

14 So in designing the experiments, we wanted
15 to minimize experimental uncertainty and again,
16 identify the parameters. We did certainty analysis
17 ahead of time to determine which instruments we might
18 want to improve, instrument uncertainty and then
19 determined what the important parameters are and
20 initial conditions so we could control them.

21 Again, a goal of ours is to get
22 statistically significant results. And again, we
23 wanted to assess the true variability of the process.
24 When you begin to narrow down or get more control over
25 those initial conditions, you begin to see the

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1 variability come down and say, okay, if I have these
2 initial conditions, the debris beds are much more
3 repeatable. Okay, I can take something that may show
4 you 100 percent variability and bring it down to 10
5 percent. So identifying what is the true variability
6 versus uncertainties in my measurements.

7 So that was done to design the
8 experiments. And then once we said, okay, we've
9 identified those parameters, we need to develop
10 procedures so that no matter who's running the test or
11 different conditions we can create comparable tests
12 and we can create repeatable tests. So we're trying
13 to drive to maximize repeatability of these.

14 The next bullet there is basically just --
15 what we have here because the other slides kind of got
16 moved out --

17 CHAIRMAN WALLIS: This business of
18 providing statistically significant results might lead
19 to a lot of experiments if there's a great deal of
20 variability depending upon how the stuff mixes and --

21 MR. ENDERLIN: Well, what we do is -- and
22 I'm not the expert in the statistics. We have at PNL
23 a whole group of people that do nothing but
24 experimental statistics. And the reason I bring that
25 up is sometimes you'll watch people do parametric

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1 tests where they're taking 20 tests to look at a curve
2 that, look, if you guys give me four I can define the
3 trend.

4 I need you to go down here and repeat a
5 test 10 times, or I need you to repeat these three
6 tests each five. So when we state significantly
7 significant results, you know, when we first started
8 out in my career, I remember a number of times you go
9 to the statistician. They say, "We ran 100 tests. If
10 you'd have run 75 it would give you the answer, but I
11 need you to repeat three cases 25 times." So we're
12 trying to get some statistical design up front in
13 doing our experiments.

14 CHAIRMAN WALLIS: The problem I see is
15 that if you look at some of your tests and compare
16 them with LANL's tests, you have a significant
17 difference.

18 MR. ENDERLIN: Yes.

19 CHAIRMAN WALLIS: Now, suppose you did the
20 same tests. That tells me that there's some
21 statistical variation if it's really the same tests.

22 MR. ENDERLIN: I think --

23 CHAIRMAN WALLIS: This is the same test
24 and you know, if it's lab specific or loop specific or
25 something. That's a different matter.

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1 MR. ENDERLIN: I think what we'll show you
2 later is that there are some different initial
3 conditions and we really didn't test the same beds.

4 CHAIRMAN WALLIS: You're going to show
5 those to us.

6 MR. ENDERLIN: Yes.

7 DR. BANERJEE: Are you also taking -- when
8 you take these samples out and you look at them and
9 you measure things, do you cross-section them and take
10 some --

11 MR. ENDERLIN: Well, I'll get to that. We
12 have -- the very first -- there are plans to do that
13 and the NRC has finally directed us to do that. The
14 very first thing was to determine what it takes to do
15 that. And then there will be some questions of -- you
16 know, because our plan was -- an option was to do TEM,
17 SEM to evaluate these both for -- and I'll talk about
18 that later. I don't want to get off on a tangent
19 here.

20 DR. BANERJEE: But there is some way for
21 you to determine that what you're doing is actually
22 repeatable by looking directly at the samples.

23 MR. ENDERLIN: There's a number of things
24 that we'll talk about here that we're doing to assess
25 repeatability and that is one of them and we'll all

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1 have to consider together, you know, here's what we
2 know, here's what we're proposing. I can't say we've
3 taken it to the end that I have five samples, I can
4 sit here and show they're all repeatable yet, but that
5 is a plan to assess it that way.

6 MR. TREGONING: And just so it's clear,
7 there's no real -- you know, within certain
8 constrained variables, there's no necessarily right
9 way or wrong way to conduct these tests. Certainly
10 the tests that LANL did was within the realm of
11 possible conditions, you know, the way these tests
12 could be run to be somewhat representative. So what
13 we're really trying to do in the PNNL loop are
14 understand what conditions can lead to those
15 differences and try to characterize those. But
16 because there's no ASTM standardized procedures on
17 doing this, that kind of precursor work is really
18 necessary.

19 MR. ENDERLIN: Yeah, and again, you know,
20 we didn't have to start out -- Bruce was very
21 instrumental in helping us in the very beginning to
22 say, here's what he's learned, so some of the initial
23 conditions we're identifying are based on experiences
24 learned at LANL.

25 I've put the last bullet in there as a

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1 point just we hadn't mentioned and we had gotten rid
2 of the other slides on that. But the Nukon and the
3 CalSil we're using are the exact -- from the same
4 vendor, they're from the same lot, shipped on the same
5 day to Argonne and us. So that we had some control
6 and ability to say, you know, "Here's what we're
7 using", and if you go back to the vendors and talk
8 about CalSil, if you have a sample of CalSil in 1970,
9 sample of CalSil in 1980, to 1990 to 2000, or even
10 from batch to batch, based on the fiber content and
11 now they're using cellulose, I believe they actually
12 used -- and Bruce can help me out here -- they
13 actually used asbestos at one time. So they're using
14 the -- was it calcium -- calcium silicate and what's
15 the other constituent in there?

16 MEMBER SHACK: Sodium silicate.

17 MR. ENDERLIN: Okay, and that's the bulk
18 of the insulation material but to give it its
19 structural strength, that has changed over time and
20 from a thermal standpoint, it doesn't really matter to
21 them. But what's showing up on your bed that material
22 can change depending on what sample --

23 CHAIRMAN WALLIS: They have some fibers in
24 it, don't they?

25 MR. ENDERLIN: Yes, they have a fiber and

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1 that fiber content has actually changed data and per
2 run, the volume or the mass fraction of that fiber in
3 there can change as they do quality control to meet
4 the structural strength requirements.

5 So we've talked to the vendors at length
6 about that and determined that we should at least do
7 these tests. How much that may vary our debris, we
8 don't know, but we've tried to eliminate variations
9 between Argonne and PNNL by using certified materials
10 from the same lot same production. Okay, and the
11 CalSil that we use is not what was used at LANL. We
12 initially did our first assessments with material that
13 Bruce sent us but that was in limited supply.

14 Okay, these are debris bed parameters.
15 I've also defined them at times as initial conditions.
16 These are things that we feel make a difference when
17 you go to -- that someone would have to know to be
18 able to say three beds are the same. Okay, mass
19 material introduce versus mass of debris material
20 retained on the screen. The reason that's important
21 is for several reasons as far as what you put into the
22 loop. The concentration at which material reaches the
23 screen can have an effect. You know, I like to think
24 we can all walk through the door, but if we all try to
25 walk through the door at the same time, we can get a

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1 different build-up or blockage at that doorway.

2 Second of all is, this fiber as we prepare
3 -- do any breakdown has some kind of distribution.
4 You know, I'll say size distribution but how to
5 characterize the fiber is somewhat difficult. If I
6 only wait till 10 percent of it is on the screen and
7 then I move that out, I refilter the rest. I've taken
8 most likely the largest distribution, okay, so I can
9 obviously, change the permeability or porosity of that
10 bed. So knowing what went into your loop to try to
11 determine what the distribution is in that bed is
12 important.

13 Then the next thing is what total mass is
14 on the bed, but just given the same total mass that
15 parameter alone isn't enough to make sure you have
16 identical beds. The sequence the debris constituents
17 are loaded onto the screen, I'd like to hold questions
18 on that because I'm going to talk at length about that
19 and show you some data. But I will definitely say
20 that has a major impact.

21 Debris material consistency, size and
22 distribution, that's similar to what I talked in the
23 first thing, but again, how much has this stuff been
24 disrupted in LOCA, how have we blended or prepared it,
25 what is the size, is it poly-dispersed, mono-

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1 dispersed, and how is it distributed, multiple
2 constituents distributed throughout the bed? The mass
3 ratio of the constituents in the debris bed, and then
4 that's pretty much we're saying bed formation and then
5 next one we have is the velocity at which you
6 introduce it to the screen, so that's velocity
7 history, the bed formation. We've done that two ways
8 in the Series 1 test, so they're not all exactly
9 repeated the same and it hasn't been quantified
10 exactly what difference it makes.

11 Just so that you know, and I believe it's
12 reported in all of them is the very first test our
13 loop was designed to introduce the material at .2 feet
14 per second to the bed. But Argonne was doing it at
15 .1. On our .2 feet per second, we set a flow and
16 maintained a pump speed. So as you built up material
17 on the bed, you would watch your flow go down as your
18 pressure drop across the bed increased. Almost all of
19 those tests were beginning to end with a pressure drop
20 on the order of .1, .9 feet per second. So we had a
21 velocity decrease during bed n we went to the .1 feet
22 per second to try to eliminate or alleviate settling
23 issues, we then changed pump speed to maintain a
24 constant velocity to the bed. So two different
25 scenarios that can be done, and there's multiple

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1 others you can to but just, you know, the Series 1
2 test, there are some slight differences there.

3 Okay, then once your bed is formed, why it
4 is still considered an initial condition is because
5 every data point there, if we think of it as standing
6 alone, if Bill goes in and says, "I'm going to
7 compare" -- Bill Shack goes in and says, "I'm going to
8 compare a data point done at .3 feet per second", and
9 he's run it for an hour, that's one way of one flow
10 history and I've only run it for 20 minutes but the
11 other one is, he may have run it for an hour and never
12 changed the velocity where I've cycled up and down 12
13 times. We've shown both the cycle. The cycle seems
14 to have a greater impact, it's still under
15 investigation, than the time at flow. So flow history
16 at which you're going to compare data points is also
17 important.

18 Okay, this is -- we're now talking about
19 actually physically preparing the debris material. So
20 I'm going to pass this around. This is what we refer
21 to as "as received material", just as I talk and show
22 a few pictures and you see the consistency of the bed,
23 you'll get an idea of it. This is -- when we've had
24 some tests in the past, I don't believe you have any
25 data at the moment. We've actually put this into the

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1 loop to say, "Okay, this is one bounding condition
2 relative to debris preparation". This is the material
3 that's been heat treated by the vendor and then it's
4 put through -- it's now put through a chipper. It
5 used to be a leaf shredder.

6 Okay, so we're getting material that
7 actually from the vendor the bag sent to Bruce was
8 different than how they would send it to us now. So
9 the first thing we said is, "How are we going to
10 characterize that or if Argonne is going to run a
11 test, how do we know we have the same material, we
12 have the same lot number"? So what we were working
13 was to come up with guidelines on how we could make
14 this, make it repeatable, and what are the
15 requirements. I mean, we can sit here and talk about
16 the formation. Okay. Then --

17 CHAIRMAN WALLIS: Excuse me, you're only
18 using 15 grounds? I mean, isn't a leaf shredder a
19 rather big thing for 15 grounds?

20 MR. ENDERLIN: This is to prepare a bag of
21 it. This is how I receive it from the vendor in huge
22 boxes. Yeah, I'm trying to show you what the initial
23 condition I get it in is.

24 DR. BANERJEE: It's a sample.

25 CHAIRMAN WALLIS: You make kilograms of it

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1 in this leaf shredder?

2 MR. ENDERLIN: No, I don't operate the
3 leaf shredder. What happens is -- what happens is the
4 manufacturer is going to make this in three inch or
5 three and a half inch blankets. No one is really
6 going to buy that in the industry. So we've come to
7 them and said, well -- and the utilities have come to
8 them. That was the reason it's done, "We need some
9 material that if you went through a LOCA, we need some
10 material". So what they're now doing is they take a
11 set of their blankets, record what the lot number is
12 and they go out there and say this much to get this
13 many cubic feet for Bill and this many cubic feet for
14 PNNL", and they make that lot.

15 Then they take it out to the leaf shredder
16 and they do it and it comes in boxes. First it goes
17 into big --

18 CHAIRMAN WALLIS: This goes through a leaf
19 shredder.

20 MR. ENDERLIN: That one's actually been
21 through a wood chipper. The leaf shredder -- when
22 Bruce ordered his, they thought a leaf shredder was
23 the best idea.

24 CHAIRMAN WALLIS: So it hasn't been
25 through a blender.

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1 MR. ENDERLIN: No, no, I'm showing it to
2 you know as you see the pictures to say why are we
3 doing this preparation, how are we characterizing it.
4 So they put it through the wood chipper these days,
5 put it in a big plastic bag, stick it in a box and
6 ship multiple boxes to Bill and to PNNL.

7 DR. BANERJEE: So when you say the leaf
8 shredder LS I think, or something, that is coming from
9 them.

10 MR. ENDERLIN: That's called as received
11 material. As we go on and you see additional
12 information from us.

13 DR. BANERJEE: And VP is the vendor or
14 something.

15 MR. TREGONING: That's LANL notation, LANL
16 notation in the screen penetration report that was put
17 out last year. They looked at two different types of
18 process, Nukon on its ability to penetrate screens.
19 Very coarsely processed Nukon which was processed
20 through a leaf shredder and then more finely processed
21 which is the BP or the blender process. Bruce, do you
22 want to elaborate?

23 MR. ENDERLIN: Yeah, and we're trying to
24 be as consistent as possible between LANL terminology,
25 so all of our work at the moment is VP, except we have

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1 done some of the as received material. Go ahead,
2 Bruce.

3 MR. LETELLIER: Just a historical note,
4 back in the early days of the sump blockage issue,
5 clear back to USIA 43, the very first debris
6 surrogates were actually cubes of Nukon blankets that
7 were cut into blocks and thrown against the screen.
8 And they were found to have very little head loss
9 effect but as operational events occurred and as we
10 had surrogate data from air jet testing, we needed a
11 different mechanism for generating large quantities of
12 surrogate, hence, the leaf shredder that gives you
13 flocs, anywhere from a few fibers up to several inches
14 square of fiberglass.

15 If you tried to do some head loss testing
16 using the as received material what you're holding in
17 your hand, you will have a very difficult time forming
18 uniform beds. And so we went to the next step of
19 blender processing. PNNL has refined that approach to
20 a very high degree so that they have very good
21 repeatability. They have very well separated fibers.
22 The next thing you could do is to actually manufacture
23 a filter out of fiberglass and use that for head loss
24 testing. So there's quite a range of interpretation
25 for what is prototypical.

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1 DR. BANERJEE: Have you thought of selling
2 this to the chemical industry as technology for
3 filters?

4 MR. LETELLIER: Well, there are obvious
5 reasons that fiberglass is used for air and fluid
6 filtration.

7 MR. ENDERLIN: What I'm going to pass
8 around now, just so it gets around when I get to those
9 pictures is we have done some tests with those and
10 what I'm going to go and explain is how do we
11 determine how to prepare the material? Okay, if
12 someone were to say, "What's going to get to the
13 screen", there's people working on transport, there's
14 what really exists in a LOCA. So we needed to come up
15 with something for Bill to work on as correlation but
16 we want to try to bound it in what would be real
17 reasons to test. For example, if you look at the
18 Quick Look Report, you're going to see testing up to
19 750 inches. That was to match the same matrix
20 velocity-wise that LANL did.

21 Our future testing will pretty much be
22 truncated at 405 inches, because we don't need on
23 these suction pumps to do over one atmosphere of
24 pressure drop measurements. I mean, game's over for
25 the most part. So what we've done is we've come up

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1 with a preparation and in open literature, what we had
2 found is in most of tests in which they had done
3 simulated -- and I'm not familiar with all the
4 terminology that they use, but in using water jets and
5 stuff to disassociate blankets of Nukon and then
6 passing them through different transport scenarios,
7 their claim was that most of the stuff disassociates
8 into pretty small fiber or small clumps of fiber but
9 the pictures that we saw after they had taken a pool,
10 let it settled, decanted and then dried the material,
11 this stuff was just a very uniform dispersed film on
12 the bottom of the tank in the pictures we saw.

13 So based on that criteria, we thought
14 there was a basis for disassociating the stuff more
15 that the as received material. This would be in our
16 test matrix, again, I want to keep remembering that
17 the test matrix has been built to date on target, in
18 other words, the introduction of material into the
19 loop. Okay, so this is the thinnest bed we make based
20 on the test matrix. So based on that, to start saying
21 how are we going to prepare this material, we needed
22 to bound it and come up with some requirements.

23 So these are the five requirements of
24 which our debris preparation process has been based
25 on. The fiber debris material must form a debris bed

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1 on the specified metal screen or mesh. If it's going
2 right through all the time and a bed never forms,
3 then, you know, that's not really what we're trying to
4 do for the NRC. The debris bed is uniform in
5 thickness and internally as consistent as possible in
6 a radial direction. Again, whether someone is trying
7 to say that's exactly what happens in the LOCA, we're
8 trying to make sure that that pressure drop is over a
9 uniform bed that we can well characterize versus
10 looking at something that in the radial direction
11 looks different or circumferentially looks different.
12 So that became a requirement that the bed should be
13 uniform.

14 MR. TREGONING: Hey, Carl, sorry.

15 MR. ENDERLIN: Go ahead.

16 MR. TREGONING: Frame of reference
17 question; the debris bed that's being passed around do
18 you recall what sort of pressure drop, maximum
19 pressure drop was measured over that bed? That might
20 be illuminating as it's being passed around.

21 MR. ENDERLIN: I could pass a -- if you
22 give me a second, I can tell them a Quick Look Report
23 that that would compare to.

24 MR. TREGONING: Okay.

25 MR. ENDERLIN: Do you want me to take a

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1 second to do that now or just wait till the end?
2 Okay, I have a picture. It's on the order of, I
3 believe, 178 grams per meter squared. It's also in
4 that test matrix that Bill has. It would be the
5 lowest loading. And the pressure drop measurements
6 are pretty small.

7 MR. TREGONING: We'll come back to it.

8 MR. ENDERLIN: Yeah, I think I have a
9 slide, I can show you a similar bed when we get to the
10 backup slides would probably be the easiest thing to
11 do.

12 Okay, Requirement Number 3, the uniform
13 debris beds formed over the range of debris loading
14 specified by the proposed test matrix. So Bill is
15 saying, here's a loading we want to look at. We
16 wanted to make sure, will I be able to make the thick
17 bed? Can I still make the thin bed? If I make the
18 thin bed, does that mean it becomes very non-uniform
19 at the higher loading? So we're looking for a debris
20 preparation process that will give us very consistent
21 beds regardless of the amount that we've loaded in the
22 bounds of the test matrix.

23 CHAIRMAN WALLIS: I'm looking at say, Test
24 6E. You have 18.51 grams on the screen. This one
25 says initial Nikon mass point, page 7.

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1 MR. ENDERLIN: Okay, the first thing I
2 want to point out is, can you hold up the six-inch
3 screen. That's done in the bench top loop. So I
4 don't pay any -- I don't to memory or pay any
5 attention to the amount of grams. It's all mass
6 loading for me. It should report what the mass
7 loading was.

8 CHAIRMAN WALLIS: Well, this says initial
9 Nukon mass .87 and the experiment was 18.

10 MR. TREGONING: It also gives you a mass
11 per unit area.

12 MR. ENDERLIN: Yeah, the 18 grams is
13 purity for that. The amount introduced and --

14 CHAIRMAN WALLIS: Where does it say --

15 MR. ENDERLIN: I'll get to that when we
16 get to the backup slides but again, keep in mind mass
17 loading is how we compare these.

18 CHAIRMAN WALLIS: I don't see any loading
19 here.

20 MR. ENDERLIN: Are you looking at the
21 Quick Look Reports?

22 CHAIRMAN WALLIS: Oh, gram per meter
23 square?

24 MR. TREGONING: Right.

25 MR. ENDERLIN: Yeah.

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1 CHAIRMAN WALLIS: And this is 100, so this
2 is 15 times this. So this is a pretty thin --

3 MR. ENDERLIN: Yeah, that is the lowest.

4 MR. KROTIUK: Yeah, I've been trying to
5 make sure that we report this stuff in mass per, say,
6 screen surface area because otherwise, you know, you
7 have a six-inch screen or a four-inch screen or a 10-
8 inch screen, so this one sort of you would be able to
9 compare them one to the other.

10 CHAIRMAN WALLIS: Well, this stuff is
11 felting. It's actually pushing its way through the
12 holes.

13 MR. ENDERLIN: Yes, that bed did go -- at
14 the time we were doing that, it was fairly high
15 pressures to retrieve the beds, you know, and that
16 went up to fairly high velocities. We were
17 interested at the time of would we see that rupture
18 after forming the bed so we could report to Bill for
19 the pressure drop measurements, not to be picking
20 velocities in which we can't retrieve the bed, maximum
21 velocities.

22 Beds that thin, I know, can go to over 150
23 inches and the channeling, just going off the top of
24 my head, I think is on the order of 250 or so inches.
25 It's not real consistent but channeling will usually

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1 happen right at the pipe wall.

2 CHAIRMAN WALLIS: But you've got a lot of
3 data which is high pressure than that.

4 MR. ENDERLIN: Again, those are thicker
5 beds most of those. Okay, Number 4, the debris beds
6 generated for a given composition and target debris
7 loading give us repeatable physical performance
8 characteristics. So we wanted to make sure that
9 whatever our debris preparation is set, we can control
10 and we can produce a repeatable bed. Part of our
11 repeatable bed was that we could go in and get
12 repeatable head loss measurements in our bench top
13 loop when we started the process.

14 Okay, and Number 5, now this says, once I
15 have these requirements and create the bed and meet
16 the matrix, again, as I'm going to talk later about
17 the loading procedure, or loading sequence, we need to
18 meet the NRC specifications for the debris bed
19 composition to be evaluated. In other words, are we
20 looking for the one that makes the highest pressure
21 drop or what loading of constituents because again,
22 our debris preparation is based on Nukon only and the
23 debris preparation for CalSil only.

24 So these five requirements are if we start
25 looking at backup slides, you'll see at the top in the

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1 title, you'll see requirement. It means those tests
2 were done to show we met, you know, either
3 Requirements 1 or 3 through 4 or something like that.
4 So that's when you see the word requirements
5 throughout, it's referring to these five and it was
6 this guideline that we came up with our method of
7 developing debris.

8 Okay, the results of the initial matrix I
9 have some backup slides but the matrix were originally
10 based on using dry material. Okay, and this takes a
11 very long time to evaluate this because you have to go
12 to the oven. So what we were looking at is what can
13 we do if we try to do something that's more of a quick
14 qualitative test. And again, you know, I don't know
15 of any standard way to characterize the fiber. We
16 tried to talk to people in industry and they couldn't
17 give us much other than going all the way to SEM or
18 something.

19 So to decrease the evaluation time, we
20 came up with a metric in which we prepare the
21 material, and then we pour it through a screen. It
22 has a set size and the idea is to continue to pour so
23 this is something you have to take a little bit of
24 time to train your operators, but in developing the
25 matrix, we prepare it, come up with a blender time is

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1 what we're after and it blender sensitive. That's
2 what led to this, but we were able to show three
3 operators can go in and repeat this test. So three
4 different people can go in. They can run the R4 test
5 after people have had a little bit of training. This
6 is the way we're doing it. And they can independently
7 get roughly the same R4 value.

8 CHAIRMAN WALLIS: This must depend on how
9 much stuff you try to pull through.

10 MR. ENDERLIN: Well, you saw those
11 concentration limits I had initially for putting in
12 the loop. There is -- that concentration limit also
13 exists to what goes into the blender. Okay, so
14 there's a limit. When we -- if I prepare a five -- I
15 have a one-liter blender let's just say. There's a
16 limit to how much material you can put in there. You
17 can only get it so concentrated before you're outside
18 of the bounds of doing the preparation procedure.

19 Okay, and then the R4 values, so that you
20 guys understand, is plus or minus one. Okay, if we're
21 looking for an R4-11, we accept 10 to 12. Okay, and
22 R4 value of 10 is giving us very close to within 10
23 percent of head loss --

24 CHAIRMAN WALLIS: What's an R4-11? It's
25 the Nukon plus the water divided by the Nukon.

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1 MR. ENDERLIN: Right.

2 CHAIRMAN WALLIS: How could it be 11?

3 MR. ENDERLIN: There's 94 percent of that
4 mass that's on there is water. So as I said, it's not
5 something that we're going to go patent and sell an
6 instrument on because a lot of what I'm measuring --

7 CHAIRMAN WALLIS: Then you'd pour more
8 stuff on and more Nukon would get held up. It doesn't
9 matter. This is not the really important stuff.

10 MR. ENDERLIN: Right.

11 DR. BANERJEE: They're just trying to
12 characterize it.

13 CHAIRMAN WALLIS: Right, they're trying to
14 characterize it.

15 MR. ENDERLIN: Yeah, the method has worked
16 in the bounding range that I gave you with the five
17 requirements to show repeatable beds that for a Nukon
18 bed, I can make five beds and they will all be within
19 10 percent head loss for any given velocity.

20 MR. TREGONING: Yeah, the evolution LANL
21 historically had developed methodologies and metrics
22 so that they can insure that they got relatively
23 uniform and repeatable beds. All we're trying to do
24 is take that same philosophy and make it a little bit
25 more global and portable so that any lab or any

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1 operator with any particular blender could recreate
2 the same type of result. So that was really the
3 genesis and the philosophy behind this precursor work.

4 DR. BANERJEE: If you dry these out or
5 whatever, do they show like little fibers when they're
6 dried out?

7 MR. ENDERLIN: Yes.

8 DR. BANERJEE: And can you measure their
9 length?

10 MR. ENDERLIN: That's the question. Yeah,
11 if we go to SEM, that would be one way to do it. The
12 other way is to try to take a digital picture and do
13 some -- using a software analysis. We have not done
14 that at this time. That's something, when we're all
15 done with the process and it's been determined
16 acceptable, we can do a final characterization.

17 DR. BANERJEE: So these are -- each of
18 these fibers is now free of its coating or whatever?

19 MR. ENDERLIN: No, well, the organic
20 coating, and I'm not a chemist, will depend on the
21 boiling, I believe.

22 CHAIRMAN WALLIS: I think that's already
23 been taken off, hasn't it, before they send it to you?

24 MR. ENDERLIN: Well, that's heat treated.

25 MR. TREGONING: Again, it's heat treated

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1 in the same way that the ICET product was where is was
2 single sized --

3 CHAIRMAN WALLIS: You're doing this very
4 meticulous repeatable preparation whereas what you get
5 in the sump of PWR is very irrepeatable and --

6 MR. ENDERLIN: Yeah, again, I said our
7 goal was to make sure we got controlled environment
8 and --

9 CHAIRMAN WALLIS: If I did a test where I
10 didn't use the same blender, I didn't use the same
11 process, I might get quite a different answer.

12 MR. ENDERLIN: And I'm going to show you
13 that and the method that you loaded it, yeah.

14 DR. BANERJEE: But maybe, that's what I
15 was asking, if you could take a dried sample and
16 measure some parameter related to that, which gives
17 you some idea of --

18 CHAIRMAN WALLIS: Fiber length or meters
19 squared per cubic meter --

20 DR. BANERJEE: Something.

21 CHAIRMAN WALLIS: -- surface or something,
22 yeah.

23 DR. BANERJEE: You would know at least
24 whether the blenders that you're using are the same or
25 not or giving you different results. Another way,

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1 often these suspensions of fibers on the shear, do
2 show fairly non-Newtonian behavior and you know, in a
3 quantitative viscometer.

4 MR. ENDERLIN: Yeah.

5 DR. BANERJEE: You might be able to get
6 something to characterize them like a shear viscosity
7 or something like --

8 MR. ENDERLIN: We've done a first attempt
9 at that. The question was, what concentration do we
10 do it at and at the moment, since this was working, we
11 didn't pursue that any more. We were looking at both.
12 Well, we don't expect the particle sizer -- I mean,
13 lots of times people say, "Well, the vendor says it
14 won't work". It won't work for what the vendor
15 intended it for but it will give us a metric by which
16 to measure it. So we looked at particle sizing and we
17 did go to a rheometer, but at the moment, messing with
18 the concentration, I think we need to go to much
19 higher concentrations and I didn't want to take a
20 tangent once we found something that worked, but that
21 is something we looked at.

22 DR. BANERJEE: The thing is, eventually,
23 you're going to have to characterize those particles
24 somehow or the fibers somehow by length or something
25 and there are theories which for more concentration

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1 suspensions probably can relate the length of the
2 slender body. It's not quite a slender body but on
3 the sheared line to the shear viscosity. There's
4 various viscoelastic parameters.

5 MR. ENDERLIN: Yeah, we're interested in
6 any information and trying to come to a consensus of
7 how we should characterize the fiber.

8 DR. BANERJEE: Somehow you're going to
9 have to do it.

10 CHAIRMAN WALLIS: Well, you have to
11 because, I mean, once you get down to fibers which are
12 average length less than an eighth of an inch, you
13 keep blending and blending and blending them, they'll
14 probably go through the screen.

15 MR. ENDERLIN: Well, two things on that.

16 CHAIRMAN WALLIS: -- from what you started
17 with.

18 MR. ENDERLIN: Yeah, I can talk to that
19 some. So on our R4 metric we say exactly what you say
20 is, if you see a pressure drop begin to increase with
21 R4, continually, eventually you get to a point where
22 you don't form a uniform bed and if you go back to the
23 requirements, that's how our R4 was selected as we
24 began to evaluate and say, "Okay, as I do R4 and I get
25 finer and finer", okay, and that's one thing I bring

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1 up that the R4 that created the value that we used on
2 the five-mesh screen, it may be that I can still get
3 uniform beds by going to a lower R4, lower R4 is more
4 finely blended material, because the holes are
5 smaller.

6 The other thing we've seen in our very
7 first SEM pictures we took is that -- and you can see
8 it when you just do an R4 test, that you don't need --
9 particles that are less than an eighth of an inch or
10 that screen mesh can make it. What happens is they
11 hang up at the corners of the square and you get
12 bridging, classic bridging. If you look at the bottom
13 of them, it almost looks like a honeycomb beehive
14 where you've began to get the bridging around the
15 corners and then your high flow down the center of the
16 port gives you a little bitty hole when you look at
17 the bottom. It looks like you've had a bunch of
18 cutter bees that have come to the bottom of your
19 debris bed. So smaller fiber than just that size will
20 start to form a bed.

21 MR. TREGONING: Let me try to clarify and
22 Bruce can speak more eloquently than I on this but the
23 blender does two things. There is some chopping that
24 occurs, certainly, but the primary effect of the
25 blender, at least in my opinion, is to untangle or

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1 help disassociation of the individual fibers so that
2 when you get it in a dilute solution it's more readily
3 separable and I think that that's probably the larger
4 effect of the blender. Sure there's some chopping.

5 CHAIRMAN WALLIS: Well, this is going on
6 too long. I mean, what I'm going to take away from
7 this is the results and rather than all the details of
8 how you chopped and --

9 MR. ENDERLIN: Okay, no, that's fine.
10 That's --

11 CHAIRMAN WALLIS: The problem here is
12 you're doing very, very sort of experiment specific
13 experiments here because your preparation is unique.
14 They have nothing to do with what happens in the sump.
15 I'm not sure how you make the bridge. For the
16 interest of doing repeatable experiments, this is
17 fine, but what does it have to do with a sump?

18 DR. BANERJEE: Well, because as you
19 develop a theory, you have to start somewhere where
20 you --

21 CHAIRMAN WALLIS: I agree, but it's an
22 awful long way from this to --

23 MR. TREGONING: Well, we heard earlier the
24 importance of model development. This is a case where
25 we're --

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1 DR. BANERJEE: I think you have to start
2 here.

3 MR. LETELLIER: The extreme uniformity
4 gives you a chance to develop a correlation that has
5 all of the physics that you think are important and
6 it's repeatable enough to build your confidence.

7 CHAIRMAN WALLIS: Let's see how repeatable
8 it is.

9 MR. LETELLIER: Assuming you can satisfy
10 that objective, and you have a correlation --

11 CHAIRMAN WALLIS: You see, what's nagging
12 me here is you're going through all this stuff and
13 then I see data where you've gone to a factor of 10
14 different from LANL doing presumably the same
15 experiment. That tells me that something is really
16 important here. You know, I'm not sure that it's in
17 the leaf shredder and the --

18 MR. ENDERLIN: Yeah, I'm just going to
19 skip through these. This just gives you an example of
20 received material and another R4-B and just to give
21 you an example, the one on your right is the beds that
22 we're testing that you've seen in Series 1 will have
23 a consistent --

24 CHAIRMAN WALLIS: Somebody else may have
25 a different standard than R4-B2.

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1 DR. BANERJEE: R4-2D.

2 MR. ENDERLIN: Okay, this is data from the
3 bench top. The difference there is our points are all
4 within 10 percent given the same bed preparation.
5 We're doing CalSil. The characterization for that is
6 just the particle size distribution and it's not as
7 sensitive to blending time like Nukon is.

8 Okay, just before we get to results of
9 actual debris beds, I wanted to take a second on this.
10 This is just the flow history. Things that we're
11 looking at is cycling and time at flow. This is just
12 showing examples. The number of circulations when we
13 start to do the mass balance that there is a specified
14 amount of time or circulations that for different
15 conditions, different initial bed formations, they're
16 all following this relationship, that we've got to get
17 up here before we have 95, 90 percent of our material
18 on the bed.

19 So if someone starts taking data down
20 here, part of their history, this is going to be just
21 additional mass showing up on the bed. Okay, you said
22 results. Do you want to hear about the loading
23 sequence then?

24 CHAIRMAN WALLIS: You tell us whatever you
25 think is most interesting.

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1 MR. ENDERLIN: Okay, when we're looking at
2 the loading sequence, we began to see some difference
3 in our Series 1 test and different from LANL. Our
4 initial injection system looked at trying to
5 simultaneously introduce the material. So it was
6 thought that that may create different ways of forming
7 the bed.

8 Again, LANL used a premixed material and
9 the question is, premixing causing conglomerations of
10 CalSil to attach to the fiber such that the CalSil is
11 not just introduced to the bed based on velocity and
12 passing it through the porous flow path. So in Case
13 1 that you're going to see here is introduction to
14 CalSil after a Nukon debris bed has formed. So this
15 would be the classic sandwich case with any CalSil
16 that's being penetrated into the bed.

17 Introduction to Nukon and CalSil is a
18 premixed slurry. This was to get a comparison to what
19 LANL and Argonne were doing. Case 3, you're not going
20 to see results off. It was an introduction to Calsil
21 and I know there had been a question earlier. We did
22 this two ways and never formed a uniform bed. The
23 idea was we'd look at CalSil first with the Nukon on
24 top but we introduced the CalSil by putting it in
25 incrementally and putting the same loading in all at

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1 once. While we do see a difference, we're not able to
2 get that stuff to --

3 CHAIRMAN WALLIS: You need a little bit of
4 Nukon first.

5 MR. ENDERLIN: Yes. And the last one is
6 what we call a time delay. And what we're doing there
7 is after you've put the Calsil into the loop and we're
8 talking just short delay so that some fibers can get
9 there, they've never been in contact with the CalSil,
10 and as this thing is recirculating, your Nukon is
11 basically being introduced to your porous media only
12 into the flow paths. Okay.

13 So if we come out here and look this is
14 where you're going to see some significant
15 differences.

16 CHAIRMAN WALLIS: Why does the premixed
17 pre-data not go down to the same velocities as the
18 other data, like .05? I can extrapolate it by --

19 MR. ENDERLIN: Okay, the reason being is
20 again, I said flow history. There is data that does
21 that. What I'm trying to give you is the same flow
22 history of behind these. So these are basically ramp
23 up three. So if I go through a cycle to form the bed
24 and I ramp down, okay, remember that in the bench top
25 the initial bed formation was made at .2. So I -- my

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1 system can still get the velocities higher than .2.
2 What's happening is in the bench top loop looking at
3 this, I can't get to that velocity because the
4 pressure drop has gotten so high and what we're trying
5 to see is at least the same number of cycles. Okay,
6 I'm trying to, as much as possible avoid apples and
7 oranges here.

8 CHAIRMAN WALLIS: I'm taking say the data
9 of a premix debris of .2 which gives me 300 and I'm
10 saying I extrapolate lineally back to .01 and I get
11 something like 15 and I got another experiment where
12 I've got 1,015.

13 MR. ENDERLIN: Correct.

14 CHAIRMAN WALLIS: So you're saying there's
15 a factor of, I don't know, 100 or something difference
16 between these different experiments?

17 MR. ENDERLIN: Yes.

18 CHAIRMAN WALLIS: Well, that's very
19 reassuring. Leaf shredders and all that apart, this
20 is very dramatic, isn't it, if --

21 MR. ENDERLIN: Yeah, well, now the other
22 thing that's going to hop onto this is the bed height
23 of these beds do not change much. The bulk porosity
24 is calculated based on --

25 CHAIRMAN WALLIS: It doesn't change much?

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1 MR. ENDERLIN: No, and if you think of it
2 as --

3 CHAIRMAN WALLIS: CalSil must be somewhere
4 else in the bed then.

5 MR. ENDERLIN: Well, if you think of the
6 premixed, if you premix it, you're allowed to have --
7 if you think of a Nukon bed first, just imagine it as
8 being a porous media. I now distribute CalSil
9 material in voids that wouldn't have contributed to
10 flow paths anyway. As I go to the Nukon bed first,
11 I've created a Nukon bed, added CalSil on top. Now,
12 if I take the time delay which are the -- and there's
13 a slight difference between those, the red and the
14 aqua are the same test and I'll tell you the
15 difference of the blue in a minute but in those,
16 essentially each layer of Nukons being added and the
17 Calsil is only going in to plug flow paths. It's
18 being introduced by flow.

19 Therefore, in essence over here I have a
20 higher concern -- I have more CalSil to plug the flow
21 areas than I do over here, because I've taken CalSil
22 that would have never blocked the flow path and
23 uniformly distributed it in there. And the percent
24 mass retained is, I believe, within -- all these are
25 within approximately three percent. So we've got --

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1 CHAIRMAN WALLIS: Well, one reason the bed
2 doesn't compress much more is you've got about the
3 same pressure drop. It's the pressure drop that
4 compresses the bed. So we don't --

5 MR. ENDERLIN: Yes.

6 CHAIRMAN WALLIS: -- expect it to compress
7 all that much if it's governed by the fiberglass; is
8 that right?

9 MR. ENDERLIN: Correct. The bullet case
10 here, just to explain the difference of that, is the
11 question was, well, what's the fiber structure of the
12 Calsil, how much is that effecting it? So, in the
13 blue condition here, we showed we can even get higher
14 by this initial process of CalSil which I'm not going
15 into great detail, but it's basically disassociating
16 the material from the fiber in a dry matter, like a
17 mortar and pestle. And then the fiber was removed.
18 So the CalSil was screened. So in the blue, we
19 removed the CalSil fiber.

20 CHAIRMAN WALLIS: So let's say this is
21 LANL Test 6E, 6E2?

22 MR. ENDERLIN: I'm going to show you a
23 comparison of that if you --

24 CHAIRMAN WALLIS: If I look at your Slide
25 28, the LANL at .1 has a pressure drop of something

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1 like 15 or 20 or something.

2 MR. ENDERLIN: Okay, is there a pointer
3 here I can go --

4 CHAIRMAN WALLIS: And so the LANL's that
5 are even lower. I mean, we're talking about a factor
6 of 100. It's look almost like a factor of 1,000, if
7 you take the time delay versus the LANL data.

8 MR. ENDERLIN: Correct, and I was going to
9 show you that our --

10 CHAIRMAN WALLIS: This is kind of mind-
11 boggling, isn't it, a factor of 1,000 difference
12 between two experiments supposedly the same? It's
13 almost like something out of surreal science or
14 something.

15 MR. ENDERLIN: The question is, the
16 comparison here is Condition 6E. So is the mass on
17 LANL's bed the same as ours? Is the debris
18 preparation the same in LANL as in --

19 CHAIRMAN WALLIS: But you see what I'm
20 getting at?

21 MR. ENDERLIN: Oh, yeah.

22 CHAIRMAN WALLIS: I don't care about the -
23 - the sump gives you whatever it gives you. And if
24 you don't know what it's giving you, you don't know
25 where you are between these extreme --

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1 MR. ENDERLIN: Well, we're trying to
2 provide data for --

3 CHAIRMAN WALLIS: I think it's very, very
4 useful what you're doing but it's extraordinary.

5 MR. ENDERLIN: Yeah, the question is for
6 the correlation is we can test different constituents.
7 My point is, is --

8 CHAIRMAN WALLIS: How can you test the
9 correlation when it's a factor of 1,000 difference
10 between --

11 MR. ENDERLIN: Because you need to govern
12 those parameters which are the initial conditions.

13 CHAIRMAN WALLIS: You need to say
14 something more about the details of the bed, right?

15 MR. ENDERLIN: Yes.

16 MR. KROTIUK: Right, what's --

17 CHAIRMAN WALLIS: How can they possibly
18 know that for the sump?

19 MR. KROTIUK: In order to calculate the
20 pressure drop in a correlation, you have to know the
21 composition of the bed and the distributions in the
22 bed. That's what I'm --

23 CHAIRMAN WALLIS: I think there's a
24 guidance out there which I read which said that it's
25 conservative to assume it's a homogeneous -- I think

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1 I remember reading that in NEI guidance. It doesn't
2 sound like as if that's a very good piece of guidance,
3 is it?

4 MR. ENDERLIN: I wouldn't use it.

5 DR. BANERJEE: Now, do you know the reason
6 for the difference between the LANL and your data?

7 MR. ENDERLIN: I'm do know that we're
8 comparing the same mass on the screen. Bill will
9 address that.

10 CHAIRMAN WALLIS: Well, it says 6E and you
11 said these are test conditions 6E. They would be
12 loading same as LANL.

13 MEMBER SHACK: Well, if you extrapolate
14 the premix debris to the right velocity, you're in the
15 neighborhood --

16 CHAIRMAN WALLIS: It's the same debris.

17 MEMBER SHACK: -- since LANL was done with
18 a premix test.

19 DR. BANERJEE: And this is not premixed?

20 MR. ENDERLIN: Well, this is -- I'll show
21 you -- that's why I've taken these out of order and
22 it's going to create more questions.

23 CHAIRMAN WALLIS: Well, the LANL premixed
24 even that is quite different from your premixed.

25 MR. ENDERLIN: Right, but I'm not sure

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1 that this isn't close to premixed.

2 CHAIRMAN WALLIS: And your 6E-2 -- well,
3 I mean, we can go on forever. It's a value which is
4 very much different from LANL's 6E.

5 MR. ENDERLIN: Right.

6 CHAIRMAN WALLIS: We could go on like this
7 forever.

8 MR. ENDERLIN: Because the series -- well,
9 you can go on this forever, based on our Series 1
10 tests that we introduced the material by a method that
11 we don't think was as controllable. By understanding
12 that, I can now go in and repeat this test by knowing
13 how to introduce material.

14 CHAIRMAN WALLIS: Why shouldn't I reach
15 the conclusion that what happens in a sump with these
16 kind of materials is completely unpredictable?

17 MR. ENDERLIN: Because I don't know that
18 you've seen all the results of the transport test to
19 tell us that we know what can get to the screen.

20 CHAIRMAN WALLIS: But you see what I'm
21 getting at.

22 MR. ENDERLIN: Yes.

23 CHAIRMAN WALLIS: If you've got a factor
24 of 1,000 difference for what looks like the same
25 experiment, there are very few areas of science where

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1 that happens.

2 MR. TREGONING: Yeah, it's not the same
3 experiment, no.

4 MR. ENDERLIN: Yeah, it's not the same
5 experiment.

6 CHAIRMAN WALLIS: But it is. Officially,
7 it's the same.

8 MR. TREGONING: No, not at all.

9 CHAIRMAN WALLIS: It's the same debris
10 loading.

11 MR. ENDERLIN: If I asked you --

12 MR. TREGONING: It's the same loading,
13 it's not the same --

14 CHAIRMAN WALLIS: So if you've got a
15 correlation which only depends on debris loading,
16 you'll be able to predict something --

17 MR. TREGONING: Can I --

18 CHAIRMAN WALLIS: -- you repeat one value
19 not a range of values.

20 MR. TREGONING: Yeah, I think what we're
21 saying and we said this from the very beginning, it's
22 not just the function of the loading.

23 MR. KROTIUK: But let me say one other
24 thing; I -- the loading, and Carl mentioned this
25 earlier, the loading was -- of the mass going into the

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1 loop was attempted to be the same in terms of
2 kilograms per square surface area. However, what
3 caused -- and I have a graph to this, is that they're
4 able to measure the amount of Nukon and CalSil on the
5 bed, and when you look at that, the amount of CalSil
6 that's actually in the bed is only a fraction of what
7 is added. The Nukon is much closer.

8 CHAIRMAN WALLIS: That's very different
9 from LANL. LANL measured turbidity or something and
10 they concluded from their tables that you were up in
11 the 90 percent of the Calsil being trapped in -- up to
12 99 percent, I think in some test. So they were
13 concluding all the CalSil was trapped in the bed.

14 MR. KROTIUK: And that's not what we're
15 finding from --

16 CHAIRMAN WALLIS: So that's another big
17 difference between you.

18 MR. KROTIUK: Yes.

19 MR. TREGONING: Well, again, here's where
20 the --

21 CHAIRMAN WALLIS: Maybe that's because
22 you've blended it so well. You're really letting the
23 CalSil through, aren't you? You're letting the CalSil
24 through.

25 MR. TREGONING: Some CalSil does go

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1 through, yes.

2 MR. KROTIUK: We're recirculating it.

3 CHAIRMAN WALLIS: You're recirculating it,
4 aren't you?

5 MR. TREGONING: We are recirculating it.

6 MR. ENDERLIN: For these tests, that's
7 what I was trying to stress --

8 CHAIRMAN WALLIS: Not recycling.

9 MR. ENDERLIN: -- for these tests we're
10 trying to match --

11 CHAIRMAN WALLIS: You are recirculating
12 it.

13 MR. TREGONING: Yes.

14 CHAIRMAN WALLIS: So you'd expect it to
15 get -- eventually to get trapped.

16 MR. TREGONING: But I don't know -- did
17 you match the exact number of circulations that LANL
18 did? I mean, that's --

19 MR. ENDERLIN: No, LANL did one -- that's
20 why I'm thinking we're premature to be here if we
21 don't discuss the other results.

22 DR. BANERJEE: Let's start from where you
23 were before.

24 CHAIRMAN WALLIS: Yeah, let's go back to
25 where you were before. That was Slide 24.

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1 MR. ENDERLIN: I'm going ahead.

2 DR. BANERJEE: Give us a reason for these
3 differences.

4 MR. ENDERLIN: Well, I don't know that we
5 know them all but there are some significant ones.
6 Okay, if we go here again, what we're looking at is
7 all of these -- there are slight differences and
8 additional testing has shown that we can start to get
9 much better repeatability if we use the same initial
10 conditions and so from these results, these are done
11 in the bench top loop. And we're going to come back
12 to that same slide with some additional Series 1 tests
13 on it.

14 Just to speed things up, there are some
15 bench mark tests being done at LANL, PNNL. We have
16 three cases identified that you can read what they are
17 there. And the main thing is that we're trying to
18 make all the debris preparation, all the bed formation
19 to get rid of those variables so that we compare
20 measurements systems and the actual introduction
21 method. So the loading sequence will be the same, but
22 we're going to be able to determine is our two
23 different ways of injecting the stuff into the loop,
24 is that creating a difference in what's winding up in
25 the bed?

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1 Okay, these are Series 1 test results.
2 This is an example of them. The reason 6E has become
3 the example is because I have two cases and that was
4 a case where we didn't get repeatability and --

5 CHAIRMAN WALLIS: This case 4C, this black
6 square, very dark blue or black or something, that --

7 MR. ENDERLIN: Where are we?

8 CHAIRMAN WALLIS: On the back of 24, is
9 that point up to 1,000. That's a point up to the
10 1,000, that dark blue color square.

11 DR. BANERJEE: That's time delay, right?

12 CHAIRMAN WALLIS: But that's a point which
13 essentially said the thing became completely
14 impermeable.

15 MR. ENDERLIN: Yes, that's my
16 understanding, is we --

17 CHAIRMAN WALLIS: Why?

18 MR. ENDERLIN: -- we have a number of beds
19 that are becoming impermeable.

20 CHAIRMAN WALLIS: Completely jammed up.

21 MR. ENDERLIN: Yes, if I pull the thing
22 off, I get just a slow, slow drip out the bottom, when
23 I unhook the bottom piping.

24 CHAIRMAN WALLIS: It's a bit self-
25 reinforcing, because once it gets impermeable, the

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1 pressure drop goes up with squeezes it more.

2 MR. TREGONING: Right, so you're pressure
3 -- again, once you've got -- once you've reached --

4 CHAIRMAN WALLIS: Which is well-known in
5 certain problems of chemical engineering. You get
6 this tick valve effect. The thing blocks --

7 MR. ENDERLIN: Yeah, the final 10 percent
8 fines is what's going to take you out of business.

9 CHAIRMAN WALLIS: Sugar beet production
10 amongst other things. I mean, trying to get the sugar
11 out of the beet. You know, you can actually plug up
12 the filter completely. But that's a very dramatic --
13 you stand by that data, do you? I mean, that's
14 something that --

15 MR. ENDERLIN: Again, I want to stress
16 that I stand by the relationship between the different
17 methods and it was measured in the bench top. So
18 again, I don't want to take the magnitudes and say
19 they've all been verified in the large scale test loop
20 but I stand by the premixed is going to give you
21 pressure drops. We've repeated enough of the tests
22 now that are going to be significantly different
23 compared --

24 CHAIRMAN WALLIS: If I were in RL looking
25 at that, I'd say what am I going to do?

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1 MR. ENDERLIN: But you'd need to begin --
2 it would appear to me you'd need to again, the
3 transport of how the material gets to the screen
4 becomes a more important factor.

5 CHAIRMAN WALLIS: Can you ever predict
6 that really?

7 MR. ENDERLIN: The question is can you
8 bound it?

9 CHAIRMAN WALLIS: Okay, I guess we have to
10 go on. I was trying to get to these kind of results
11 because I think these are the most important things
12 we're going to hear today. Okay, which one is this
13 one?

14 MR. ENDERLIN: Okay, this is Slide 26.
15 This is the 6E test and just to give you an example,
16 of things that may be different between the LANL as we
17 get there is our bed formation process, he formed all
18 his beds at .1 and did you maintain velocity or did
19 you maintain a pump speed? See, so he started at a
20 lower velocity and maintained a pump speed, okay.
21 When we went to .1 we maintained a constant pump
22 speed. We allowed at least 20 recirculations, I
23 believe, and then we had a criteria for what we have
24 as far as what we're calling steady state. Our bed
25 formation is tighter than what we do per data points.

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1 CHAIRMAN WALLIS: You have shown on this
2 figure also 6E, where you --

3 MR. TREGONING: That's the next one.

4 CHAIRMAN WALLIS: 6E, no, no, it's 6E
5 something else.

6 MR. ENDERLIN: 6-2E.

7 CHAIRMAN WALLIS: 6-2E, yeah, 6-2E comes
8 in at about .2 screen velocity and it zig-zags up to
9 about 700.

10 MR. ENDERLIN: Yeah, I'll show you a
11 comparison between the two.

12 CHAIRMAN WALLIS: It's almost constant
13 velocity. It zig-zags up to about three times what
14 this one is. So --

15 DR. BANERJEE: It's 28.

16 CHAIRMAN WALLIS: You have that, do you
17 have that here? I'm sorry, I'm going ahead.

18 MR. TREGONING: One more.

19 MR. ENDERLIN: That's still 6E and LANL.

20 CHAIRMAN WALLIS: No, that's all right.
21 It's just that that's supposed to be you repeating
22 your experiment.

23 MR. ENDERLIN: No, no, no, no, no.

24 CHAIRMAN WALLIS: No, 6-2E.

25 MR. ENDERLIN: Correct. That's what I'm

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1 trying to explain. Okay, on this test, if we look at
2 -- I believe Dr. Wallis is talking about right here.
3 This is 6E and this is 6E-2.

4 CHAIRMAN WALLIS: Yeah, there's quite a
5 bit of difference.

6 MR. ENDERLIN: There was, based on what
7 LANL did, some difference in the flow history to get
8 to these data points, but what we've tried to do and
9 the reason you're not going to see velocities down
10 here is I was trying to explain on the previous one,
11 is our sequence of how we took tests. And we were
12 looking for input on that is to where you're going to
13 compare this data if we're not getting the steady
14 state. Do remember that if you want to compare LANL,
15 that's the only data you should compare to LANL.

16 Okay, LANL did it once up and once down.
17 Okay, so this other data, LANL -- you don't know where
18 LANL would have gone if they had done it multiple ramp
19 ups. Two, they have a difference in bed formation, so
20 what would have happened to their bed formation,
21 that's the question. As I do this, do I get more
22 repeatable on the third ramp up?

23 CHAIRMAN WALLIS: Not only repeatable,
24 they got results where they'd go along and then it
25 would sort of jump up.

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1 MR. ENDERLIN: And that comes down to the
2 importance of --

3 CHAIRMAN WALLIS: And we don't know how --
4 yeah, they might have jumped up to agree with you if
5 the cycle was --

6 MR. ENDERLIN: Correct, and the jump-up
7 may just mean that they added mass to the bed.

8 CHAIRMAN WALLIS: Well, we don't know what
9 it was. It just happened.

10 MR. ENDERLIN: Right.

11 DR. BANERJEE: It didn't seem like they
12 added mass to the bed. At least they didn't say they
13 added mass.

14 MR. ENDERLIN: Right, but I'm just trying
15 to point out --

16 DR. BANERJEE: If they done it, it was not
17 to the knowledge in the report.

18 MR. ENDERLIN: Based on the LANL results
19 these are things we've identified that need to be
20 controlled that when he's trying to match to a
21 correlation, is he using the same bed height, the same
22 mass that's in there? You know, this may become not
23 as random or various as long as you understand how the
24 bed is formed.

25 CHAIRMAN WALLIS: You've shown us 6E, 6I

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1 the difference between LANL and you is a factor of
2 about 20, I think.

3 MR. ENDERLIN: Yeah, I think it's 18 or
4 something.

5 CHAIRMAN WALLIS: 18 or 20, I guessed 20.

6 MR. ENDERLIN: Yeah, and again, reasons
7 for that is in our Series 1 test, okay, the way we did
8 it, we're not going to do it the same. Okay, we need
9 to come to a decision but the question is, did I have
10 premix because I opened the valves exactly at the same
11 time and it was close to premix and when I went here,
12 I started to form a Nukon bed and then CalSil came
13 behind it. So that's what we're saying is these
14 little perturbations in how you form the bed.

15 MEMBER SHACK: Now when you say premix
16 then, you mean, that you open the valves at the same
17 time. You didn't sit there and mix --

18 MR. ENDERLIN: No, I'm saying this gave me
19 results that are close to -- if I go in here and
20 premix and I get repeatable tests, you know, this is
21 a little off but I never get a premix that looks
22 anything like that.

23 CHAIRMAN WALLIS: See, the problem you
24 have here is that any test that the industry is going
25 to do is going to supposedly predict what happens in

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1 the sump. So the industry does a test and they get a
2 form with a green diamond, a green triangle like that.
3 How do they know they're not going to get a black
4 diamond in the sump, because they're not controlling
5 what happens in the sump and they're probably not
6 controlling what happens very well in their fairly
7 large --

8 MR. ENDERLIN: Right, but do they have --

9 CHAIRMAN WALLIS: How do you know where
10 you are in this? If I were an engineer, I'd say, I've
11 got to have some completely different solution than to
12 this problem if I'm going to predict anything.

13 MR. ENDERLIN: Yeah, that question I have
14 is in the transport.

15 CHAIRMAN WALLIS: That's my first reaction
16 to this. It's intolerable to have this much variation
17 in predictability. So you have to do something else.

18 MR. TREGONING: The industry does, as part
19 of the SE evaluation, need to look at a thin bed which
20 is essentially again these particulate saturate
21 effects in both either analysis and/or testing,
22 depending on how they want to evaluate.

23 CHAIRMAN WALLIS: You have a uniform bed.
24 You work very, very hard to have a uniform bed. They
25 don't have anything like that. They have a vertical

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1 screen rather than a horizontal screen and all that.
2 How are you going to apply any of this to their stuff
3 as well?

4 MR. LETELLIER: That was part of the value
5 of recommending that they assess the homogeneous bed
6 formation complete -- with complete coverage of their
7 design screen surface area.

8 CHAIRMAN WALLIS: We can study this stuff
9 until we're all dead and never get an answer that
10 really applies to a sump.

11 MR. LETELLIER: The bed formation is
12 intentionally very uniform and very regular. There is
13 no -- there's some evidence that beds can form that
14 way over limited surface areas but I think that's the
15 point of the industry testing is to demonstrate that
16 that condition does not occur over manifold screens.

17 CHAIRMAN WALLIS: It's very interesting to
18 see where they are because probably where they're
19 going to be is way down below all this stuff, I would
20 hope.

21 DR. BANERJEE: They obtain no velocity.

22 CHAIRMAN WALLIS: This sort of velocity?
23 Well, I would hope that --

24 DR. BANERJEE: .01 or something.

25 CHAIRMAN WALLIS: -- it would always be

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1 way down below all of yours. The reason you're
2 getting these high head losses is because you're being
3 so meticulous about the way you're doing the
4 experiment. And, you know, that isn't going to happen
5 in the sump except by some fluke.

6 MR. ENDERLIN: Right, and again, I'm
7 trying to provide data to develop --

8 CHAIRMAN WALLIS: It's a completely
9 different way of premixing the debris and mixing the
10 debris and all that. And likely, they're going to be
11 lower but that's only a likelihood. I don't know how
12 much confidence I can have in that.

13 MR. TREGONING: The larger screen area
14 certainly lead to a much lower approach velocities.
15 Now, granted once you start to get clogging, those
16 flow velocities will elevate locally.

17 CHAIRMAN WALLIS: Look at this though, the
18 blue square, that disconcerting one which I know it's
19 there because you couldn't measure anything higher but
20 it's at the top of the graph.

21 MR. ENDERLIN: No, because I didn't have
22 any --

23 CHAIRMAN WALLIS: That's at a very low
24 velocity. That looks to me like .01 or less.

25 DR. BANERJEE: What happened there? Can

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1 you tell us?

2 MR. ENDERLIN: The part, I reached -- in
3 the bench top I reached the pump capacity. I didn't
4 want to -- I dead-headed the pump.

5 CHAIRMAN WALLIS: So the pump -- the
6 pressure drop could have been obviously higher than
7 that.

8 MR. ENDERLIN: If I could increase the
9 velocity, yeah. I'm up near the top of my range. I
10 instruct them when they get to a certain value, they
11 must turn off.

12 CHAIRMAN WALLIS: What was the flow rate?

13 MR. ENDERLIN: It's like .012 or
14 something. It's next to nothing.

15 CHAIRMAN WALLIS: .01, okay.

16 MR. ENDERLIN: I mean, this thing is
17 plugged. We don't have data there.

18 DR. BANERJEE: Back to that condition,
19 what did you do different? You say time delay.

20 MR. ENDERLIN: No, the only -- the
21 difference between these points and that is that I
22 took the CalSil fiber out. Okay, the time delay,
23 again, says that you put the CalSil into -- get a
24 cloud of CalSil into the loop. Before it's began to
25 recirculate even once, the Nukon gets introduced.

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1 So you have just a time phase length.

2 CHAIRMAN WALLIS: To have to have
3 something to deposit --

4 MR. ENDERLIN: What's that?

5 CHAIRMAN WALLIS: You make something to
6 deposit the CalSil on.

7 MR. ENDERLIN: Yes, so that the CalSil
8 will be forced into the porous media rather than be
9 evenly distributed as might happen here. So that all
10 CalSil --

11 DR. BANERJEE: Sorry, the Nukon bed first,
12 you're introducing the Nukon.

13 MR. ENDERLIN: I'm making a Nukon bed and
14 that Nukon bed meets my steady state requirements
15 before I even think about mixing my CalSil and putting
16 it in.

17 CHAIRMAN WALLIS: Well, let's look at then
18 the sump. The CalSil being fine arrives first, comes
19 with the water. It goes right through the screen and
20 through the loop which is the reactor, right? By the
21 time it gets back again, there's a little bit of Nukon
22 there.

23 MR. ENDERLIN: Right.

24 CHAIRMAN WALLIS: Something like what you
25 did here.

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1 MR. ENDERLIN: Right.

2 CHAIRMAN WALLIS: Could be, could be.

3 DR. BANERJEE: Could be or they could
4 arrive at the same time.

5 MS. BUSHMAN: Yeah, the relative arrival
6 times are going to be a function not only of the
7 density but where they're dispersed within the pool
8 after, you know, compared to the sump screen when
9 recirculation is initiated.

10 DR. BANERJEE: So when you form this Nukon
11 which comes up the insulation, is the CalSil usually
12 associated with the same areas so that they fall into
13 the same area or widely disparate in terms of where it
14 goes in the pools and things like that?

15 MR. TREGONING: You're asking with respect
16 to plants, right?

17 DR. BANERJEE: Yeah, just an idea of what
18 happens in a plant.

19 MR. TREGONING: I can't answer that. I
20 mean, it's going to certainly be dependent on where
21 break location is and on the specific layout of
22 insulation where --

23 CHAIRMAN WALLIS: Do you see you're saying
24 it depends on all these things which you're not going
25 to know very well.

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1 DR. BANERJEE: But there's a distance,
2 right?

3 MR. TREGONING: Well, again, the plants
4 know their insulation layouts very well.

5 CHAIRMAN WALLIS: They don't know where
6 the break is and they don't know --

7 MEMBER DENNING: But they're down in that
8 suppression pool for awhile before you go into
9 circulation.

10 DR. BANERJEE: That's the point, are they
11 sort of mixed up in the suppression -- in the pool
12 area or are they going to be in widely different
13 areas?

14 MEMBER DENNING: The pool areas are fairly
15 similar areas. They enter the pool area in similar
16 draining areas, you know, I mean, CalSil was wiped out
17 by the same jet that wiped out the --

18 MR. ENDERLIN: Right.

19 MEMBER DENNING: -- primarily. There is
20 also spraying, of course, that produces some more --

21 DR. BANERJEE: Well, I guess Los Alamos
22 had some transport calculations and when you did those
23 transport calculations, did they arrive roughly at the
24 same time to the screens or widely disparate times?

25 MR. LETELLIER: You have to understand

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1 that the transport calculations were limited to CFD
2 computations of the fluid field and they were coupled
3 with experimental empirical results of the transport
4 initiation velocity. We've never actually modeled the
5 physical tumbling of debris products and it's very
6 dependent on where they're injected into the pool.
7 Whether it's a spray, containment spray cascade that
8 comes down a designed return path or whether it's
9 placed on the floor and pushed around by the fill-up
10 flows which are higher velocity.

11 CHAIRMAN WALLIS: Well, isn't it like no
12 one's going to ever be able to predict with must
13 confidence whether or not some CalSil gets their first
14 or some fibers get their first?

15 MR. LETELLIER: That's correct, and that's
16 one of the major reasons -- those uncertainties are
17 the reason that the regulatory guidance demands that
18 they assess a saturated thin bed condition, assuming
19 that the fibers arrive first and they're dominated by
20 a particulate loading thereafter.

21 CHAIRMAN WALLIS: But we had this
22 discussion a year ago or something. We had this
23 little piece of CalSil on the table here which as
24 enough to block the screen if you did it that way.

25 MR. LETELLIER: That's correct.

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1 DR. BANERJEE: The problem is that you can
2 always form a thin bed which would block everything.

3 CHAIRMAN WALLIS: You can always
4 hypothesize about it.

5 DR. BANERJEE: You know, some scenario
6 like that one.

7 MR. LETELLIER: That particular piece of
8 guidance has motivated the industry to over-design the
9 screen areas to both reduce their velocities, which
10 removes a head loss momentum effect and also to
11 prevent contiguous bed formation under their design
12 debris loadings. And the guidance --

13 DR. BANERJEE: Even at .01 you're getting
14 a very high particle loss.

15 CHAIRMAN WALLIS: A thousand inches of
16 water, whatever that is.

17 MR. LETELLIER: If the bed is contiguous
18 and if it's saturated.

19 CHAIRMAN WALLIS: Yeah, 40 psi or
20 something, what is it?

21 MR. ENDERLIN: 405 is an atmosphere for --
22 just off the top of my head I'm remembering here.

23 CHAIRMAN WALLIS: So it's something like
24 40 psi.

25 MR. ENDERLIN: Yeah.

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1 CHAIRMAN WALLIS: It's out of sight in
2 terms of MPSH and this is only .01 velocity.

3 MR. ENDERLIN: Just assume it's a plugged
4 bed. I mean, I'm not going to claim that that
5 measurement versus the velocity, I've had them --
6 we've had them shut it down for instrumentation
7 reasons and pump reasons.

8 DR. BANERJEE: Well, if the Nukon arrives
9 first, you've got other points at low velocities which
10 have quite significance, almost an atmosphere at 30
11 feet of water.

12 MR. ENDERLIN: Yeah.

13 CHAIRMAN WALLIS: We're getting all
14 excited over this. I just wanted to be sure that you
15 haven't done something which is so unrealistic, it's
16 never going to happen in the real sump.

17 MR. WHITNEY: Excuse me, Leon Whitney,
18 NRR. For a moment there we were talking about actual
19 configurations in plants, and I want to go over again
20 what we talked about yesterday with Oconee and their
21 pocket strainer with a design that inherently at very
22 low velocities will tend not to form a thin bed.

23 CHAIRMAN WALLIS: How much do you mean by
24 very low velocity? What do you mean by --

25 MR. WHITNEY: .01 or I mean .1 or so,

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1 velocities low enough where they don't lift the fibers
2 and the materials up to the top of the pocket.
3 Remember the pocket strainer design? You have a
4 chance not to form a thin bed on say one-quarter of
5 the surface of each pocket and again, that's depending
6 on -- you have to --

7 CHAIRMAN WALLIS: You don't lift the
8 fibers up onto the screen at all?

9 MR. WHITNEY: Excuse me?

10 CHAIRMAN WALLIS: You don't get the fibers
11 on the screen at all?

12 MR. WHITNEY: You get, in theory, fibers on
13 three-quarters say of this pocket but the -- if you
14 have a velocity low enough and the velocities are very
15 low and there's some theory it wouldn't lift to the top
16 of each pocket --

17 CHAIRMAN WALLIS: Okay, so then the rest
18 of the screen has no fibers on it.

19 MR. WHITNEY: This top portion of each
20 pocket potentially.

21 CHAIRMAN WALLIS: Has not fibers on it and
22 then they --

23 MR. WHITNEY: And they'd have to show that
24 through analysis. I'm just pointing out there are
25 screen designs that have the potential to have open

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1 spaces and not have -- you know, this vertical test
2 loop is a worse case design, recirculating through a
3 horizontal --

4 CHAIRMAN WALLIS: Yes, it is, it is. In
5 that case, we get more screen bypass and we have to
6 think about what happens to all the stuff that's going
7 to --

8 MR. WHITNEY: Then we're back to the
9 downstream issues.

10 MR. ARCHITZEL: I'd like to contradict my
11 colleague just a second here. It's sort of a similar
12 comment but the testing that we're observing and it's
13 similar but I wouldn't make Leon's comment about there
14 is no thin bed. We insist, you won't get any head
15 loss in that type of configuration where you have a
16 significant amount of open area in that screen. So
17 when these vendors do this testing for the thin bed
18 condition, they test until they get a thin bed, but by
19 the time they've gotten a thin bed over the entire
20 screen where you have these areas like don't have near
21 the coverage of the other areas, there are significant
22 portions of that screen that have thicker coverage.

23 So that during the actual test, they need
24 to test for the thin bed. When they've got the thin
25 bed, they've got significant areas of the screen that

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1 have much different thicknesses and the toleration for
2 head loss is much lower. So even in the case Leon's
3 talking about, CCI will get a thin bed coverage in the
4 upper portion of that screen but by the time they've
5 got that, they've got a lot of fiber at the base of
6 those screens.

7 CHAIRMAN WALLIS: That's why having a
8 vertical screen is a much better thing than having a
9 flat horizontal one.

10 MR. ARCHITZEL: Right, but they have to
11 test the thin bed. When they get that thin bed,
12 they've got at thin bed, but in order to get that,
13 they've got significant areas that have much more
14 carrying capability.

15 MR. TREGONING: Yeah, let's be clear.
16 We're trying to engineer uniform, as much as we can,
17 you know, very consistent well-deposited beds so that
18 we can use that to provide data to look at developing
19 these correlation models. You know, so we're trying
20 to engineer no bypass and things like that where sump
21 designers and licensees are trying to do exactly the
22 opposite. So we're approaching this problem from sort
23 of the opposite --

24 CHAIRMAN WALLIS: I think the problem is
25 going to be though, since there are a lot of

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1 imponderables and uncertainties, what kind of
2 assumptions are you going to allow in terms of
3 conservatisms and so on, and if you're going to say
4 you've got to have a thin bed, in fact, everywhere,
5 it's not going to work. So you can't just way we're
6 going to be conservative. You've got to have
7 something that's much more realistic and then the
8 question is, well, what's a proper judgment or how are
9 you going to evaluate how far you are from realism and
10 so on. It's very tricky.

11 MR. ENDERLIN: Yeah, I want to stress the
12 objective. I'm in no way saying this represents LOCA.
13 What I'm saying is, I had requirement 5 on my debris
14 bed. The question was, can I make a repeatable bed
15 and can I give you different scenarios. So the NRC
16 can go back and say, "We want this test condition",
17 and I'm saying, how you introduce the material makes
18 a difference and so give me the scenario from a
19 transport test that you may want to look at or the
20 bounding conditions. We feel we can to out there and
21 match those. So this was determined so that they can
22 make an evaluation of what do we do for that
23 requirement 5 and that can you ever put that material
24 on there? Do we need to pay attention to this? Yeah,
25 we can go way up there to high pressure drops.

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1 CHAIRMAN WALLIS: Well, we thought there
2 was a problem with these horizontal screens when we
3 looked at the data about a year ago. You have simply
4 made it more dramatic, extended our concern but it may
5 well be that this is not typical of a sump in any way.

6 MR. ENDERLIN: And I feel that these tests
7 allow me to explain the differences now created by 6E
8 and 6E-2. If I was asked to repeat those tests, I
9 would now be able to get repeatable tests by making
10 sure I --

11 CHAIRMAN WALLIS: Why did 6E-2 go zig-
12 zagging up though at almost constant velocity? That's
13 a --

14 MR. ENDERLIN: Are you looking at the
15 overhead or the Quick Look Reporter?

16 CHAIRMAN WALLIS: I'm sorry. Well, we
17 probably have to go on. You know, there are questions
18 of history that, you know, time, the time dependence
19 of things that --

20 MR. ENDERLIN: Yeah, and that's being
21 evaluated.

22 CHAIRMAN WALLIS: -- is not fully answered
23 by this business of --

24 MR. ENDERLIN: Right, and our current test
25 what we're finding is cycling is more important than

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1 the time. I mean, that's what we've seen to date so
2 far is that it's like shaking the bag of potato chips.
3 Every time that you compress a bed and let it go, did
4 I break the fiber at all and then when I compress it
5 again, did I allow CalSil to migrate down. So if I
6 keep shaking the bag by cycling, am I pushing CalSil
7 farther down and that's the reason, am I getting
8 higher pressure drops due to mass being added or by a
9 rearrangement of the bed?

10 MEMBER DENNING: Now, the cycling is
11 interesting. Now, do you think that the cycling has
12 an element of reality to the real system though?
13 You're saying if there are shaking going on, you're
14 thinking that's the equivalent of cycling?

15 MR. ENDERLIN: No, again, I'm trying to
16 look at do we get to steady state? The NRC is going
17 to have to guide me when they're all done saying,
18 "Here's a condition we want to run". I'm saying I can
19 cycle my tests. I see an effect. You can't turn
20 around and say when we go bench mark against ANL that
21 you can't pay attention to the flow history when you
22 compare two points. It may be that the industry is
23 going to turn these on, you're going to see a
24 velocity. There's no cycling; therefore, do you look
25 at ramp up 1, even though you made some addition, or

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1 do you do ramp up 2 and that's when you end the test?

2 We did these to try to say what's going to
3 happen for the purpose of being able to defend the
4 test and the results.

5 MR. TREGONING: So they're just looking at
6 bed compressibility effects as a function of velocity
7 differences. They're not meant to be representative
8 in any way of anything in the plant.

9 MEMBER DENNING: There is the question, to
10 be conservative would you go through a number of
11 cycles or wouldn't you, although I'm not saying
12 phenomenologically why you would --

13 MR. LETELLIER: There is no operational --
14 excuse me, there is no operational analogy to cycling.
15 In fact, these beds are largely non-adherent. If they
16 ramp the flow-down near zero it would literally fall
17 free.

18 MR. ENDERLIN: Right. And again, the
19 other task here was to be able to help define Series
20 2 test conditions, compare to LANL and see if we could
21 define the differences. If we look at my biggest
22 difference, it's in my first cycle, okay. So if I did
23 this test and that's all I showed and did ramp up 2,
24 we'd have a question, but when we begin to look at
25 ramp up 2 to 3, 3 to 4 and we move on, the question is

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1 now we see that there's an importance based on
2 building on the LANL test that we're not going to be
3 able to just maybe do this with ramp up 1 and down and
4 you're going to be done.

5 CHAIRMAN WALLIS: And in 6I, you ramped up
6 once and caught up to very high values on the first
7 ramp-up before it came down --

8 MR. ENDERLIN: Correct.

9 CHAIRMAN WALLIS: -- which is different
10 from this. I think we have a real problem here and
11 I'm trying to wrestle with it. The danger is that
12 you'll be told that this is so unrealistic, it should
13 be naught. It has nothing to do with sumps. But then
14 the question is, well, what is realistic for sumps?
15 Now, this is telling you something about how careful
16 you have to be in order to predict anything.

17 MR. ENDERLIN: And what parameters the
18 correlation must begin to include.

19 CHAIRMAN WALLIS: So it is valuable and
20 the question is, what are you going to do knowing all
21 this kind of stuff about an engineering situation?

22 DR. BANERJEE: That's a separate issue.

23 CHAIRMAN WALLIS: It's a separate issue
24 and it's not a very easy one at all.

25 DR. BANERJEE: The issue here is whether

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1 you can get reproducible data and try to understand
2 some of the parameters which govern --

3 MR. ENDERLIN: Right, and the test doesn't
4 start by saying, "Throw stuff on a screen". Someone
5 now has to start looking and investigating, defining
6 how does -- how will it get to the screen and what
7 variability exists in the different ways it can get to
8 the screen. I mean, there is an issue that if I'm
9 making these beds with a larger fiber that never can
10 be transported to the screen, we can eliminate those
11 conditions.

12 DR. BANERJEE: Yeah, you certainly
13 demonstrated that's important and the compressibility
14 is important because as you cycle more and more, you
15 get --

16 CHAIRMAN WALLIS: Well, the engineering
17 solution is probably to say, we don't care how it gets
18 to the screen. Once it gets there, we'll scrape it
19 off or something -- something that makes the problem
20 go away, that seems to be the way this is driving,
21 because there's so many uncertainties about trying to
22 predict what happens if we just have a static screen
23 and let things develop in some natural way. You have
24 to have some active thing which controls what happens
25 better.

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1 MEMBER DENNING: It's probably premature
2 to say that, Graham, because there are other
3 solutions, like there are ways that you can do
4 sacrificial screens where the first few screens get
5 clogged up and they go --

6 CHAIRMAN WALLIS: Okay, it's another
7 engineering solution. It's changing the way things
8 happen not just letting them happen but --

9 DR. BANERJEE: Well, in fact, to some
10 extent having these top hats in that area, you know,
11 some of those --

12 CHAIRMAN WALLIS: They'll just get clogged
13 up and then the others ones are all right. Yeah.

14 DR. BANERJEE: Who knows?

15 CHAIRMAN WALLIS: But a lot has to be
16 demonstrated somehow, presumably.

17 DR. BANERJEE: Yeah, maybe.

18 CHAIRMAN WALLIS: Well, it's certainly not
19 going to be predicted from fundamentals.

20 DR. BANERJEE: Stranger things have been
21 predicted.

22 MR. ENDERLIN: So that was an example
23 today and my understanding is you have the Quick Look
24 Reports. I'd be happy afterwards to discuss things
25 with you on the Quick Looks, but --

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1 CHAIRMAN WALLIS: The thing that -- we
2 haven't had any of this stuff sent to us until a week
3 or two ago from anybody, so this is the first time
4 we've looked at any of it. Can we -- is there some
5 way that we can be kept abreast of these things more
6 readily than --

7 DR. BANERJEE: On a continuing basis
8 maybe.

9 CHAIRMAN WALLIS: Well, we're not the NRC.
10 We don't want to review it all the time but it
11 shouldn't be such a long gap between seeing something
12 and then seeing something else.

13 DR. BANERJEE: When you get so much
14 information all together, it's really hard to digest
15 it.

16 MR. TREGONING: This is relatively fresh
17 information. I mean, this has been, you know, evolved
18 and developed over the last month or two. So it's not
19 like --

20 CHAIRMAN WALLIS: It is very fresh, so --

21 MR. ENDERLIN: Oh, the debris preparation
22 sequencing was not sent to Bill Krotiuk till the end
23 of January.

24 CHAIRMAN WALLIS: I didn't even know you
25 were doing experiments at PNNL.

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1 MR. KROTIUK: Yeah, we haven't even
2 finalized a Quick Look Report on the sequencing study.

3 MR. TREGONING: I know I should have
4 mentioned it last July at a minimum that we were
5 planning for these tests. I believe that I did, but
6 possibly I neglected to mention it.

7 CHAIRMAN WALLIS: Quite likely we didn't
8 listen.

9 MR. ENDERLIN: So you're telling us we're
10 the illegitimate child at the family reunion.

11 MR. TREGONING: I have a hard time
12 believing that.

13 CHAIRMAN WALLIS: Well, we have so much
14 stuff that we have to listen to. Okay, so go ahead.

15 MR. ENDERLIN: Okay, so now let's assume
16 that we've retrieved a bed. These are additional
17 measurements we take. We're taking detailed
18 dimensions of retrieved wet rebed so I cannot stop the
19 flow, as Bruce said, and retrieve my bed. I must
20 continue to allow the flow to go through the bed so
21 that I retrieve the bed when it in error.

22 We take -- well, as soon as we get it
23 there, so the bed is drained. It has whatever
24 residual water is in it and detail it. The debris bed
25 is dried to obtain the final bed mass on the screen so

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1 we know what went in that was dry masses, that was put
2 into the loop and we know what we retrieved on the bed
3 and one of the things we evaluate is the percent dried
4 material. That's for the total mass. In situ bed
5 topography, we've taken a picture of all the test
6 conditions, then we go in there and start to evaluate
7 those and what we try to do is evaluate, say at when
8 you initially make the bed and you've said the bed's
9 formed at the end of the first ramp up and then you'll
10 do it at the end of your last ramp-up at the end of
11 your last ramp-down.

12 So you can go and analyze the data, but
13 we're first trying to determine is there a change in
14 the function of ramping up in velocity and is there a
15 change in bed dimensions based no cycling. Again,
16 these dimensions are in situ under flow. And I'll
17 explain that in a little more detail for that method.
18 The mass fraction of CalSil assessed by a chemical
19 dissolution, that process is not finalized but what
20 we're using is ion selective electrode probe for
21 calcium and trying to evaluate by dissolving the bed
22 after we're retrieved it.

23 So one issue that comes up is I can't
24 section a bed that I'm going to assess CalSil in. But
25 when we're all done, if I put in 200 grams, I get out

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1 180 grams, I put 100 Nukon, 100 CalSil, by mass, my
2 uncertainty in the CalSil is 80 to 100 grams.

3 CHAIRMAN WALLIS: Can't you cut cuts of
4 pie slices and use each one for different evaluations?

5 MR. ENDERLIN: Well, the other option is
6 we can use SEM to try to -- we need to determine if we
7 can do that because of the many constituents in CalSil
8 when we took our first example over, it just becomes
9 somewhat costly for that analysis. This may be a
10 cheaper analysis.

11 CHAIRMAN WALLIS: But even optical
12 methods, if you section it, should tell you quite a
13 lot.

14 MR. ENDERLIN: Yes, using TEM and we have
15 some people who do diagnostic bolzman (phonetic) work
16 on filters and stuff and they have some methods. That
17 is an option. I'll talk about that in a minute.

18 So again, trying to get the mass fraction
19 of the CalSil is basically a separation process is
20 what we're looking at doing when we're retrieve the
21 bed. Sectioning of the dried retrieved bed allows
22 for transmission of electronic microscopy and scanning
23 electron analysis, we can look at the bed void
24 fraction as a function of height. We can look at the
25 constituents. It can also allow a scan down the road

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1 if people are looking to model these, that direct scan
2 using a Gray scale that they use can help generate bed
3 models.

4 DR. BANERJEE: But you'd need a 3D
5 structure.

6 MR. ENDERLIN: Yeah, and we can do that.
7 Yeah, in fact, while we're talking, now this is not a
8 bed that's been polished for SEM. This just gives you
9 an example, okay. And these beds were beds that were
10 sent over and there was a process had to be worked on
11 because if you do some of the samples that way they
12 did, you'd actually explode the bed, okay. So they
13 had to work to get that impregnated with the epoxy and
14 the bed has to be dried. So we know that the bed
15 dimensions are going to change some after you pull it
16 out and I'll show you just how radical or how much
17 that's been under-flow and then you have to dry it
18 before you can do this. Okay, as you dry it, there's
19 no way to evenly dry this.

20 Just as if you are drying felt, you will
21 start to get some lifting at the edges. Once that's
22 done and they impregnate it, I can cut this thing up
23 into very thin slices. I mean the piece that they're
24 actually going to analyze is a very small one. But
25 this is just an example of a bed and that's not

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1 necessarily the final process we use today for
2 impregnating it with epoxy.

3 DR. BANERJEE: So you get the
4 configuration for a dried bed. So somebody wants to
5 do some flow through these dry beds, would have to
6 reconstitute it in some way into a --

7 MR. ENDERLIN: We'd have to consider the
8 in situ measurements because we know it's not going to
9 have that height any more either but at least the
10 ratio of constituents should still be preserved.

11 DR. BANERJEE: And probably something
12 about the topography, what is fiber, what is particle.

13 MR. ENDERLIN: Yes.

14 DR. BANERJEE: And then it has to be
15 reconstituted.

16 CHAIRMAN WALLIS: Well, can't you cut it
17 up under water and look at it?

18 MR. ENDERLIN: We have tried that. Due t
19 the fibrous nature so far, we've even -- I mean, the
20 only way we know --

21 CHAIRMAN WALLIS: You don't have a sharp
22 enough knife.

23 MR. ENDERLIN: You still get distortion at
24 the part you're trying to look at. There was talk of
25 trying to do it with a laser but that winds up

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1 creating a drying process. We've been to numerous
2 people who make their living doing sectioning and
3 stuff and this, they found to be a very challenging
4 problem that they were not able to provide a
5 successful answer to yet.

6 CHAIRMAN WALLIS: I guess --

7 MR. ENDERLIN: So if you have any, we're
8 more than interested.

9 DR. BANERJEE: you would hope that some
10 form of tomography would do it, but it's not easy to
11 see how it's done. What's the molecular weight of
12 this stuff? It's fairly --

13 MR. ENDERLIN: I believe the CalSil is on
14 the order of -- we'll it's not a homogeneous material
15 but I think it's on the order of 2.6 and what is the
16 Nukon? It's fiberglass.

17 DR. BANERJEE: I think they have high atom
18 numbers so they would contrast with water again in a
19 gamma --

20 MR. ENDERLIN: Yes, the question is if you
21 take the velocity off that bed and you put it in
22 water, if I take a bed and retrieve it and I leave it
23 in water, you wind up with oatmeal. This stuff will
24 not stay together very well.

25 DR. BANERJEE: So it has to be actually

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1 done in situ.

2 MR. ENDERLIN: Yes, yeah.

3 DR. BANERJEE: So you can't actually take
4 it in water and --

5 MR. ENDERLIN: We've tried for the purpose
6 of doing topography actually rehydrating a bed, even
7 transporting a bed before you dry it out. We're
8 talking extremely challenging to move this thing to
9 the next building. If you take it and leave --

10 CHAIRMAN WALLIS: Well, I'm still -- as an
11 engineer, why would I want to do all of this stuff?
12 You're examining this as if it was the most important
13 scientific discovery of the ages and do we really need
14 to know all this stuff?

15 MR. TREGONING: Well, sectioning is --
16 well, if we want to try to understand what happens
17 with these big pressure differences, understanding
18 what the particulate distribution throughout the bed
19 is, is incredibly critical to understand it.

20 DR. BANERJEE: Where the holes are and
21 where the particles are, I guess. I mean, maybe it's
22 not a huge effort but I think it's worth doing.

23 CHAIRMAN WALLIS: But you're trying to
24 understand at the level of detail, you're never going
25 to be able to predict in the reality.

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1 DR. BANERJEE: It's not out of the
2 question. I mean, you won't do it over the whole bed
3 but for small sections of the bed, you might.

4 MR. TREGONING: So you're recommending --

5 CHAIRMAN WALLIS: So how many resources
6 are you going to put into this effort to get a perfect
7 solution to this intractable problem?

8 DR. BANERJEE: Whether you use a clever
9 design or not, you know, for example, these rocket
10 cleaners or whatever they're called, you really do
11 have to calculate what's happening if you're bypassing
12 or whatever. You're going to have to be able to do
13 that calculation, so you're going to have to be able
14 to see where those fibers are going in rough terms at
15 least; otherwise there are going to be arguments like
16 the one that's going on. Is there going to be a thin
17 film, is there not going to be a thin film? Is there
18 going to be particles?

19 I think you can do some calculations at
20 least to support those arguments. At the moment,
21 they're all hand waving, you know, and the parameter
22 space is so large that you're going to eventually have
23 to do some calculations.

24 CHAIRMAN WALLIS: I would go back and try
25 to change the problem, but anyway, let's move on here.

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1 DR. BANERJEE: That's a separate issue.
2 Throw the water away, put some new water in.

3 CHAIRMAN WALLIS: Yeah. Anyway, let's
4 move on.

5 MR. ENDERLIN: So, to take a topography of
6 the bed in situ, to take dimensions, we basically use
7 a optical triangulation, put a known grid of lines on
8 it that's been calibrated against a standard. Take
9 the digital picture which we can analyze, post-test.
10 These are some measurements that we got. The BF
11 stands for nearing bed formation, so that's not a
12 complete made bed. It was -- this was the first time
13 -- we'd done shake-down testing. This was basically
14 the first official test and so as an example, what
15 we've tried to show is just what the height of the rim
16 is, initially, after material gets -- before we've
17 increased the flow or we've left it there fore very
18 long a period.

19 So as you can see on the rim at bed
20 formation, we've got something that's .635 inches.
21 Now, Ramp up 1 says --

22 CHAIRMAN WALLIS: RU 1 is Ramp up 1.

23 MR. ENDERLIN: This is -- the value here
24 is the velocity in feet per second. So at bed
25 formation, I'm at .18 feet per second at the time the

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1 picture was taken, .98, .96 and .05 feet per second.
2 So this tells you your velocity and this tells you the
3 sequence at which we ran the test. So this is Ramp up
4 1.

5 You've gone up -- that previous test
6 you've gone through the velocity sequence once. Okay,
7 the body of the center of the bed went from .307 to
8 .055 inches so it compressed quite a bit. Then when
9 we cycle it four time and compare at the same velocity
10 only a flow history where we cycled it four times, we
11 see that the rim is .281 and the body center is .04.

12 CHAIRMAN WALLIS: Is smaller, yeah. Then
13 when you come back, it springs back?

14 MR. ENDERLIN: Yes.

15 DR. BANERJEE: But not all the way, right?

16 MR. ENDERLIN: Well, I don't have the
17 comparison data here for this test. That hasn't been
18 analyzed at the moment.

19 CHAIRMAN WALLIS: Oh.

20 MR. ENDERLIN: I can't tell you at the
21 exact time I made the bed, when I culled the bed.

22 CHAIRMAN WALLIS: This is the same test
23 and then you've backed off of -- RD4 means Ramp down
24 4.

25 MR. ENDERLIN: Right.

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1 CHAIRMAN WALLIS: And you've gone down to
2 a low velocity and it sprung back to .129 from .04 at
3 one time.

4 MR. ENDERLIN: Right.

5 DR. BANERJEE: Well, from .307 at a low
6 velocity.

7 MR. ENDERLIN: But don't consider that we
8 assume the bed was completely made at .307. This
9 occurs right here when the material first hits. At
10 the time of flow it would sit there at compress.

11 CHAIRMAN WALLIS: Well, it seems to me
12 never completely made. You can keep cycling and it
13 still changes a little bit each time, doesn't it?

14 MR. ENDERLIN: Correct.

15 CHAIRMAN WALLIS: It's never completely
16 made.

17 MR. ENDERLIN: Well, that's the question.
18 Is material passing through, are we changing the
19 structure of the bed? And from this we can take the
20 volume of the bed, which helps us get a porosity for
21 these correlations.

22 CHAIRMAN WALLIS: Now, lots of your Quick
23 Look Reports don't report thicknesses very much, do
24 they?

25 MR. ENDERLIN: They report manual

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1 measurements. We've done a test of 1A which the Quick
2 Look has just been sent to Bill Krotiuk. It was a
3 repeat test. That is what these measurements are from
4 and the head loss measurements in the first two ramp
5 downs -- ramp up and ramp downs were on the order of
6 .2 to .3 percent difference in head loss. When we
7 went to the higher -- to follow-on ramp ups and ramp
8 downs, we began to deviate to differences on the order
9 of 12 percent. If we take all our data points, the
10 median and the mean percent difference between 1A and
11 1A repeat was on the order of five to six percent and
12 that Quick Look the NRC will be passing that to you
13 after Bill Krotiuk has had a chance to review it some
14 time.

15 Okay, prior to doing Series 2 which are
16 tests that at the moment my understanding is to go to
17 the perforated plate and to be looking at lower
18 velocities. This is more looking towards what the
19 utility solutions are so that we're getting data for
20 Bill's test matrix. Issues that we have to determine
21 are debris loading sequence, procedure to be used,
22 selected to find how we're going to put the material
23 in there, how are we expecting -- you know, what
24 debris bed does he want to evaluate there.

25 What we've tried to show is, yes, it makes

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1 a difference. These are the parameters that make a
2 difference. Yes, we can control it, and we can get
3 repeatable data. Now tell us what do you want to
4 test.

5 The velocity sequence procedure gearing to
6 be selected, defined. Okay, the test we did was to
7 try -- when we went through the first ramp-up and
8 ramp-down, we obviously saw most of the tests were
9 well over pressures of interest. We don't expect in
10 Series 2 to be going over an atmosphere pressure and
11 the question is, what are we going to use for
12 comparable data. If we compare to ANL, are we going
13 to second ramp up? Do we need to do as many
14 incremental velocity, since the trend seems to be the
15 same? So the sequence of the test needs to be
16 determined.

17 CHAIRMAN WALLIS: It will be interesting
18 to see if somebody following your procedures with leaf
19 choppers and blenders and all of that kind of thing
20 independently from somewhere else all together --

21 MR. ENDERLIN: We're going to do that.

22 CHAIRMAN WALLIS: -- could duplicate your
23 results.

24 MR. ENDERLIN: ANL and --

25 CHAIRMAN WALLIS: They're going to do

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1 that?

2 MR. ENDERLIN: Yeah.

3 CHAIRMAN WALLIS: They're going to use the
4 same blender with the same sharpened blades and --

5 MR. ENDERLIN: No, they're going to use
6 the same R4 metric.

7 CHAIRMAN WALLIS: Oh, the same R4 metric,
8 okay.

9 MR. TREGONING: That's one of the purposes
10 of the bench mark test, the overlap test.

11 MR. ENDERLIN: In summary, the Series 1
12 tests are completed. They used the five-mesh screen.
13 The purposes were to use them for learning the results
14 we might expect and to evaluate these additional
15 parameters, identify since the LANL tests were
16 completed, and to get comparison results to LANL --
17 results to compare to LANL to determine if we could
18 understand if they were the same or if we could
19 explain the differences.

20 Results obtained to date, the debris
21 preparation and the sequence that the debris arrives
22 or is loaded on the screen strongly influenced the
23 head loss. Additional investigation is currently in
24 progress. The next large scale testing is the bench
25 mark test to be conducted by LANL and PNNL using the

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1 same test plan. Series 2 test, the test matrix is
2 currently preliminary. It includes the bench mark,
3 the three cases in the bench mark test. It will focus
4 on perforated plate and lower approach velocity.

5 I turn it back over to --

6 CHAIRMAN WALLIS: Did you guys and Argonne
7 have a plan which said by some date you would have a
8 predictive method or is this completely open-ended
9 research with no time line at all?

10 MR. KROTIUK: That was what I was going to
11 talk to.

12 CHAIRMAN WALLIS: Okay, thank you.

13 MR. KROTIUK: The next topic is head loss
14 modeling.

15 CHAIRMAN WALLIS: I think we ought to
16 stick with it and try to close up before too late.

17 MR. KROTIUK: I'll try to accelerate a
18 little bit.

19 CHAIRMAN WALLIS: Fine, because I looked
20 at all your equations in your report and I thought
21 this is very interesting but given the data --

22 MR. KROTIUK: Yeah, I was going to try to
23 address that but you know --

24 MR. TREGONING: So we're back to slide 9
25 of the previous package, just to keep track.

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1 CHAIRMAN WALLIS: Now you see you've got
2 this to conservatively predict.

3 MR. KROTIUK: Well, let me explain what my
4 thoughts are and you may have some inputs in that but
5 I'll tell you what I'm thinking as I'm going along.
6 But I will try to accelerate a little bit. I don't
7 think I necessarily have to go through this. I'll
8 just --

9 CHAIRMAN WALLIS: But you say your
10 objective is to conservatively predict.

11 MR. KROTIUK: Right.

12 CHAIRMAN WALLIS: Does that mean only the
13 worst case?

14 MR. KROTIUK: That's -- when Carl was
15 talking a moment ago about what we would be testing,
16 in other words, how would we build the bed, that was
17 one of the things and we haven't come to a conclusion
18 how we're going to do that. However, I have some
19 thoughts and I'll just go over it quickly on how to be
20 able to put in a model prediction of a conservative
21 limit but that will have to be reviewed.

22 I'll skip this one, it's just motivation.
23 Okay, yeah, I'll start here. Basically, what I've
24 done is that I want to base the amounts on the
25 classical form of the porous media flow equation. And

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1 basically, I'm working on two models. One is a one --
2 has a one control volume model for the entire bed. So
3 this is essentially equivalent to what was previously
4 done in the 6224 correlation and it's assuming
5 everything is, as I said, homogeneous. The second
6 approach that I'm looking at using a bed that has two
7 control volumes and I could look at the concentration.
8 Say we have a Nukon CalSil bed. I would be able to
9 look and specify what the concentration is of say
10 CalSil and a portion of it and it could be different
11 than another part and then try to use that to come up
12 with a predictive tool.

13 CHAIRMAN WALLIS: You're going to be able
14 to do an experiment to verify that?

15 MR. KROTIUK: Well, what I was hoping to
16 do and this is why I asked Carl for these tests that
17 were done with the sequencing, the timing of the
18 CalSil and the Nukon and addition to the bed. I want
19 him to -- I have given him instructions to come up
20 with the sectioning of those so I could see what the
21 distribution is and try to get some insight into that.

22 CHAIRMAN WALLIS: It looks from his data
23 that if you get the worst case, the layer which is
24 almost impermeable --

25 MR. KROTIUK: Right.

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1 CHAIRMAN WALLIS: -- then the rest of the
2 bed is irrelevant.

3 MR. KROTIUK: That's true but some of the
4 thoughts in the back of my mind is, is that as you
5 were saying, is that how realistic is their case and
6 should we be looking at a case that is conservative
7 but more realistic.

8 CHAIRMAN WALLIS: Well, let's think about
9 it. This thin bed effect was discovered as a result
10 of analyzing an event in a PWR, wasn't it?

11 MR. KROTIUK: I'm not -- was it a PWR?

12 CHAIRMAN WALLIS: Yeah, they were BWR.
13 Nothing significant happened in the PWR in terms of
14 this sort of problem as I understand. These events
15 were in BWR.

16 MR. KROTIUK: Right, okay.

17 CHAIRMAN WALLIS: And the pressure drop
18 was higher than expected. This is because of the
19 sludge and the torres (phonetic) or something which
20 actually made a thin -- but this is where the thin bed
21 idea came from, isn't it?

22 DR. BANERJEE: And the screens were bent
23 or something.

24 CHAIRMAN WALLIS: We have at least
25 precedent in a real system of finding a thin bed

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1 effect.

2 MR. KROTIUK: Right, and I'm not -- the
3 only thing I'm trying to say is that as I said before,
4 it's a phenomena but it's not --

5 CHAIRMAN WALLIS: In terms of was it
6 realistic or not, we have already seen --

7 MR. KROTIUK: Yes, yes, and I'm not
8 denying that.

9 CHAIRMAN WALLIS: All right, so that's
10 pause for thought, too.

11 MR. KROTIUK: Right.

12 CHAIRMAN WALLIS: You can't just dismiss
13 it as being --

14 MR. KROTIUK: No, I am not dismissing it
15 and I'm just telling you what -- what I was eluding to
16 was my thought process.

17 CHAIRMAN WALLIS: When I say "you" I mean,
18 a person -- one cannot.

19 MR. KROTIUK: Okay, one cannot. Okay. My
20 plans at this point is to try to finish the derivation
21 and development of a model by June with a final
22 publication in September. That's what my plans are.
23 Okay, let me just go a little bit about the
24 development of the model. And basically I used --
25 it's described more --

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1 CHAIRMAN WALLIS: This is -- the LANL work
2 uses a slightly different one which is for fibers
3 rather than particles, I think.

4 MR. KROTIUK: Well, actually the model
5 that I'm using is applicable to fiber cylinders or
6 particles. And maybe I'll just skip to the -- just to
7 show it in this term.

8 CHAIRMAN WALLIS: The power is slightly
9 different in the fibers case.

10 MR. KROTIUK: This, if you look at this
11 term here and this term here and then these terms here
12 without the 6, that's the classical form of an Ergun
13 equation.

14 CHAIRMAN WALLIS: Now, I think in these
15 low velocities, the kind of data -- stuff you're
16 getting the viscous term is the denominator (phonetic) of
17 one.

18 MR. KROTIUK: For the very low velocity,
19 that's true but I have the kinetic term in there also.
20 And --

21 CHAIRMAN WALLIS: It makes some of the
22 analysis easier.

23 MR. KROTIUK: Yes. The -- what I've done,
24 though, is to try to -- I have this non-dimensional
25 permeability here which really provides a -- in

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1 essence, it's a modification to the specific surface
2 area. It's a way of trying to modify it and say as a
3 function of void ratio, which is really related to
4 porosity and all. It's how that -- what -- how you
5 could determine what that change in that S_v really is
6 and that's similar to this term over here for the
7 kinetic term.

8 CHAIRMAN WALLIS: I think you have a
9 problem in that you don't know S_v and X independently.
10 They both come from pressure drop data. There's no
11 sort of independent way of measuring them.

12 DR. BANERJEE: Unless you take sections.

13 CHAIRMAN WALLIS: Well, even then, you
14 have to infer them from the pressure drop data because
15 S_v isn't measured independently. If you just take
16 particle size distribution, you don't get a very good
17 value, you get it from the pressure drop.

18 MR. KROTIUK: Right, S_v cannot be
19 determined theoretically. It's really a function of
20 your experiments.

21 DR. BANERJEE: But then it just becomes a
22 fitting parameter if you can't go and look at the data
23 that you might get and find the surface area from
24 that.

25 CHAIRMAN WALLIS: Ralph, are we -- okay.

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1 MR. KROTIUK: I agree with what you're
2 saying but I didn't include all my --

3 DR. BANERJEE: That could be a physical
4 thing.

5 MR. KROTIUK: Sv?

6 DR. BANERJEE: Yeah, in other words,
7 otherwise it's just a fitting parameter.

8 MR. KROTIUK: It's -- yeah, but I'm trying
9 not to treat it as a fitting parameter. What I'm
10 trying to say is to keep the Sv constant but there is
11 a multiplier for the Sv which is in this factor here
12 which is the dimensions permeability which is a
13 function of whether the particles are -- whether the
14 porous beds is particles or the porous bed is fibers,
15 there's --

16 DR. BANERJEE: Sure, I mean, x is a
17 measure of that.

18 MR. KROTIUK: X is a measure of that but
19 K also has a function to it.

20 DR. BANERJEE: Right.

21 MR. KROTIUK: And you have to determine --

22 DR. BANERJEE: K is a function of X.

23 MR. KROTIUK: It's a function of the --

24 DR. BANERJEE: The rod to the particle.

25 MR. KROTIUK: It's a function of some

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1 relationship of the particles or relationship to the
2 fibers.

3 DR. BANERJEE: It has to be a universal
4 function to be useful though.

5 MR. KROTIUK: It's a universal function
6 for all particles or all fibers in a certain
7 orientation.

8 CHAIRMAN WALLIS: So the way you define
9 it, as the bed is compressed it changes.

10 MR. KROTIUK: As the bed is compressed
11 that's changing, correct. That is correct, and in my
12 original derivation, I actually have a graph of this
13 KX as a function of porosity.

14 DR. BANERJEE: It's like a Darcy
15 permeability except your --

16 MR. KROTIUK: It's related very -- yes,
17 and that's what I was trying to say. I skipped over
18 it very quickly but I was trying to say I used a
19 Kozeny-Carman equation to relate to permeability,
20 velocity and the debris surface area and then you come
21 up with this non-dimensional parameter.

22 MR. LETELLIER: You still basically have
23 two free parameters, Sv and Epsilon because K(X) is
24 inherently a function of Epsilon given a specific
25 geometry. You still only have two free parameters in

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1 the model. Is that correct?

2 MR. KROTIUK: Yeah, that's correct.

3 DR. BANERJEE: Yeah, but you can achieve
4 the same Epsilon with different --

5 MR. LETELLIER: Configurations.

6 DR. BANERJEE: X, yeah.

7 MR. LETELLIER: Yes.

8 CHAIRMAN WALLIS: Now, this is a pressure
9 gradient, isn't it? Isn't this a pressure gradient
10 you're talking about here?

11 MR. KROTIUK: Yes.

12 CHAIRMAN WALLIS: Because the
13 compressibility is different in different parts of the
14 bed. The compression is different.

15 DR. BANERJEE: This is Darcey's equation.

16 CHAIRMAN WALLIS: The PTL it shouldn't be
17 the P over L, it should be PTL, that's the basic
18 equation.

19 MR. KROTIUK: You're right.

20 CHAIRMAN WALLIS: And as you compress it,
21 these parameters on the right side integrate through
22 the bed.

23 MR. KROTIUK: Right, and that's why I'm
24 trying to look at multiple thicknesses.

25 CHAIRMAN WALLIS: When you use PTL you get

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1 in all kinds of trouble.

2 MR. KROTIUK: Right, okay. This is the
3 hydraulic portion and I just put it this way but,
4 you're right. Now, what I did, I looked at the CalSil
5 and the Nukon and I just used that equation to come up
6 with an equation that includes both the KX for Nukon
7 which is for fibers and like I say, the KX, the
8 permeability factor for CalSil, which is particles.
9 And this is what I kind of derived.

10 CHAIRMAN WALLIS: You didn't have to deal
11 with the inertia part. It would be a lot simpler.
12 You have a linear thing in velocity and you wouldn't
13 have these weird 0.071 powers and things.

14 MR. KROTIUK: Right, that's --

15 DR. BANERJEE: But even leaving -- yeah,
16 you probably should kill the inertia part but that's
17 a separate issue. The X's though, I mean, the way you
18 defined X was the volume fraction of -- I forget --

19 MR. KROTIUK: To the void.

20 CHAIRMAN WALLIS: The void is changing as
21 you --

22 DR. BANERJEE: Rods, to -- so Nukon is
23 something or the other.

24 MR. KROTIUK: So it's really the volume of
25 the -- the void to the volume of the solid.

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1 CHAIRMAN WALLIS: Right, which could never
2 be more than a certain amount if it's packed solid.

3 MR. KROTIUK: Yeah, but as you compress,
4 it could change.

5 DR. BANERJEE: But the volume of the solid
6 has rods and cylinders, right? Are you going to
7 differentiate between them or not?

8 MR. KROTIUK: That's why I did this, is I
9 had a different -- this is the equation -- the is the
10 permeability -- the dimension permeability equation
11 for the cylinder portion and this is for the particle
12 portion.

13 CHAIRMAN WALLIS: What do you do with the
14 calcium phosphate?

15 MR. KROTIUK: I'm not addressing that
16 right now.

17 CHAIRMAN WALLIS: Presumably that's
18 another term or another factor or something in here.

19 MR. KROTIUK: That would have to be.

20 DR. BANERJEE: So you're getting two
21 different K functions?

22 MR. KROTIUK: That's correct because
23 that's a function of geometry.

24 CHAIRMAN WALLIS: So it's like a PhD
25 thesis?

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1 MR. KROTIUK: Excuse me?

2 CHAIRMAN WALLIS: So it's like a PhD
3 thesis.

4 MR. KROTIUK: It was work done -- I'll
5 just say it and then you could -- I have references in
6 what I handed out. An individual called Happel
7 actually did -- had his thesis on this subject and he
8 actually came up with these permeability relations and
9 it came out of his thesis.

10 DR. BANERJEE: He did cylinders and --

11 MR. KROTIUK: He did cylinders along the
12 direction of flow, cylinders across, you know, and
13 spheres.

14 DR. BANERJEE: But all mixed together?

15 MR. KROTIUK: No, he did them separately.

16 DR. BANERJEE: That's different.

17 MR. KROTIUK: Yeah, but I'm trying to
18 relate them and put them into one equation.

19 CHAIRMAN WALLIS: Oh, I like this figure.

20 MR. KROTIUK: Okay, let's talk about the
21 compression and as we said earlier, hysteresis has
22 been observed. Now, what I've done is I've taken the
23 approach -- you know, we have this velocity going up
24 and then coming down. There is a recognition that,
25 you know, it's a complicated phenomena so I made the

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1 simplification that during the first velocity
2 increase, you have a non-recoverable, irreversible
3 process and all subsequent compressions or expansions
4 of the debris bed would be a irrever -- an elastic
5 process after that with a constant compressibility.
6 Now, that's what I've done at this point in time.

7 That's my assumption. So using that
8 assumption you come up with basically two
9 relationships. One is for the first compression where
10 you calculate your void ratio as a function of your
11 mechanical stress on a section of the debris bed.
12 Which could be the entire bed in my one volume model
13 or could be part of the bed in a multi-volume model
14 and you relate that to the mechanical stress at the
15 start of compression --

16 CHAIRMAN WALLIS: Is this just what's
17 available in the pore of the fiberglass? Is that all
18 that is?

19 MR. KROTIUK: I'm sorry say again?

20 CHAIRMAN WALLIS: This is what's available
21 in the pores of the fiberglass?

22 MR. KROTIUK: Essentially, yes.

23 CHAIRMAN WALLIS: Because it says nothing
24 about the CalSil yet.

25 MR. KROTIUK: Well, this relationship is

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1 really -- I've applied it to both the Calsil and the
2 Nukon both. Basically, I'm saying that during the
3 first compression I can calculate the void ratio based
4 on the void ratio at some starting point and the
5 mechanical stress across the debris bed at that
6 starting point.

7 CHAIRMAN WALLIS: It's just like the
8 length over the original length in a way, isn't it?
9 Isn't it related to just the strain, the length over
10 the --

11 MR. KROTIUK: Oh, yes, yeah.

12 CHAIRMAN WALLIS: So isn't it a simple
13 transformation from the strain to X over X prime?

14 MR. LETELLIER: He hasn't derived it that
15 way. In essence it would be.

16 CHAIRMAN WALLIS: I would be.

17 MR. LETELLIER: He has a decaying spring
18 constant to account for the --

19 MR. KROTIUK: And it's related with the --
20 the parameter N is really the material specific
21 parameter, which I would try to get from the test
22 data. And then after the first compression when you
23 have the elastic portion, the relationship comes out
24 in this fashion. You are now relating your void ratio
25 in the section of the debris bed to the maximum

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1 mechanic stress at the highest velocity point.

2 And again, the factor of N is again in
3 there and looking at say the LANL series 6 data, I
4 came up with an invalid of about .3 and a -- somewhere
5 I'm getting around .2 to --

6 CHAIRMAN WALLIS: These are the typical
7 values from bed compression here, aren't they? It's
8 just compression without any particles at all to get
9 something like this.

10 MR. KROTIUK: Oh, yeah, right, you're
11 right, yeah, something of that nature but so then this
12 way when I do the calculations, what I'm doing is I'm
13 solving the hydraulic portion for a period of time and
14 then for a given point in time and then looking at
15 where I am, whether it's the first compression or one
16 of the -- after the first compression from the elastic
17 portion, and I do an iterative calculation between the
18 hydraulic conditions and the compression conditions
19 and you could come up with a final bed thickness.

20 CHAIRMAN WALLIS: And P is the pressure
21 drop or something? What's this PM?

22 MR. KROTIUK: You can -- the derivation to
23 P which is mechanical stress, is actually equal to the
24 pressure drop across that section of the debris bed or
25 the entire debris bed if you're taking it as a

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1 homogeneous bed. So you could actually --

2 DR. BANERJEE: It's basically the same
3 type of model. It's the total force.

4 CHAIRMAN WALLIS: Yeah, that's right,
5 that's what it should be.

6 MR. KROTIUK: It's the force, yeah.

7 CHAIRMAN WALLIS: The strain is
8 proportional to stress or is not proportional to this
9 N index. Strain is related to stress, not stress
10 gradient.

11 DR. BANERJEE: Not gradient, yeah.

12 CHAIRMAN WALLIS: So then you've got a
13 correlation of some sort.

14 MR. KROTIUK: Yeah, and I just wanted to
15 show you, like this is for the LANL Series6 data and
16 I actually --

17 CHAIRMAN WALLIS: I'm surprised you got --
18 I did something similar I think, you find and I
19 actually put in the --

20 MR. KROTIUK: Yeah, you did something very
21 similar, yes.

22 CHAIRMAN WALLIS: -- put in different
23 symbols for different tests, which can perhaps tell
24 you something.

25 MR. KROTIUK: Yeah, I've done this -- I've

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1 plotted this a number of ways and I actually have
2 plots with all the different tests separated out.

3 CHAIRMAN WALLIS: But my curve went
4 through all the data.

5 MR. KROTIUK: Excuse me?

6 CHAIRMAN WALLIS: Yours seems to scatter
7 more, that's all -- but that's another matter all
8 together.

9 MR. KROTIUK: But like, you know, this is
10 the point -- this is with the .23 and then there's
11 these outlying points which are test --

12 CHAIRMAN WALLIS: A lot of your scatter is
13 artificial. If you look at what they did, they could
14 only measure to a certain -- a quarter of an inch or
15 something accuracy. So the data went in steps and if
16 you actually plot the steps instead of the points, the
17 steps sort of covered the correlation.

18 MR. KROTIUK: That's a good point.

19 CHAIRMAN WALLIS: It looks much better
20 than if you just show this like this, it ignores that
21 fact that they couldn't measure accurately, so they go
22 in steps.

23 MR. KROTIUK: Yeah, that's a good point.
24 I'll replot it as that.

25 Then I needed that starting point, in

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1 other words, the bed thickness at that starting point.

2 CHAIRMAN WALLIS: It's just some reference
3 thickness.

4 MR. KROTIUK: Right, some reference
5 thickness but I tried to relate it to again, this is
6 the Series 6 data.

7 CHAIRMAN WALLIS: I presume it's
8 proportional to the amount of fiberglass.

9 MR. KROTIUK: Exactly, that's what
10 happened. There was only one point --

11 CHAIRMAN WALLIS: So you might as well use
12 kilogram per meter squared.

13 MR. KROTIUK: That's what I'm doing,
14 kilogram per meter --

15 CHAIRMAN WALLIS: Because that's a better
16 measurement than undetermined thickness.

17 MR. KROTIUK: Right.

18 CHAIRMAN WALLIS: In fact, since you've
19 got P over PM to some power, the prediction is that
20 with no stress on the bed, it's infinitely thick,
21 which doesn't really help you very much. So it's much
22 better to refer to some kilogram per square meter. Do
23 you see what I mean?

24 MR. KROTIUK: Yeah, I see what you mean.

25 CHAIRMAN WALLIS: Because it's a

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1 horizontal bed. There's nothing to compress it before
2 you've got any pressure and it's infinitely thick
3 until you get a little bit of something squeezing it
4 up. If it's vertical, it's got its own weight that
5 holds it down --

6 MR. KROTIUK: Right.

7 CHAIRMAN WALLIS: -- which isn't in this
8 theory.

9 MR. KROTIUK: Because a lot of the --

10 CHAIRMAN WALLIS: If it were underneath
11 the screen, it wouldn't be there at all. You'd have
12 to have some pressure to bring it up.

13 MR. KROTIUK: Correct.

14 CHAIRMAN WALLIS: So I think to tie it to
15 kilogram to square meter is a much better way to do it
16 than to try to measure an uncompressed length.

17 MR. KROTIUK: Yeah, and I could do that.

18 CHAIRMAN WALLIS: Right. Isn't that what
19 you've done?

20 MR. KROTIUK: Yeah, that's exactly what
21 I've done. This is kilogram per square meter versus
22 bed thickness.

23 CHAIRMAN WALLIS: Right.

24 MR. KROTIUK: Then this is what I was
25 eluding to earlier. This is just a comparison for the

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1 equivalent tests that were run for LANL. This is 6A.

2 CHAIRMAN WALLIS: So why doesn't it go
3 through zero? I mean --

4 MR. KROTIUK: Yeah, that -- yes.

5 CHAIRMAN WALLIS: The bed with no mass
6 would have no thickness.

7 MR. KROTIUK: Yes, you are absolutely
8 right. And with the -- I didn't include it here but
9 I'm still working on this. I've included some of the
10 measurements from the PNNL data and it actually goes
11 through zero. You know, I need more data points,
12 basically.

13 CHAIRMAN WALLIS: I think your 6C, 6G and
14 6H are just the ones which have some rather weird
15 pressure drop data.

16 MR. KROTIUK: Could be, but I have
17 actually plots of this with the PNNL data and for that
18 one --

19 CHAIRMAN WALLIS: I mean, they had
20 anomalous data. They had data where the thickness of
21 the compressed bed was greater than the thickness of
22 the uncompressed bed, that kind of thing. 6C was
23 really anomalous that way. Something was very odd
24 about 6C as I remember.

25 MR. KROTIUK: That's why I threw that one

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1 in, but I'm looking at -- I'm trying to, you know,
2 look at this more.

3 CHAIRMAN WALLIS: Okay.

4 MR. KROTIUK: And this is just what I was
5 eluding to before. Is that this is the comparison of
6 the LANL test and these are somewhat the equivalent of
7 tests that were done at PNNL and the key thing I want
8 to point out is that when we have this added mass, add
9 a Nukon, add a CalSil mass and then I have a column
10 here for bed Nukon and bed CalSil, the key thing that
11 I wanted to point out is that like for instance in
12 this case which is equivalent to 6B, .78 kilograms per
13 meter squared. I tried to do everything in kilograms
14 per unit area, .78 was added but only .67 was measured
15 as deposited into the bed.

16 And you could see that in t his case, .5,
17 .33, so it seemed to indicate that even though you
18 added a certain amount to the loop, not everything was
19 deposited into the bed. Whereas, if you look at the
20 Nukon, the Nukon in most cases is much closer.
21 There's only one case here that seems to be an
22 outlier, but you know, what was ended up from the
23 actual measurements, you added the Nukon and the Nukon
24 was deposited on the bed.

25 CHAIRMAN WALLIS: Now, this CalSil, where

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1 did that come from? This was the weight at the end of
2 a test?

3 MR. KROTIUK: That's correct.

4 CHAIRMAN WALLIS: From whose experiment?

5 MR. KROTIUK: From PNNL's.

6 CHAIRMAN WALLIS: Okay, because LANL used
7 this --

8 MR. KROTIUK: Right.

9 CHAIRMAN WALLIS: -- and they reached a
10 different conclusion.

11 MR. KROTIUK: That's correct, and so in
12 their case, you can see that the -- what they
13 estimated was in the bed was very, very close to what
14 was added to the loop.

15 CHAIRMAN WALLIS: Right, that's right.

16 MR. KROTIUK: So that -- the question I
17 have is --

18 CHAIRMAN WALLIS: So that's another cause
19 for uncertainty, isn't it, in the whole thing?

20 MR. KROTIUK: Yes, so the question is that
21 how do --

22 CHAIRMAN WALLIS: What wasn't in the bed
23 went through the reactor.

24 MR. LETELLIER: That's right, several
25 times. Bill, for the PNNL when you're doing the mass

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1 balance, you're assuming 100 percent of the fiber is
2 actually on the screen?

3 MR. KROTIUK: No, I did not.

4 MR. LETELLIER: How did you separate them
5 post-test?

6 MR. KROTIUK: Because you measure the
7 weight of the entire bed and then using the technique
8 that they've developed, you could calculate the weight
9 of the CalSil in the bed and then you just subtract
10 it, so you know, total weight minus CalSil weight.

11 MR. LETELLIER: Through the dissolved
12 concentration, that's how you did it.

13 MR. KROTIUK: Right, yeah. So it's as
14 good a measurement as you could get.

15 MR. LETELLIER: How did that compare --
16 out of curiosity, how much fiberglass continues to
17 circulate or was otherwise lost to the bed?

18 MR. KROTIUK: In none of these instances,
19 as you could see, here's the -- for the fiberglass,
20 for the Nukon, okay. If you can look at this column
21 here, there's the added Nukon and there's the bed
22 Nukon. You can see that they're very --

23 MR. LETELLIER: Very close.

24 MR. KROTIUK: -- very close. So most of
25 the Nukon gets deposited onto the bed.

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1 DR. BANERJEE: I want to ask you one
2 question. I mean, look at the people at Los Alamos
3 and so on, they've done so many pressure loss and
4 other calculations to complex media including porous
5 media with cracks and everything under the sun. If
6 you've got bed sections, they can even scan these into
7 the codes and run them because these are very little
8 random numbers. These are things which is easy to run
9 with the -- takes half an hour. So why don't you do
10 that rather than such an empirical approach?

11 MR. KROTIUK: We were actually thinking of
12 that and we wanted to take -- this is a simpler
13 approach.

14 DR. BANERJEE: Right, sure. I mean, this
15 may lead to -- the problem with all of these things is
16 that it becomes very dependent on the geometry of the
17 fibers, you know. I'm sure that you can derive a
18 correlation for Nukon specifically and maybe CalSil of
19 certain size distribution, whatever.

20 MR. KROTIUK: Right.

21 DR. BANERJEE: But if you change the thing
22 a little bit and something arrives which is oriented,
23 all aligned one way or something, the permeability
24 correlations will start changing quite a bit depending
25 on the geometries and stuff like that.

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1 MR. KROTIUK: I mean, I hear what you're
2 saying but you know, this is an approach also is that
3 you know, you have to -- when you try to develop a
4 correlation like this, you have to make an assumption
5 and the assumption is is that I have the fibers 90
6 degrees to the direction of flow. So --

7 DR. BANERJEE: But they may or may not,
8 you don't know.

9 MR. KROTIUK: Yes.

10 DR. BANERJEE: And once you get the core
11 samples you know, when they've cut it.

12 MR. KROTIUK: Yeah, we will have some of
13 that data.

14 DR. BANERJEE: The reason I'm saying this
15 that the oil industry even uses these types of methods
16 now for doing their porous media factor calculations
17 and stuff.

18 MR. KROTIUK: The chemical industry uses
19 it, too.

20 DR. BANERJEE: Yeah, in fact, I've seen
21 Dow, for example, for their pack beds, they even are
22 looking at the formation fo the pack bed. There's
23 some problems where they're depositing the packing
24 which is very complex, into a bed and then looking at
25 the flow through it. There's a guy named David West

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1 at Dow is the head of the Fluid Dynamics. So this is
2 industrial practice today to look at the deposition
3 and looking at flow-through sort of complex media.

4 MR. KROTIUK: But as Dr. Wallis has said,
5 is that we're looking at a process of deposition into
6 the bed that is not very well defined.

7 DR. BANERJEE: No, but it's a question of
8 where you put -- you know, if you know -- there are
9 all sorts of things, but if you do know enough to use
10 this correlation which, as you know, when water is
11 being delivered and all this stuff, so --

12 MR. KROTIUK: If you know what's being
13 delivered, yes.

14 DR. BANERJEE: Yeah, so that you have to
15 know.

16 MR. KROTIUK: Yes, that's right.

17 DR. BANERJEE: What sequence, that has to
18 be connected to something, some estimate, but you are
19 going to need that anyway for this.

20 MR. KROTIUK: You need that for this
21 correlation, yes, you do need it for this correlation
22 and that's why I was saying from the beginning that I
23 was hoping that with a multi-volume debris bed we
24 could make some sort of conservative yet not overly
25 conservative assumption in terms of --

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1 CHAIRMAN WALLIS: I'm a little puzzled by
2 this table because it looks as if LANL had more CalSil
3 that was retained in the bed than PNNL in the same
4 conditions.

5 MR. KROTIUK: That's correct.

6 CHAIRMAN WALLIS: But LANL had a lower
7 pressure drop at the same conditions, typically. So
8 it's not consistent with what you'd expect. You'd
9 expect if there's more CalSil retained in the bed for
10 the same conditions, you would have a higher pressure
11 drop.

12 MR. LETELLIER: Please remember those were
13 estimated masses based on --

14 MR. KROTIUK: Yes.

15 CHAIRMAN WALLIS: Based on their
16 stability.

17 MR. LETELLIER: Right.

18 CHAIRMAN WALLIS: They're actually in your
19 report, they're on a table so I --

20 MR. LETELLIER: They are.

21 CHAIRMAN WALLIS: So I'll use them when
22 I'm considering --

23 MR. KROTIUK: Right.

24 CHAIRMAN WALLIS: It's the best we have,
25 really from that experiment.

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1 MR. KROTIUK: So, you know, my feeling is,
2 is that this assumption for the LANL test that all the
3 Nukon is on the bed is probably pretty good but is
4 this really 100 percent correct?

5 CHAIRMAN WALLIS: That was measured
6 though. Maybe the measurement technique was not a
7 good one for that.

8 MR. LETELLIER: The primary fault is the
9 calibration. Keep in mind that we're looking at
10 really low concentrations so we had to do a
11 calibration standard to units of NTU.

12 CHAIRMAN WALLIS: So it's very, very non -
13 - this is very, very clear?

14 MR. LETELLIER: Visually, it's very clear
15 and --

16 CHAIRMAN WALLIS: Because I think Bill
17 Shack's was not very clear.

18 MR. LETELLIER: No, after many
19 circulations with CalSil fiber.

20 MEMBER SHACK: Right, I mean, it gets
21 clear, yeah.

22 MR. ENDERLIN: We can physically, in both
23 our large and our small scale and you can see the
24 cloud visibly as the opaqueness in about four passes,
25 you watch the cloud and you can watch after about the

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1 fourth pass the fluid is clear and every time you see
2 it come out, you watch a little blip on the pressure
3 measurement as you're doing your bed formation.

4 CHAIRMAN WALLIS: Now you tap the test
5 section, you knock it, rap it, does stuff come out of
6 the bed?

7 MR. ENDERLIN: I paid a lot for the
8 polycarbonates so we haven't --

9 CHAIRMAN WALLIS: No, but you see what I'm
10 getting at.

11 MR. ENDERLIN: Yeah, we haven't -- we have
12 not see a lot come out when we rap the PVC one down
13 below but I can't -- I don't have as good a visual
14 underneath the bed in that one.

15 MEMBER SHACK: I mean, if you up the
16 velocity, you get a puff out, don't you?

17 MR. ENDERLIN: If you don't degas you get
18 puffs, but when we ramped the velocity up, we don't
19 get a lot of visual seeing puffing unless you have air
20 in your bed.

21 MR. KROTIUK: No shedding.

22 MEMBER DENNING: Graham, why don't we go
23 ahead.

24 CHAIRMAN WALLIS: Yeah, we have to finish.

25 MR. KROTIUK: Yeah, I'm just -- the rest

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1 is my guess at a correlation right now, so --

2 CHAIRMAN WALLIS: It seems to me that it
3 works on the PNNL but it doesn't work so well on the
4 LANL.

5 MR. KROTIUK: Right, and this is my first
6 shot through so it's not really meaningful --

7 CHAIRMAN WALLIS: You have to know which
8 one to check against when they're not the same.

9 MR. KROTIUK: Yeah, and one of the other
10 things that I do want to look at is just to make an
11 approximation maybe of what would have really been
12 using the data from PNNL, what really the CalSil would
13 have been in the bed and see if that matches closely.
14 This is really my first guess at this and I don't
15 think it's --

16 CHAIRMAN WALLIS: So who is going to do an
17 experiment with a vertical bed which is something like
18 a real screen to show that you can predict it?

19 MEMBER DENNING: The green is --

20 CHAIRMAN WALLIS: This horizontal bed was
21 very, very carefully prepared and stuck. Who is going
22 to do an experiment for the vertical bed with
23 realistic layers of stuff on it, most at the bottom
24 and the top.

25 MEMBER DENNING: Nobody.

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1 CHAIRMAN WALLIS: So how are you going --

2 MEMBER DENNING: I'm sorry, the industry
3 is going to do that. The industry is going to do that
4 to some extent. They're going to take sections.

5 DR. BANERJEE: But they would need to make
6 more detailed measurements.

7 CHAIRMAN WALLIS: How do you do confirmed
8 -- how do you evaluate the industry stuff if you don't
9 have your controlled experiments for something like
10 what they have because this isn't what they have?

11 MR. KROTIUK: No, but we said from the
12 very beginning, I remember awhile ago, months ago,
13 that this is for basically a bed that was uniformly --

14 CHAIRMAN WALLIS: What's LANL going to do?
15 These guys come in. They say, we've done experiments
16 and we've -- we got this, empirically we're going to
17 use this and it's two orders of magnitude away from
18 what you predict using this curve, well, that's
19 because you've got a different distribution. How are
20 you doing to have any kind of a confirmatory measure
21 of what they've done?

22 MR. KROTIUK: That's not what this
23 correlation was intended to look at.

24 DR. BANERJEE: Maybe this works locally,
25 you know. Let's look at it this way; you need

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1 something locally but I think you really need to
2 eventually bite the bullet and have a particle
3 transport code so you know the distribution is going
4 to be this way, which is thicker at the bottom and
5 thinner at the top. Without that, you don't have
6 anything.

7 MR. LETELLIER: One approximation that
8 we've used is --

9 MEMBER KRESS: It would be dominated by
10 the open parts.

11 CHAIRMAN WALLIS: Yeah, Mark has --

12 MR. LETELLIER: One approximately that we
13 have used is to assume that these one dimensional
14 models apply at any point locally on the face of the
15 screen. And, in fact, if you assume a uniform
16 suspension, you can actually track the build-up
17 profile that looks very much like some of our vertical
18 screen testing. You can predict head loss over a non-
19 uniform bed by using this as the kernel, if you will,
20 for accumulation.

21 DR. BANERJEE: But then you have to know
22 something about the fluid mechanics that flow through
23 this bed and the bypassing and so you have to do that
24 -- you have to do a CFD calculation and the NRC is way
25 back in like --

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1 CHAIRMAN WALLIS: But then you've got an
2 array of 20 top hat screens, which are all catching
3 different amounts of debris.

4 MR. LETELLIER: You tend to incorporate
5 the inertial effects of debris transfer if you have to
6 do that. I was simply assuming a flow following
7 tracer material.

8 DR. BANERJEE: It's surprising how far we
9 are behind here, behind industry. That really
10 surprises me. People are doing this for chemical
11 reactors and distillation columns and things and we're
12 just sitting here and doing these things.

13 CHAIRMAN WALLIS: Well, maybe we need to
14 sleep on it. If you can make your bed in under 70
15 hours, we -- this is all very interesting stuff. I
16 think we're complete saturated with information by
17 now. We'll come back tomorrow with clear minds and no
18 debility of any sort in our heads and see what we can
19 make out of it all.

20 We have some more interesting stuff
21 tomorrow. We're going to recess. It's now 6:30,
22 we'll recess.

23 (Whereupon, at 6:30 p.m. the above-
24 entitled matter recessed to reconvene on February
25 16th, 2006.)

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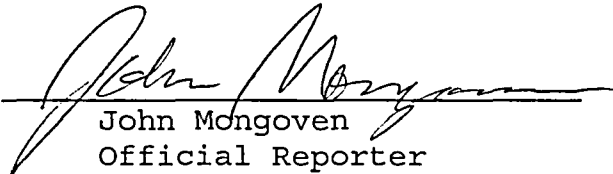
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before the United States Nuclear Regulatory Commission
in the matter of:

Name of Proceeding: Advisory Committee on
Reactor Safeguards
Meeting

Docket Number: n/a

Location: Rockville, MD

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PNNL Activities Associated with Head Loss Testing for Sump Screen Debris Beds in Support of the Resolution of GSI-191

February 15, 2006

Principal Investigator: CW Enderlin

Engineering Team: WH Combs, AD Guzman, ES Mast, TE Michener,
F Nigl, TJ Peters, BE Wells

Battelle

**Pacific Northwest
National Laboratory**
Operated by Battelle for the
U.S. Department of Energy



Outline

- ▶ Test Loop Capabilities and Measurements
- ▶ Debris Bed Parameters
- ▶ Pretest Evaluation/Testing

- ▶ Benchmark Tests

- ▶ Example of Test Procedure/Results
- ▶ Post Test Measurements/Evaluation

- ▶ Issues for Series II tests



Test Loop Capabilities & Measurements

- ▶ Bench top loop - 4 inch diameter test section
 - Provides rapid means of investigation
 - Assess methods of debris bed preparation introduction, and loading
 - Initial assessment of proposed test matrix
- ▶ Limitations:
 - Pressure ports not in ideal locations
 - Limited ability to degas water
 - No temperature control



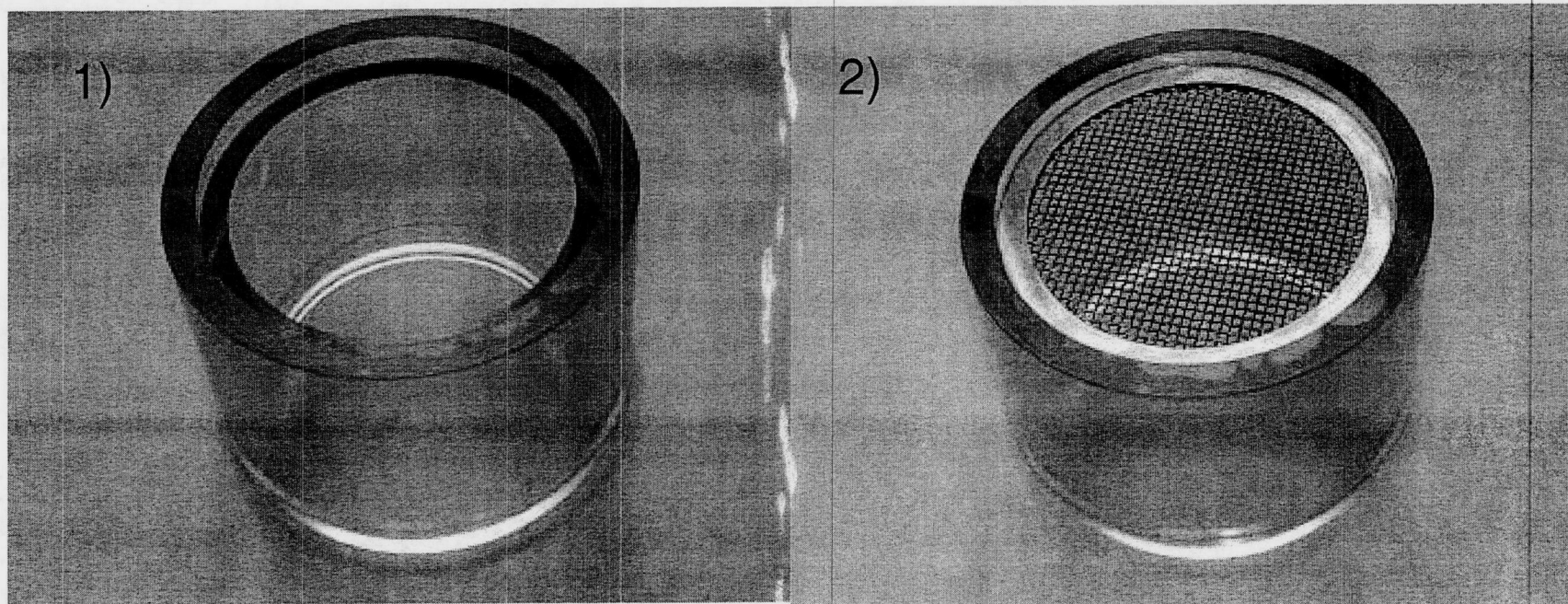
Large-Scale Loop Capabilities

► 6-inch Diameter Test section

- Uniform cross section, screen extends into pipe wall
- Screen fixed in transparent polycarbonate assembly with custom cut gaskets to minimize discontinuity at pipe connections
- Screen assembly designed to reduce or eliminate bowing
- Straight section of piping in excess of 20 L/D upstream and 10 L/D downstream of screen



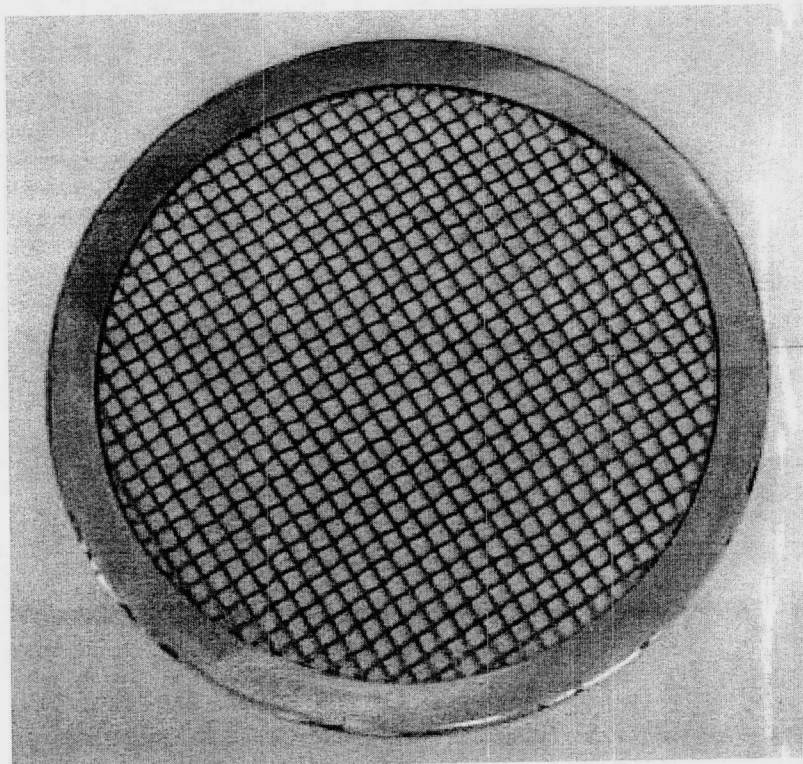
Transparent Test Section



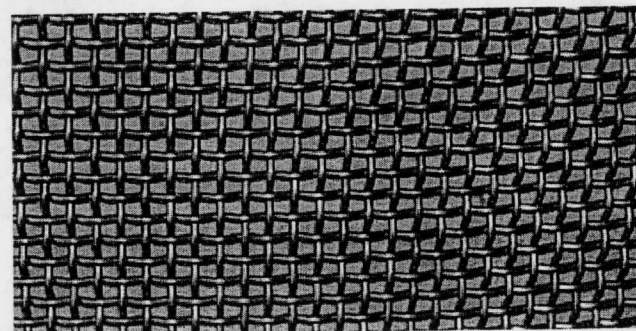
- 1) Bottom half of test section
- 2) Screen assembly inserted (gaskets not pictured)



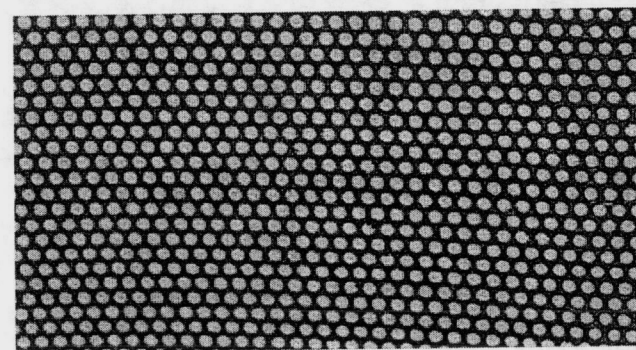
Large Scale Screen Assembly and Materials



Woven wire screen welded
into support ring



Woven wire screen



Perforated metal screen



Large-Scale Loop Capabilities (cont.)

- ▶ Head loss across the debris bed measured with a delta-P transmitter array:
 - Range (0 - 5, 0 - 30, 0 - 150, 0 - 2770 [now 0 - 750] inches H₂O)
 - Multiple pressure ports:
 - Six upstream ports: 5 @ 2 L/D (2" increments), 5 L/D, 10 L/D
 - Two downstream ports: 5 L/D, 10 L/D
- ▶ In situ debris bed height measured under flow
 - optical triangulation
 - visual observation at test section wall



Large-Scale Loop Capabilities (cont.)

► Operating Conditions:

- Pressurized (150 psig maximum) to eliminate gas bubbles
 - Cover gas system reduces gas absorption by fluid
- Temperature controlled (60° F - 185° F)
 - Fluid properties can be altered by changing temperature
- Velocity range (0.02 - 2 ft/s) with current pump



Large-Scale Loop Capabilities (cont.)

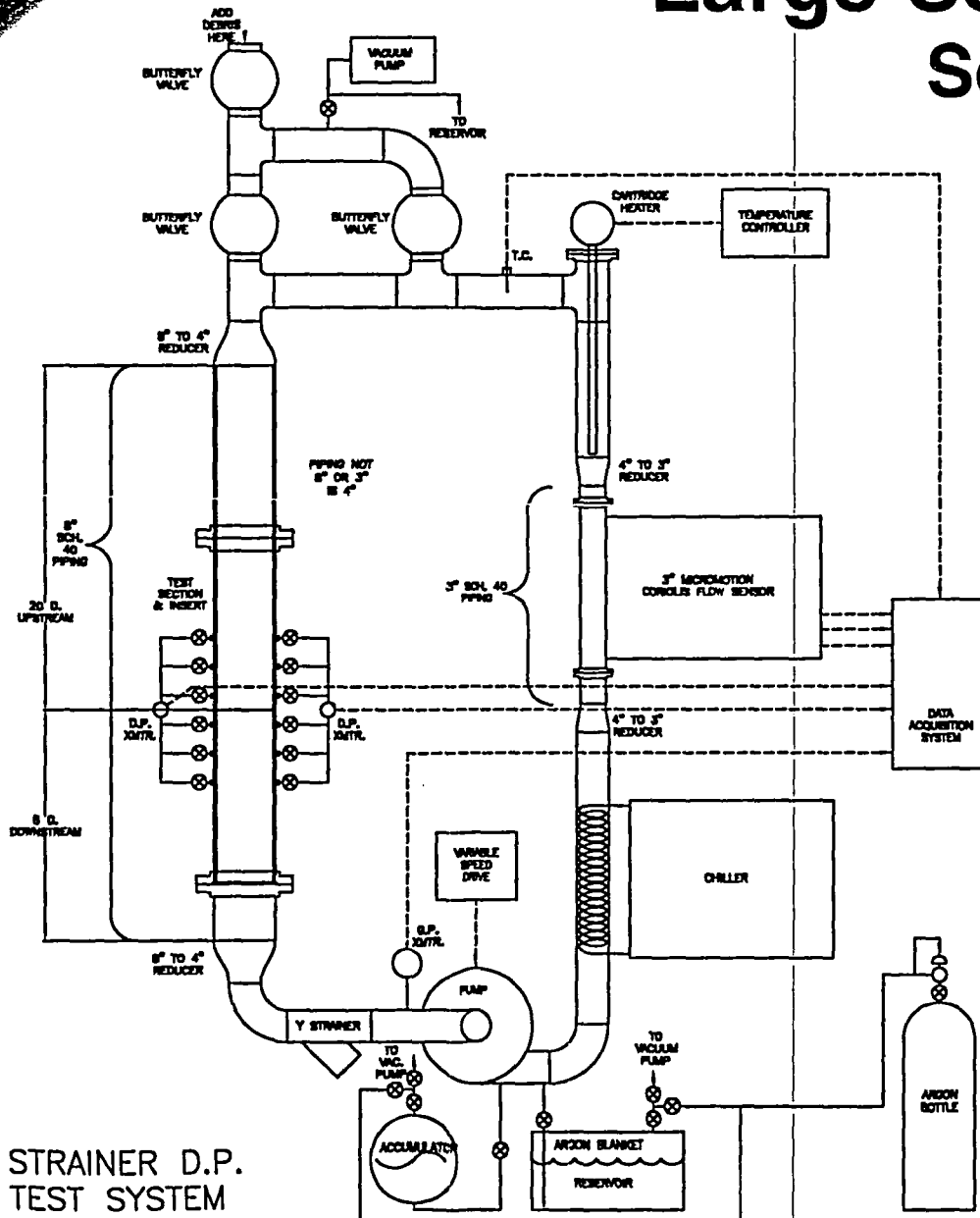
► Filtration system

- Eliminates suspended solids after debris bed formation
- Allows capture of mass discharged from debris bed during tests

► Debris holdup minimized by:

- welded fittings
- custom cut flanges
- pinch valves for throttling flow
- Minimize lengths of pipe dead legs

Large-Scale Test Loop Schematic



STRAINER D.P.
TEST SYSTEM

Battelle

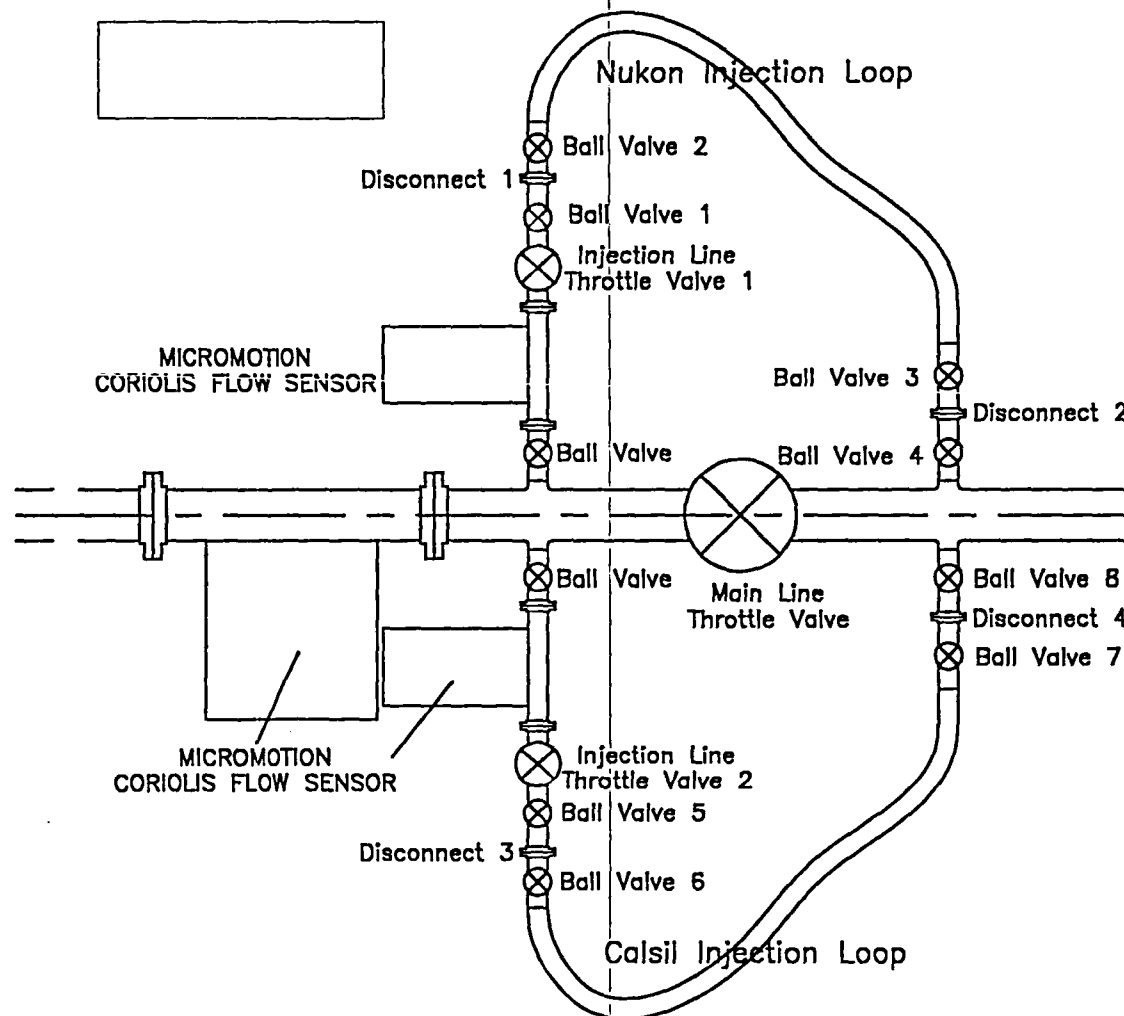
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Debris Injection System

- ▶ Closed system
- ▶ Debris slurry introduced through two injection lines for separate simultaneous or sequential introduction of two debris constituents. Large scale:
 - Injection lines 1.5 inch diameter, 160 inch long
 - Volume 1.2 gal (0.16 ft³) each injection line
 - Current guideline for minimum dilution 28 g/gal. Minimum dilution in proposed test matrix approx. 17g/gal
- ▶ Throttling valves and upstream mass flow meters provide control for repeatable debris introduction

Debris Injection System Schematic





Debris Bed Parameters

- ▶ Identify/determine initial conditions that impact head loss to:
 - Design Experiments
 - Minimize experimental uncertainty and provide statistically significant results
 - Assess true variability associated with debris bed formation for a given composition and loading
 - Develop Procedures
 - Control initial conditions to maximize repeatability of debris bed head loss measurements
- ▶ Nukon vendor – Performance Contracting Inc.
- ▶ CalSil vendor – Johns Manville



Debris Bed Parameters

- ▶ Mass of material introduced versus mass of debris material retained on screen
- ▶ The sequence debris constituents are loaded onto the screen
- ▶ Debris material consistency, size, and distribution
- ▶ Mass ratio of constituents in debris bed

- ▶ Velocity history during debris bed formation
- ▶ Flow history following bed formation
 - Velocity
 - Time at flow
 - Sequence/cycling of velocities



Pretest Evaluation/Testing Debris Preparation

- ▶ Nukon and CalSil debris materials
- ▶ Preparation guidelines from previous work establish initial baseline preparation
- ▶ Defined five requirements for debris preparation
 1. Fiber debris material must form a debris bed on the specified metal screen or mesh.
 2. Debris bed uniform in thickness and internally as consistent as possible in the radial direction.
 3. Uniform debris beds formed over the range of debris loadings specified by the proposed test matrix.
 4. The debris beds generated for a given composition and target debris loading yield repeatable physical and performance characteristics.
 5. Meets NRC specifications for debris bed composition and evaluation.



Pretest Evaluation/Testing Debris Preparation (cont.)

- ▶ Results of initial metrics using dried material
 - Effects of preparation time and Nukon mass evaluated
 - Visual observation of slurry consistency considered
- ▶ To decrease evaluation time a metric was employed using wet conditions
 - Prepared slurry poured through a 5-mesh screen

$$R4 = \frac{\text{Nukon and Water Mass on Screen}}{\text{Initial Nukon Mass}}$$

- ▶ Testing determined value of R4 that gave highest resistance over velocity range of interest.

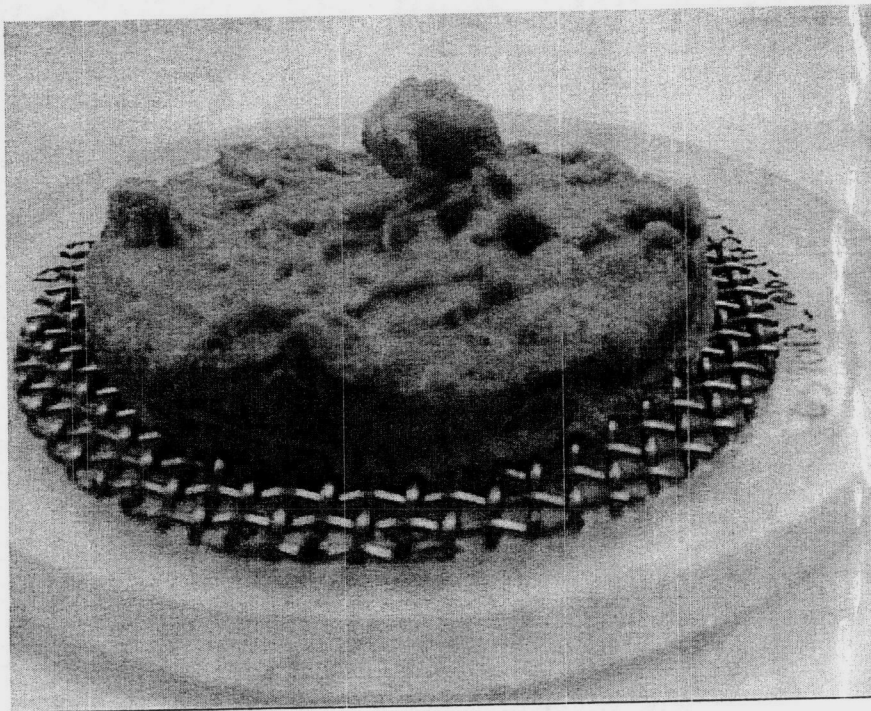


Pretest Evaluation/Testing

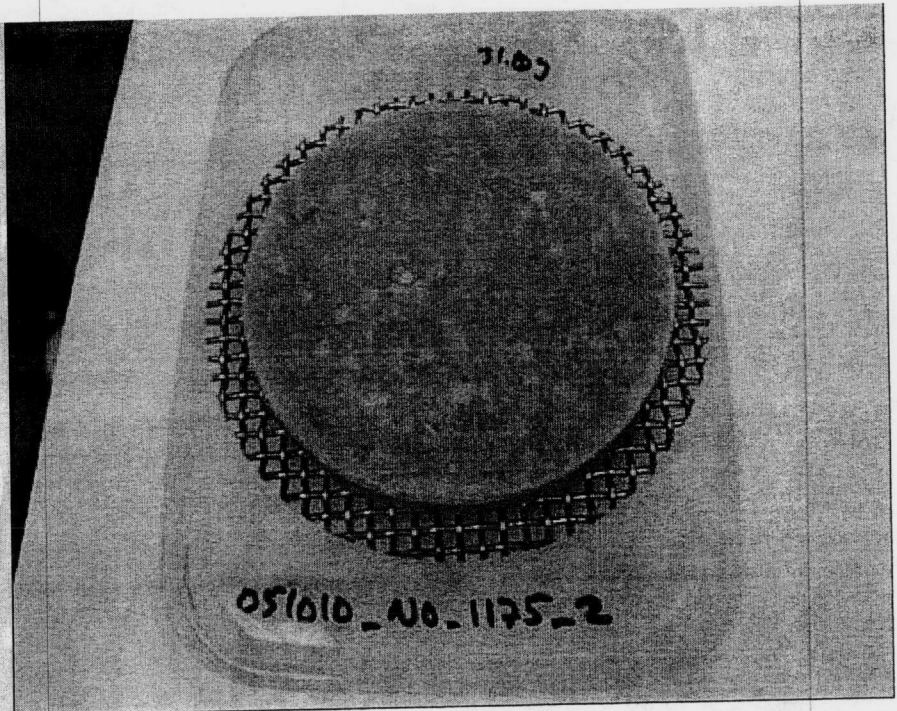
Debris Preparation (cont.)

Requirement 2

1449.5 g/m² Target Debris Loading



R4A

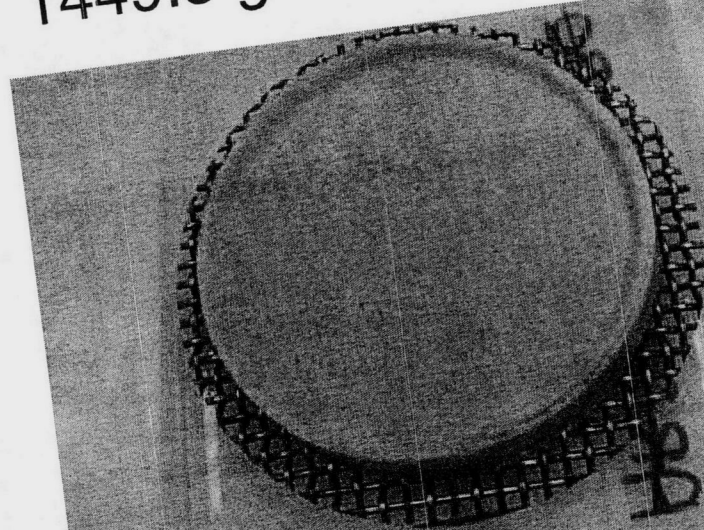


R4B

$$R4 = \frac{\text{Nukon and Water Mass on Screen}}{\text{Initial Nukon Mass}}$$

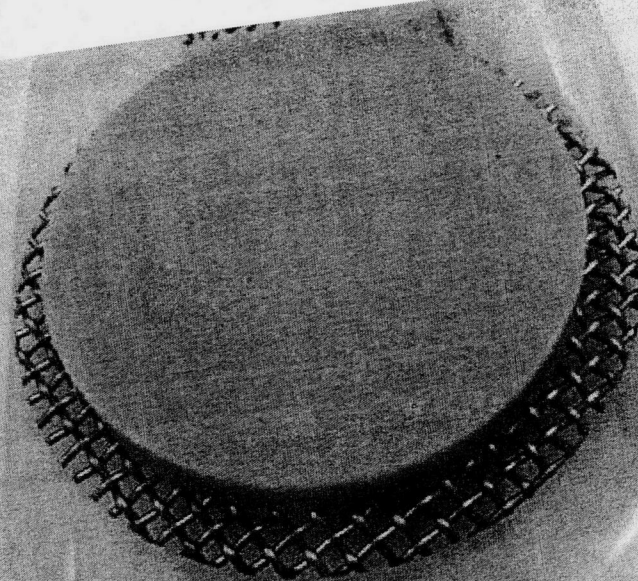
Pretest Evaluation/Testing
Debris Preparation (cont.)
Requirement 2

1449.5 g/m² Target Debris Loading



051010_NO-175-3

R4C



051010_NO-175-7

R4D2

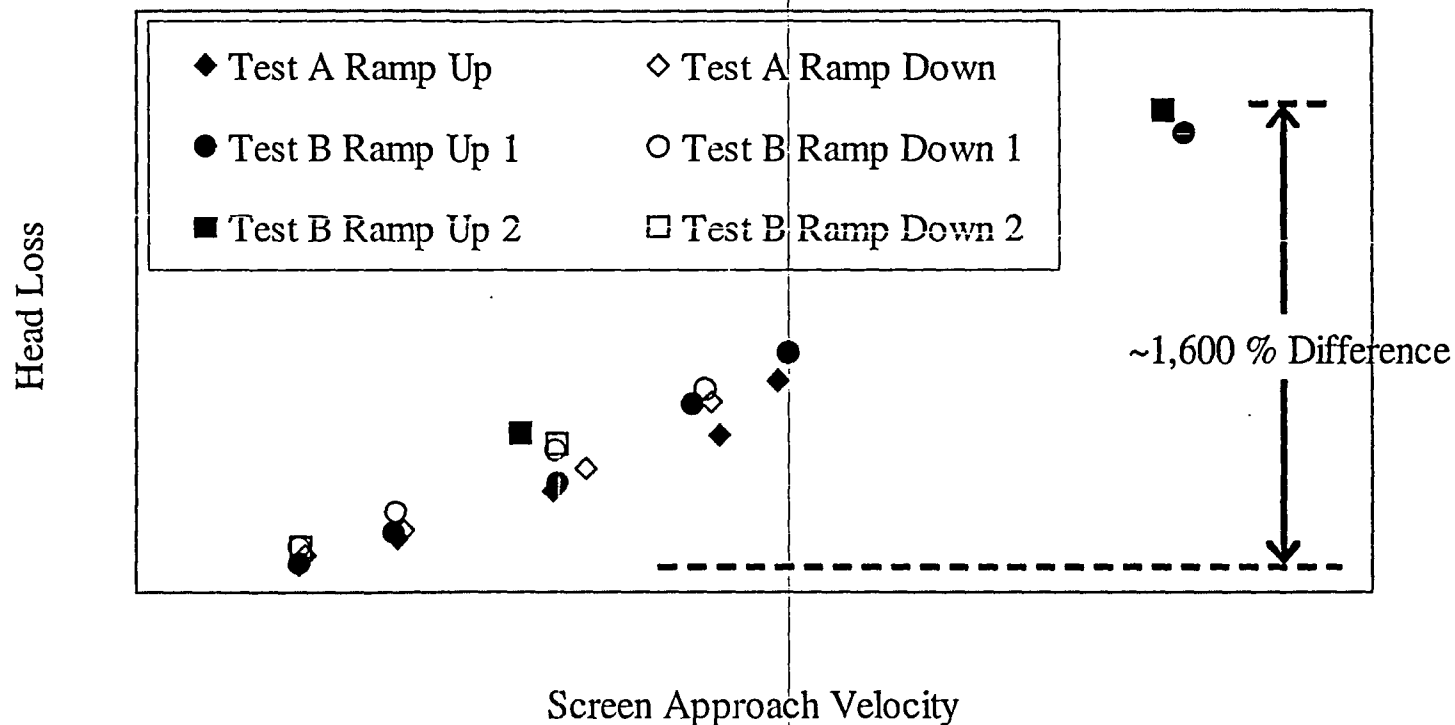
$$R4 = \frac{\text{Nukon and Water Mass on Screen}}{\text{Initial Nukon Mass}}$$



Pretest Evaluation/Testing

Debris Preparation (cont.)

Requirement 4 (Repeatability)



Nukon only 1681.4 g/m² Target Debris Loading

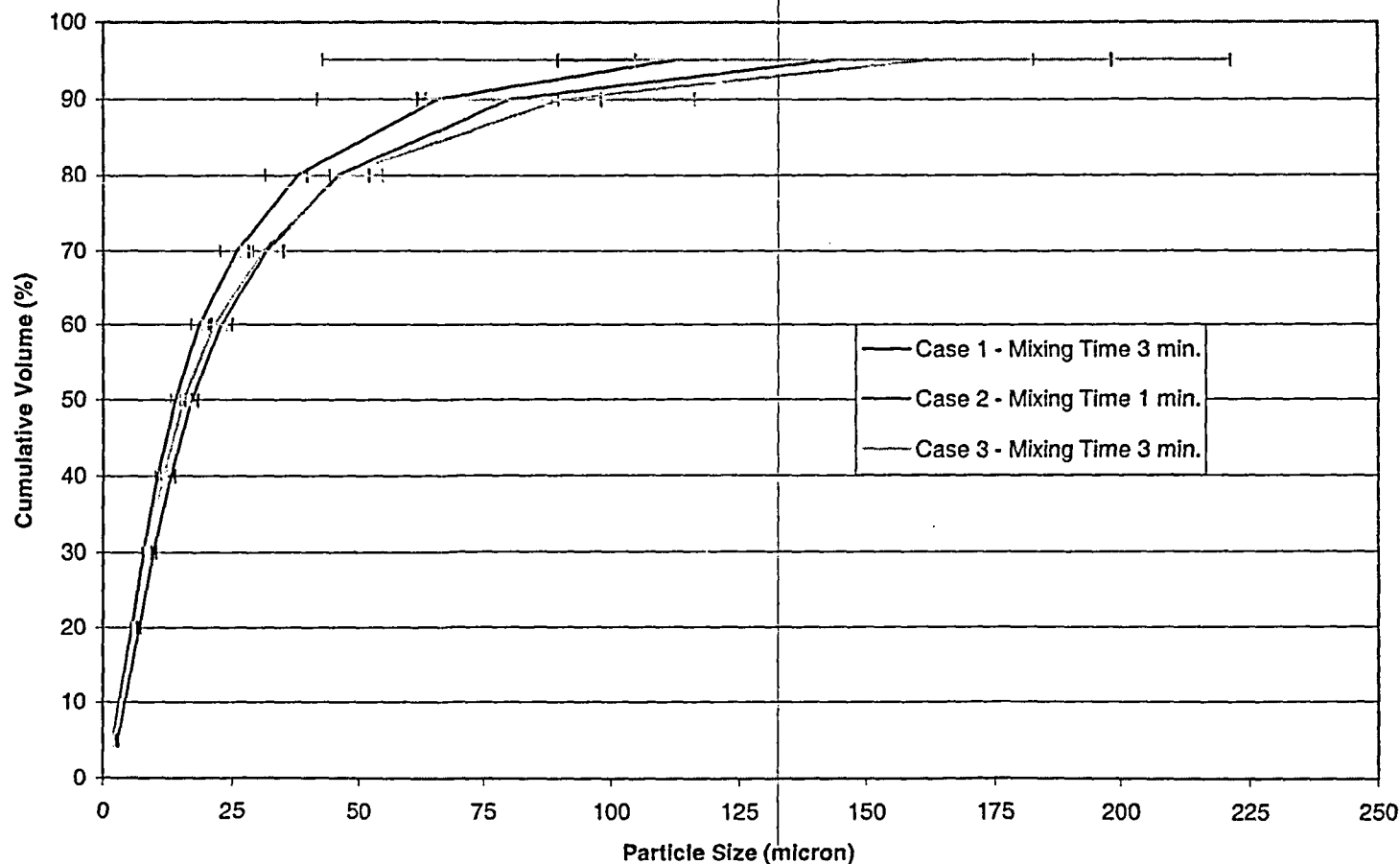


Pretest Evaluation/Testing Debris Preparation (cont.)

Particle Size Distribution Analysis for CalSil Debris by Volume %

Comparison of Particle Size distribution based on Volume count for CalSil Slurries
with different mixing times.

The datapoints are averages of Re-runs #0. Errorbars the standard deviations.



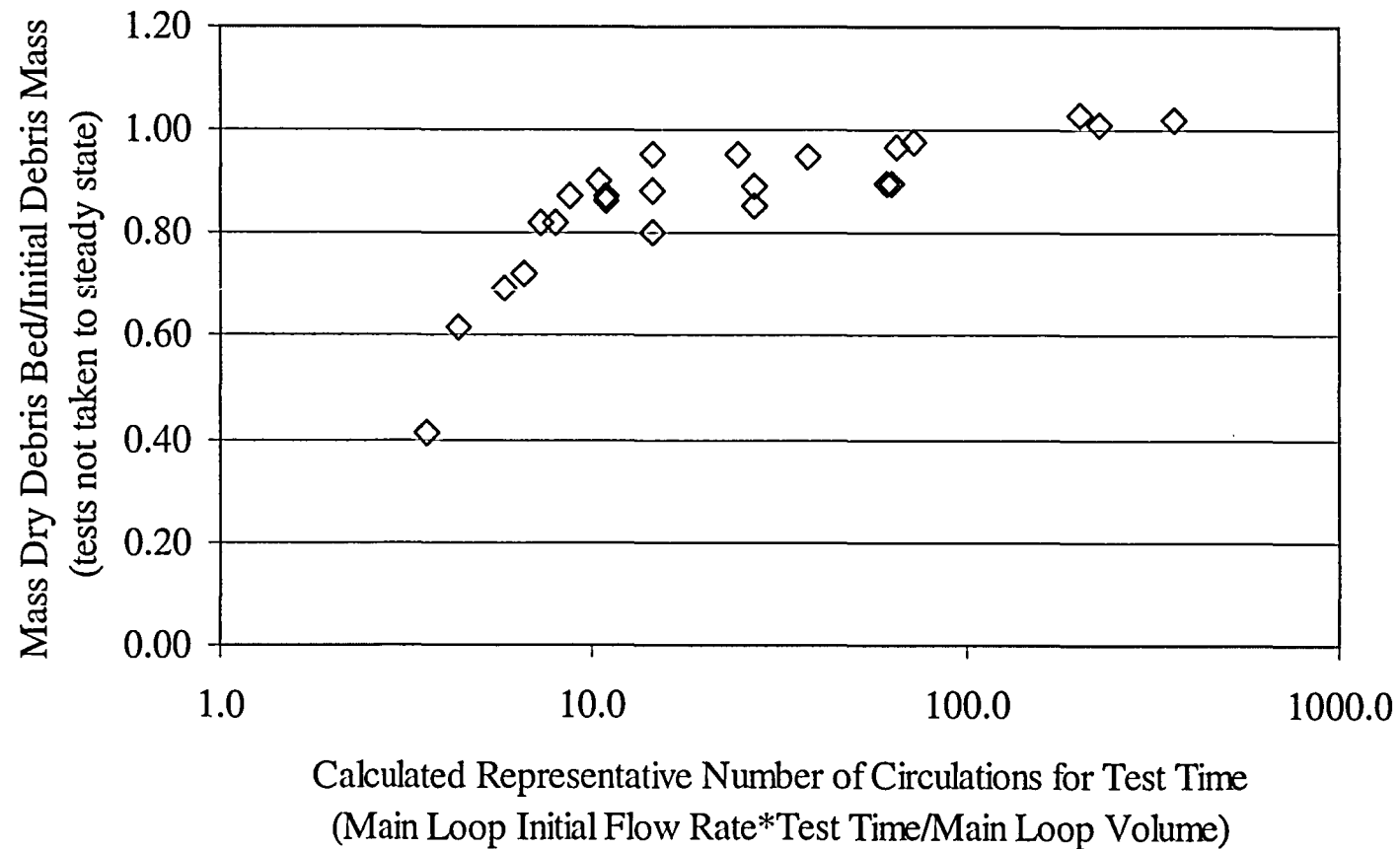


Pretest Evaluation/Testing Debris Preparation (cont.)

- ▶ Debris preparation uses PNNL defined requirements, procedures, and metrics
 - R4 metric used for Nukon
 - Particle size distribution (PSD) used for CalSil
- ▶ R4 metric not perfect but sufficient for project needs.
- ▶ Debris preparation methodology/procedures currently used by PNNL have been demonstrated to be:
 - Controllable
 - Quantifiable
 - Repeatable



Pretest Evaluation/Testing Flow History





Pretest Evaluation/Testing

Variations in Debris Loading Sequence

Four Test Cases:

1. Introduction of the CalSil after a Nukon debris bed has formed
2. Introduction of the Nukon and CalSil as a pre-mixed slurry
3. Introduction of CalSil only. (Introduction of the Nukon after a CalSil debris bed has formed)
4. Time delayed introduction of the Nukon after CalSil has been introduced into the flow loop



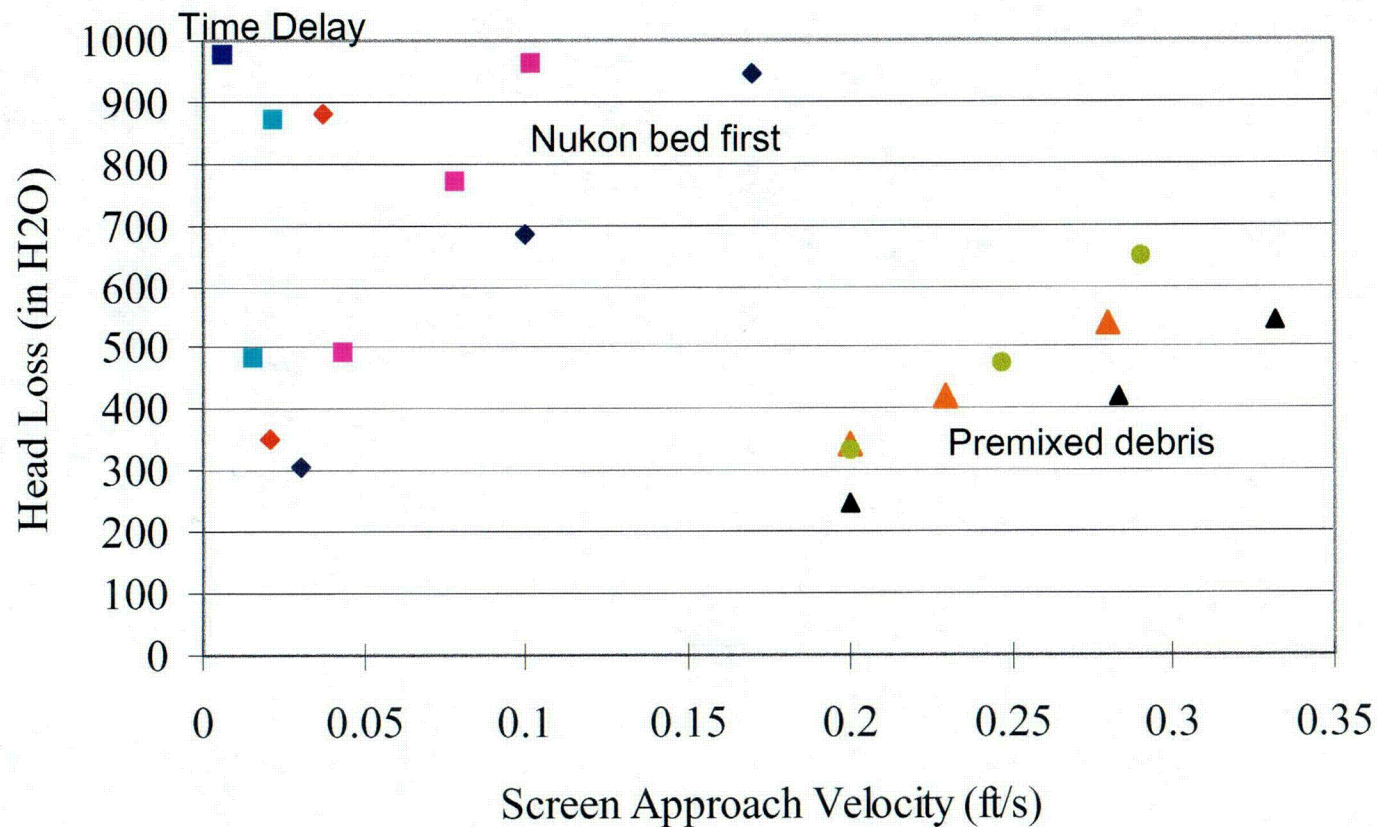
Pretest Evaluation/Testing

Variations in Debris Loading Sequence (cont.)

Debris loading same as LANL test condition 6e & 6e2

Target conditions: Nukon-1.01 kg/m², Calsil-0.51 kg/m², total loading-1.52 kg/m², mass ratio 2:1

◆ Case 1 A ■ Case 1 B ▲ Case 2 A ▲ Case 2 B ● Case 2 C ◆ Case 4 A ■ Case 4 B ■ Case 4 C





Benchmark Tests

- ▶ Objective: to compare head loss measurements obtained in ANL and PNNL loops using different debris introduction systems
- ▶ Benchmark tests consist of three cases

Case No.	Nukon Mass Loading lb/ft ² (kg/m ²)	CalSil Mass Loading lb/ft ² (kg/m ²)	Total Mass Loading lb/ft ² (kg/m ²)	CalSil to Nukon Mass Ratio
BM-1	0.044 (0.217)	0.0 (0.0)	0.044 (0.217)	0.0
BM-2	0.148 (0.724)	0.0 (0.0)	0.148 (0.724)	0.0
BM-3	0.148 (0.724)	0.030 (0.145)	0.178 (0.869)	0.2

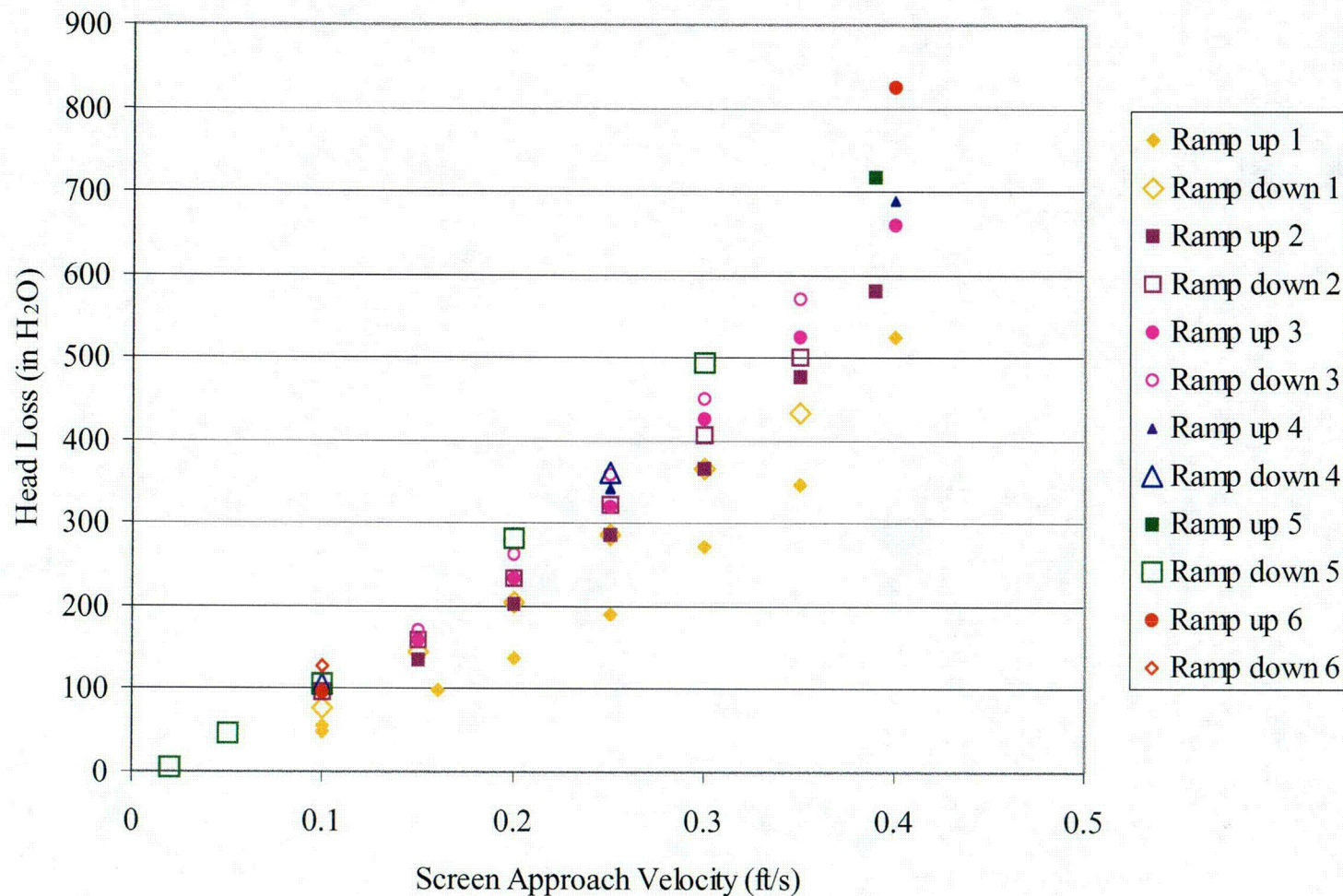
- ▶ For the benchmark tests the debris preparation and debris bed formation processes will be the same for both loops
 - Debris loading sequence will use premixed debris for test BM-3



Series I Test Results

LANL Test Condition 6e

Target conditions: Nukon-1.01 kg/m², Calsil-0.51 kg/m², total loading-1.52 kg/m², mass ratio 2:1



CO2

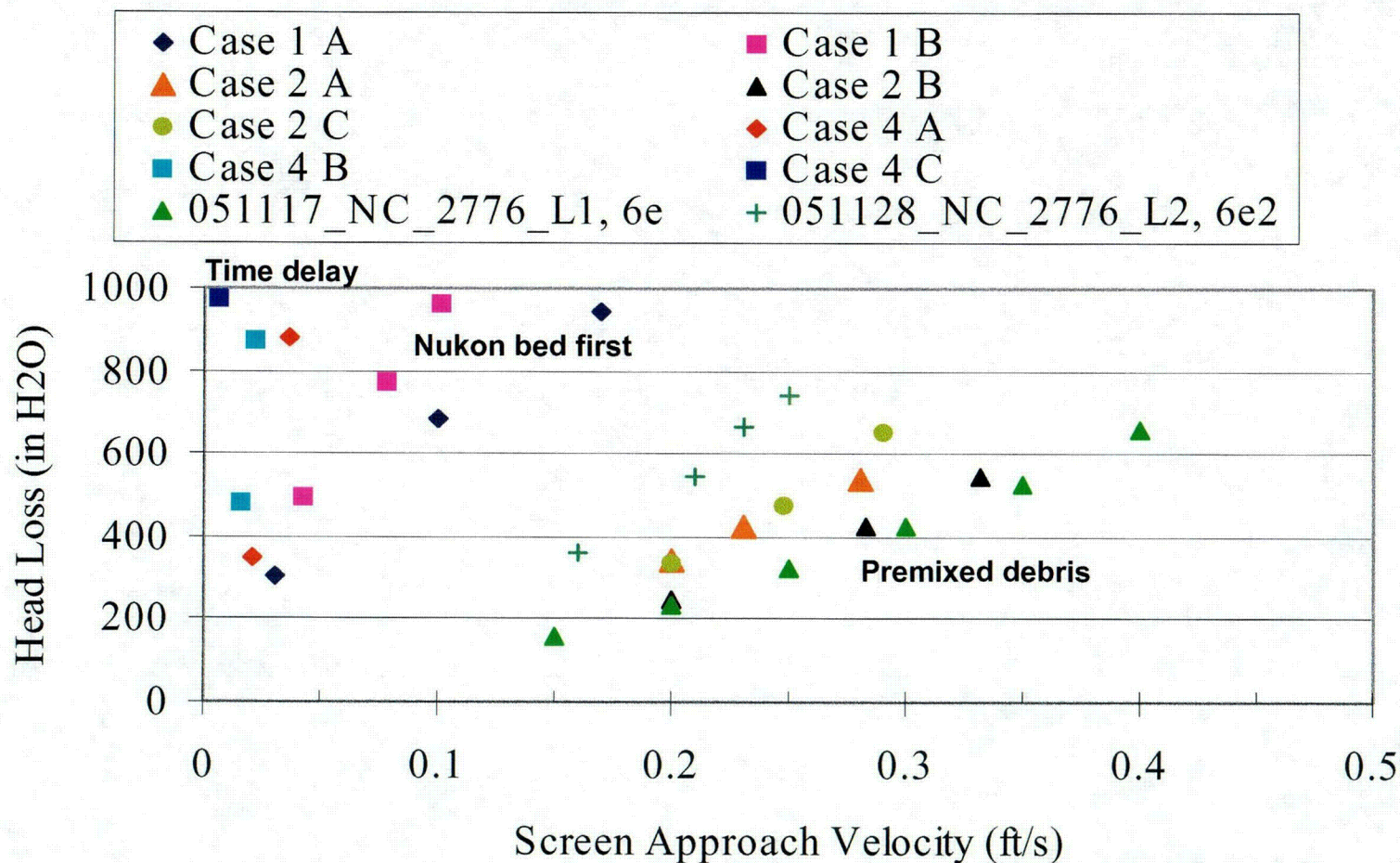


Series I Test Results

Comparison to Loading Sequence Evaluation

Debris loading same as LANL test condition 6e & 6e2

Target conditions: Nukon-1.01 kg/m², Calsil-0.51 kg/m², total loading-1.52 kg/m², mass ratio 2:1

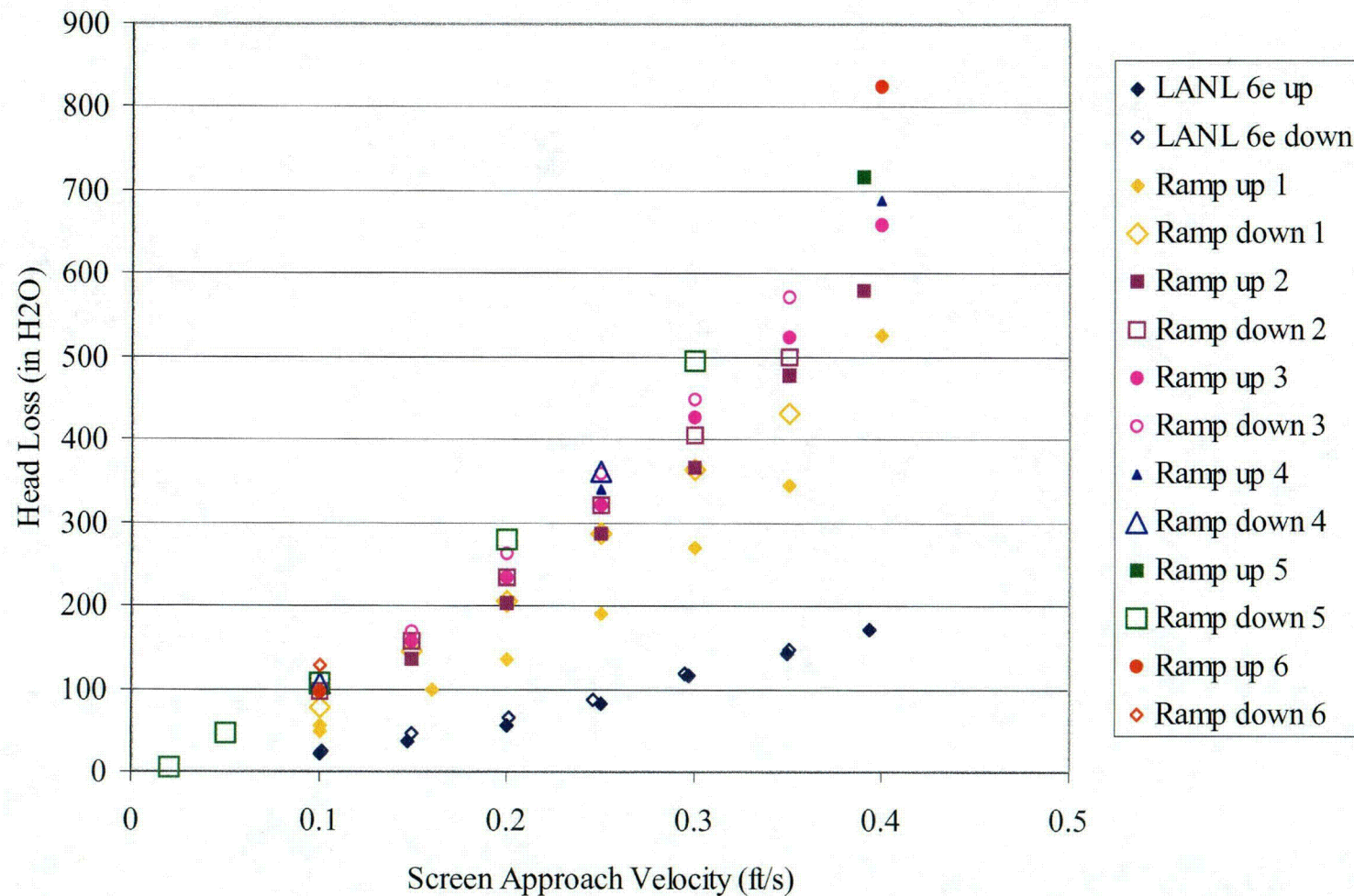




Series I Test Results

LANL Test Condition 6e Comparison

Target conditions: Nukon-1.01 kg/m², Calsil-0.51 kg/m², total loading-1.52 kg/m², mass ratio 2:1



C04



Post Test Measurements/Evaluation

► Direct measurements

- Detailed dimensions of the retrieved (wet) debris bed in transparent portion of test section
- Debris bed dried to obtain final bed mass

► In situ bed height (topography) obtained from optical triangulation

► Mass fraction of CalSil assessed via chemical dissolution and calcium ion selective electrode (ISE) probes

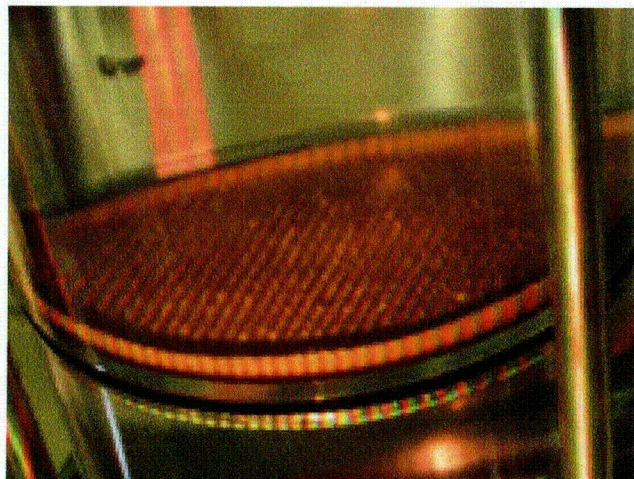
► Sectioning of dried, retrieved debris bed

- Allows for transmission electron microscopy and scanning electron microscopy analyses
- Provides insight into internal debris bed structure and component distribution which appears to strongly influence head loss

Optical Triangulation

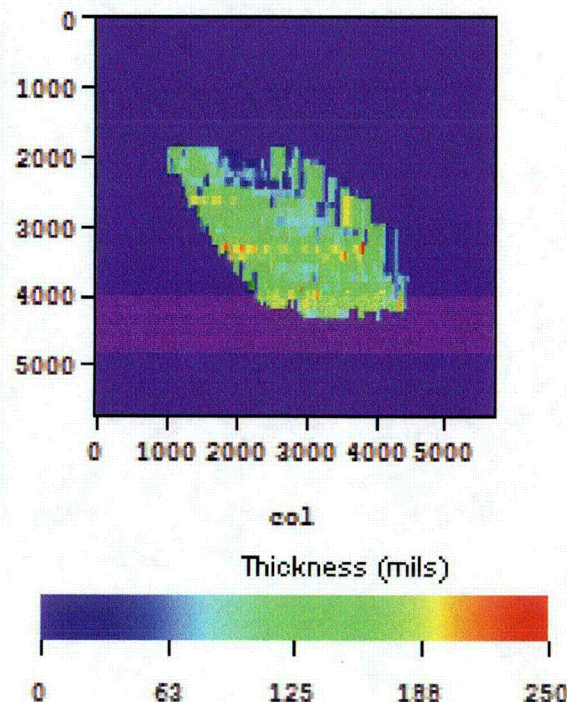
060125_L1_005_13_RD4

Raw Picture of Bed



Center Thk = 0.129 in.
Edge Thk = 0.310 in.
Avg. Plain Thk = 0.124 in.
Dia. of Plain = 5.68 in.
Vol. Of Plain = 3.13 in³
Total Vol. Of Bed = 4.04 in³

Profile of Plain



060125 L1 005 13 RD4 txt

Optical Triangulation

Picture/Test Condition	Height (in) (x)-Manual Measurement		
	Rim	Body Center	Average Body
060125_L1_018_1_BF	0.635	0.307	0.292
060125_L1_098_2_RU1	0.325 (0.41)	0.055	0.053
060125_L1_096_10_RU4	0.281 (0.37)	0.04	0.049
060125_L1_005_13_RD4	0.31 (0.49)	0.129	0.124
Post Test Manual Measurements	(0.50)	(0.37)	(0.34)

Bed Height Measurements Obtained from Test 060125_NO_3067_L1, Test condition 1a.

Comparison of measurements obtained from manual method and optical triangulation



Issues to be Addressed prior to initiating Series II Tests at PNNL

- ▶ Debris loading sequence/procedure to be selected/defined
 - PNNL testing has shown the scenario in which debris is loaded on the screen significantly affects the head loss
- ▶ Velocity sequence/procedure during testing to be selected/defined
 - PNNL initial testing has shown the head loss continues to increase as a result of flow history:
 - Time at (subjected to) flow
 - Cycling of velocity magnitude
 - Currently under investigation



Summary

- ▶ Series I tests complete
 - Used 5-mesh screen and test conditions evaluated previously at LANL
- ▶ Results obtained to date:
 - Debris preparation and sequence of debris bed formation can strongly influence head loss
 - Additional investigation is needed
- ▶ Benchmark tests to be conducted by ANL and PNNL
- ▶ Series II tests (test matrix preliminary):
 - perforated plate
 - lower approach velocities
 - NRC is revising test matrix to evaluate the trends of the utilities/industry in their resolution of GSI-191



Head Loss Testing and Modeling

William Krotiuk

Office of Nuclear Regulatory Research

ACRS Thermal-Hydraulic Subcommittee Meeting

February 14-16, 2006

Head Loss Testing

- Project Title: Head Loss Testing
 - Confirmatory head loss testing using typical debris
- Objectives:
 - Characterize PWR sump screen head loss for standard insulation debris.
 - Characterize head loss sensitivity to
 - debris bed composition,
 - debris distribution in bed,
 - fluid temperature and
 - flow conditions.
 - Design test facility to expand and improve data measurements such as
 - temperature measurement and control, thickness, mass of constituents in bed
 - Characterize head loss for qualified and unqualified coating debris.
 - Provide data to improve head loss calculational method.
- Contractor: Pacific Northwest National Laboratory

Head Loss Testing

- Motivation:

- Previous testing indicated the need to further evaluate the head loss effects of CalSil (calcium silicate) insulation mixed with other debris types such as Nukon (fiberglass) insulation.
- Address ACRS concerns regarding previous testing.

- Regulatory Application:

- Supports GL 2004-02 resolution.
- Provide NRC with additional head loss test data to evaluate licensee submittals.
- Provide additional insight on how variations in debris concentrations for different plants can affect head loss.

Head Loss Testing

- Test Matrix:

- Series 1 tests intended to duplicate several previous tests to provide confirmatory head loss data.
 - Used a woven metal screen.
 - Nukon and CalSil debris added simultaneously to test loop.
- The Series 1 tests also included tests of an unblocked screen.
- Series 2 tests will use a perforated plate to reflect changes in sump design.

Head Loss Testing

■ Test Matrix:

- Provide data for a range of CalSil/Nukon bed mass ratios.
 - Most previous tests were run at a CalSil/Nukon mass ratio of 0.5 with a few at ratios of 1.0 and 2.0.
- Provide data to identify the particulate “saturation” condition for CalSil/Nukon debris beds.
 - Identify the maximum concentration of CalSil in a specific Nukon bed at which the pressure drop increases as the bed becomes clogged with CalSil particulates.
 - This effect is possible in beds of all thicknesses, but had initially been observed in thin beds and called a “thin bed” effect.

Head Loss Testing

- Test Matrix:

- Additional Sensitivity Testing

- Will address the head loss effects resulting from variations in CalSil concentration in a Nukon debris bed
 - Concentration variations can be caused by the timing of the CalSil and Nukon debris arrival at the sump screen.

Head Loss Testing

- Status: Currently ongoing

- Schedule:

- Complete insulation testing

April 2006

- Complete coating testing

TBD

- Draft NUREG to NRC

June 2006

- NUREG release

September 2006

Head Loss Testing

- PNNL Presentation

Head Loss Modeling

- Project Title: Head Loss Modeling
- Objective:
 - Develop improved model to conservatively predict
 - pressure drop across and
 - compression of an insulation debris clogged screen or perforated plate.
 - Investigate applicability to coating debris and possible chemical by-products.

Head Loss Modeling

- Motivation:
 - The NUREG/CR-6224 model was developed for fibrous and metallic debris and based on work for BWR sumps.
 - NUREG/CR-6224 model has possible deficiencies for modeling in the presence of CalSil debris.
 - Improve model to address ACRS concerns regarding pressure drop equation and compressibility relation.
 - Extend analytical modeling to include coating debris and possible chemical by-products.

Head Loss Modeling

- Regulatory Application:
 - Supports GL 2004-02 resolution
 - Provide NRC staff with a calculational tool to perform independent assessments of licensee submittals.
 - Provide analytical tool to evaluate how plant-to-plant variations in debris concentration can affect head loss.

Head Loss Modeling

- Approach:
 - Analysis model concept
 - Base improved method on classical form of porous medium flow equation (Ergun Equation) accounting for viscous and kinetic flow components.
 - Develop improved method to predict debris bed compressibility.
 - Methods will be developed for
 - modeling the debris bed using one calculational control volume and
 - modeling the debris bed using two calculational control volumes to calculate debris concentration and porosity through a debris bed.
 - Compare calculational predictions with PNNL and LANL/UNM test data.

Head Loss Modeling

- Status:

- Basic model development complete; model is being reviewed and revised.
- Model verification and correlation activities using PNNL and LANL/UNM test data ongoing.

- Schedule:

- Complete model development and verification, and draft NUREG June 2006
- NUREG release September 2006

Head Loss Modeling

- The Viscous Term uses
 - the Kozeny-Carman equation to relate permeability, porosity and the debris specific surface area, and
 - a dimensionless permeability function to relate the void ratio to permeability by using the Happel free surface model for
 - a bed with flow perpendicular to fiber cylinders
 - a bed composed of spherical particles.
- The Kinetic Term uses
 - a semi-empirical term based on relations for
 - a woven metal screen of any weave and
 - for beds composed of spherical particles.

Head Loss Modeling

- Porous medium pressure drop equation has viscous and kinetic components.

$$\frac{\Delta p_{\text{debris}}}{L} = \underbrace{\mu V S_v^2 \frac{X^3}{K(X) (1+X)^2} \frac{(1-\epsilon)^2}{\epsilon^3}}_{\text{Viscous Term}} + b \underbrace{\left[\frac{(1-\epsilon) \mu S_v}{\rho V 6} \right]^c \frac{\rho V^2 S_v}{6} \frac{(1-\epsilon)}{\epsilon^3}}_{\text{Kinetic Term}}$$

where

Δp_{debris} pressure drop across debris bed
 L debris bed thickness
 μ fluid viscosity
 V approach velocity
 S_v debris specific surface area
 X void ratio ($\text{Vol}_{\text{void}} / \text{Vol}_{\text{solid}}$)
 $K(X)$ dimensionless permeability function dependent on type of debris
 ϵ porosity ($\text{Vol}_{\text{void}} / \text{Vol}_{\text{total}}$)
 ρ fluid density
 b, c empirical values dependent on type of debris

Head Loss Modeling

■ Equation for Nukon and CalSil Mixture Debris Beds

$$\Delta p_{\text{total}} = \Delta p_{\text{debris bed}} + \Delta p_{\text{irreversible loss}}$$

$$\frac{\Delta p_{\text{debris}}}{L_{\text{debris}}} = \left[\frac{S_{\text{Nukon}}^2 X_{\text{Nukon}}^3}{K(X_{\text{Nukon}}) (1+X_{\text{Nukon}})^2} + \frac{S_{\text{CalSil}}^2 X_{\text{CalSil}}^3}{K(X_{\text{CalSil}}) (1+X_{\text{CalSil}})^2} \right] \mu V \frac{(1-\epsilon_{\text{debris}})^2}{\epsilon_{\text{debris}}^3} +$$

$$\left[S_{\text{Nukon}}^{1.95} \left[\frac{(1-\epsilon_{\text{Nukon}}) \mu S_{\text{Nukon}}}{\rho V 6} \right]^{0.071} + S_{\text{CalSil}}^{3.89} \left[\frac{(1-\epsilon_{\text{CalSil}}) \mu S_{\text{CalSil}}}{\rho V 6} \right]^{0.13} \right] \frac{\rho V^2}{6} \frac{(1-\epsilon_{\text{debris}})}{\epsilon_{\text{debris}}^3}$$

for Nukon with $0.5 < \frac{Re}{(1-\epsilon)} < 9.85 \times 10^4$ and $0.564 < \epsilon < 0.919$

for CalSil with $440 < Re < 7.92 \times 10^4$ and $0.38 < \epsilon < 0.44$

$$\Delta p_{\text{irreversible loss}} = \Delta p_{\text{debris entrance}} + \Delta p_{\text{debris exit}}$$

Note, optimization of the values for the empirical multipliers (1.95, 3.89) and exponents (0.071, 0.13), and possibly the values of S_{Nukon} and S_{CalSil} will be determined from test data.

Head Loss Modeling

- Porous Medium Compression
 - Hysteresis in pressure drop observed during velocity increases and decreases.
 - Analytical approach
 - First compression during increase to maximum velocity is assumed to be a nonrecoverable, irreversible process.
 - After the first compression the bed is assumed to be elastic with constant compressibility.

Head Loss Modeling

- Compressibility related to void volume.

$$\beta_v = N P_m^{-b} \quad \text{where } b \approx 1, N = \text{material specific parameter}$$

- Therefore, for the first compression:

$$X = X' (P_m / P_m')^{-N} \quad \text{where } X' \text{ void ratio at } P_m' \text{ at start of compression}$$

P_m' mechanical stress at start of compression

$N \approx 0.23$ from LANL Series 6 and PNNL Series 1 tests

- After first compression:

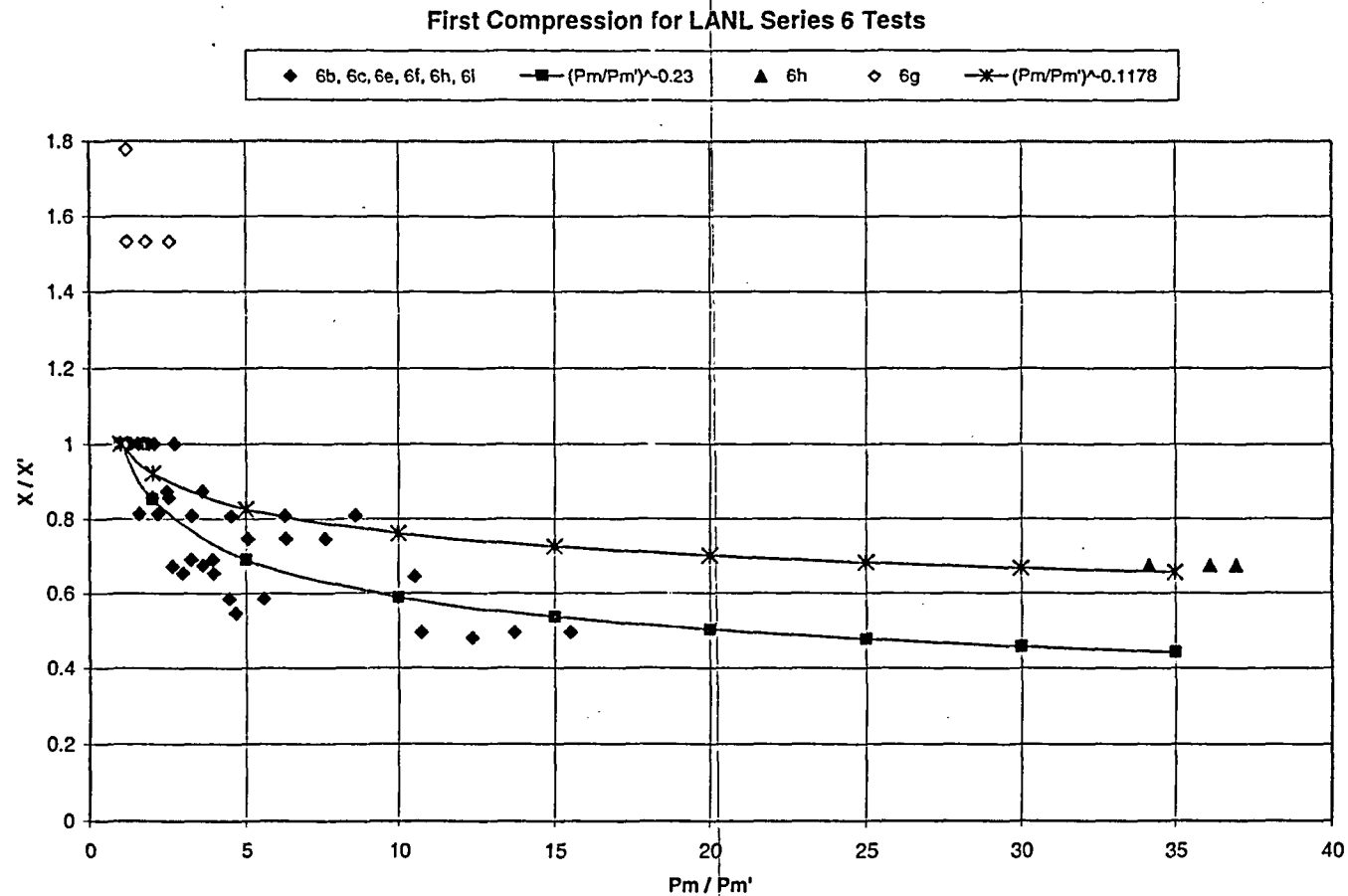
$$\beta_v = N P_{\max}^{-1} \quad \text{where } P_{\max} \text{ highest compressive stress on material}$$

$$X = X(P_{\max}) \exp \left[N - \frac{N P_m}{P_{\max}} \right] \quad \text{where } X(P_{\max}) \text{ void ratio at } P_{\max}$$

$N \approx 0.20$ from PNNL Series 1 tests

Note, the value of N will be updated as new test data becomes available.

Head Loss Modeling



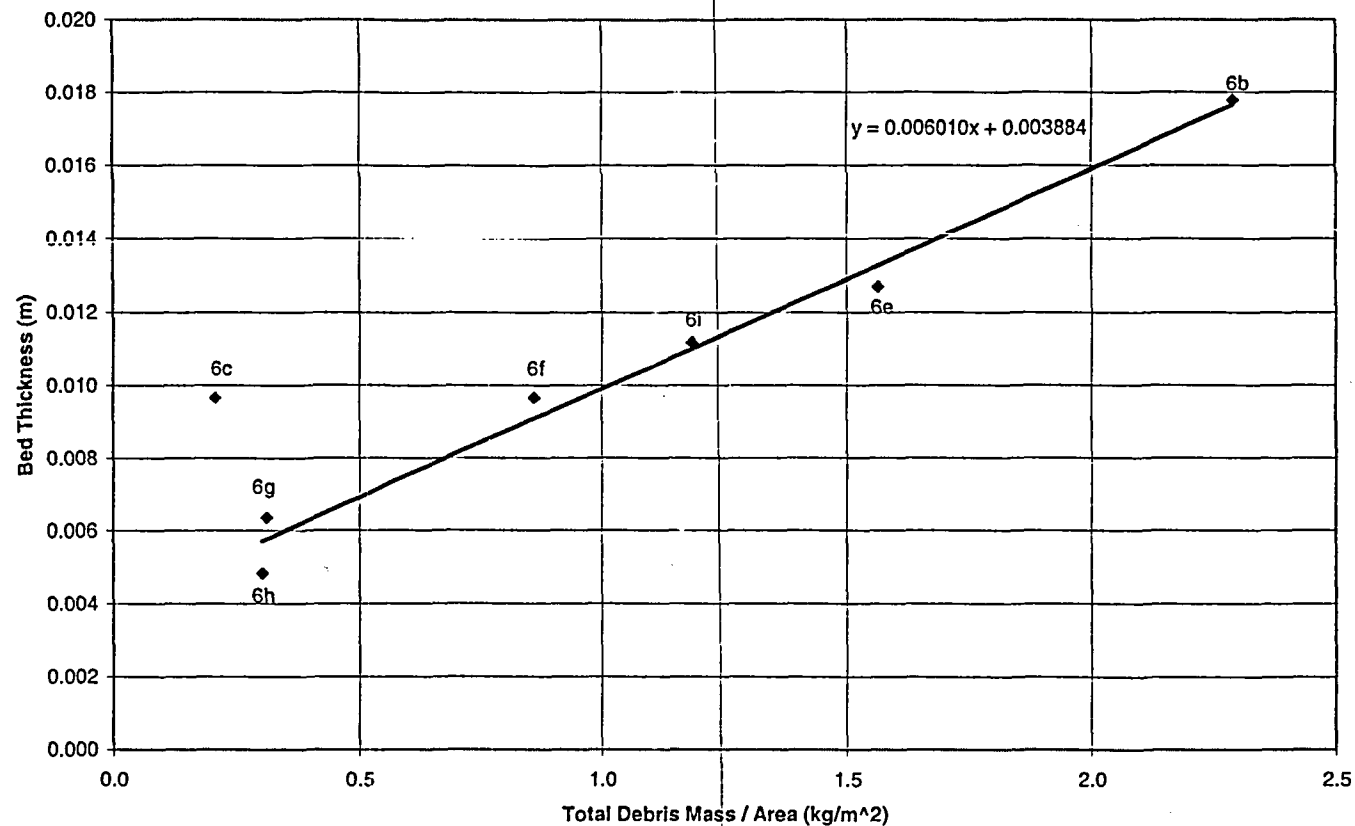
- Using the LANL/UNM test data for bed compression during the first velocity increase, the debris bed void ratio is best fit to the mechanical stress ratio using an exponent of -0.23.

Head Loss Modeling

- The bed thickness at the start of compression must be known in order to use the compression relations.
 - A linear equation for bed thickness versus total debris mass per debris bed area (kg/m^2) at the start of compression is obtained from LANL Series 6 test data at initial approach velocity of 0.03048 m/sec.
 - The equation developed using the PNNL Series 1 test data differs from the above equation.
- The bed thickness relation will be refined as more PNNL test data becomes available.

Head Loss Modeling

Bed Thickness at About 0.03 m/sec Initial Approach Velocity for LANL Series 6 Tests



- The LANL/UNM debris bed thickness at a formation approach velocity of 0.03 m/sec (0.1 ft/sec) indicates a linear relation with total debris mass per flow area.

Head Loss Modeling

- The following table presents preliminary head loss comparisons between
 - PNNL Series 1 test data obtained using a metal screen and
 - Similar LANL/UNM test data obtained using a metal screen.

Head Loss Modeling

Comparison of Head Loss Tests Using a Metal Screen

LANL* Test	Added Nukon kg/m ²	Added CalSil kg/m ²	Estimated Bed CalSil kg/m ²	Bed Thickness [§] inch	Loop Temp °C	PNNL# Test	Added Nukon kg/m ²	Added CalSil kg/m ²	Bed Nukon kg/m ²	Bed CalSil kg/m ²	Bed Thickness inch	Loop Temp °C	Comparison of PNNL and LANL Test Data
						Series 1 Tests							
						051114_SO_0000_L1	0.0	0.0	0.0	0.0	NA	17-24	NA
						051128_SO_0000_L1	0.0	0.0	0.0	0.0	NA	16-19	NA
1a	1.77	0.00	0.00	NA	21	051108_NO_3067_L1 ^{&}	1.65	0.0	1.65	0.00	0.41-0.44 [§]	20-30	$\Delta p_{PNNL} > \Delta p_{LANL}$
						060125_NO_3067_L1 ⁺	1.65	0.0	1.65	0.00	0.30-0.45 [§]	22-26	$\Delta p_{PNNL} > \Delta p_{LANL}$
6b	1.53	0.84	0.83	0.44-0.46	44	051115_NC_4098_L1	1.42	0.78	1.26	0.67	<0.45-51 [§]	21-25	$\Delta p_{PNNL} > \Delta p_{LANL}$
6e	1.07	0.53	0.53	0.31-0.44	54	051117_NC_2776_L1	0.99	0.50	0.99	0.34	0.30-0.33 [§]	21-27	$\Delta p_{PNNL} > \Delta p_{LANL}$
6e2	1.07	0.53	0.53	~0.39	38	051128_NC_2776_L2	0.99	0.50	0.93	0.33	0.19-0.24 [§]	21-27	$\Delta p_{PNNL} > \Delta p_{LANL}$
6f	0.61	0.31	0.30	0.19-0.31	60	051121_NC_1586_L1	0.57	0.28	0.57	0.16	0.20 [§]	16-27	$\Delta p_{PNNL} > \Delta p_{LANL}$
6h	0.23	0.11	0.11	0.13-0.19	44	051110_NC_0595_L1 [^]	0.21	0.11	0.20	0.05	0.08 [*]	21-25	$\Delta p_{PNNL} < \Delta p_{LANL}$
6i	0.84	0.42	0.41	0.25-0.38	60	051123_NC_2181_L1	0.78	0.39	0.78	0.25	0.16-0.28 [§]	22-32	$\Delta p_{PNNL} > \Delta p_{LANL}$

* Pipe id= 11-3/8 inch, Pipe Area = 0.06556 m²

[§] Measured thickness during testing.

[^] Area = 0.01863 m²

[&] Metal/rust particles present in bed.

[§] Measured thickness during testing.

[^] Best estimate bed masses; bed ruptured during retrieval.

⁺ Loop debris present in bed.

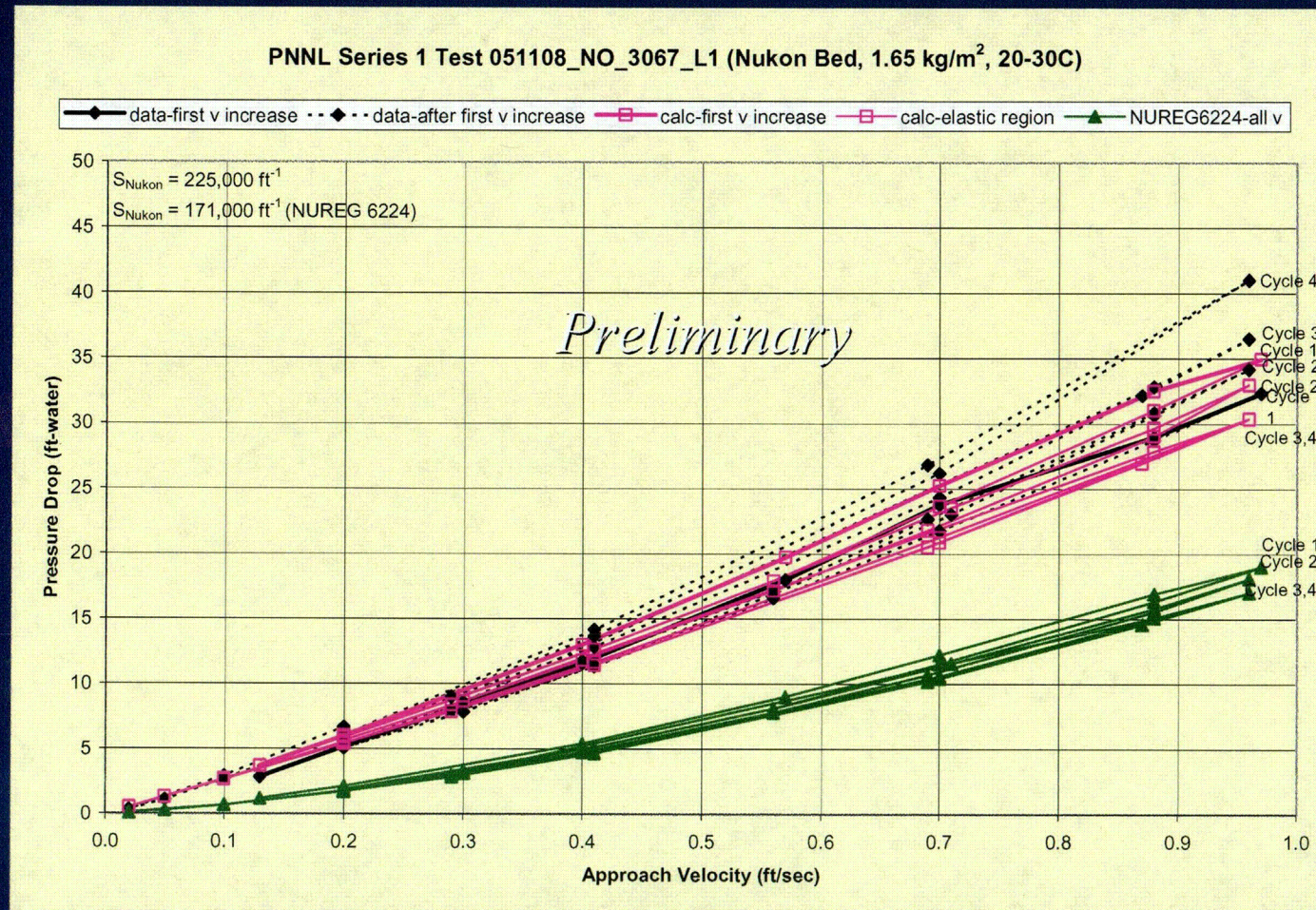
^{*} Thickness measured after bed retrieval.

- Except for test 051110_NC_0595_L1, the head losses measured during the Series 1 testing was larger than the head loss for the similar previous test cases.
- The PNNL debris bed mass measurements indicate that only a fraction of the total CalSil mass added to the test loop is deposited in the debris bed. In contrast, previous tests assume that almost all of the CalSil mass added to the test loop is deposited in the debris bed.

Head Loss Modeling

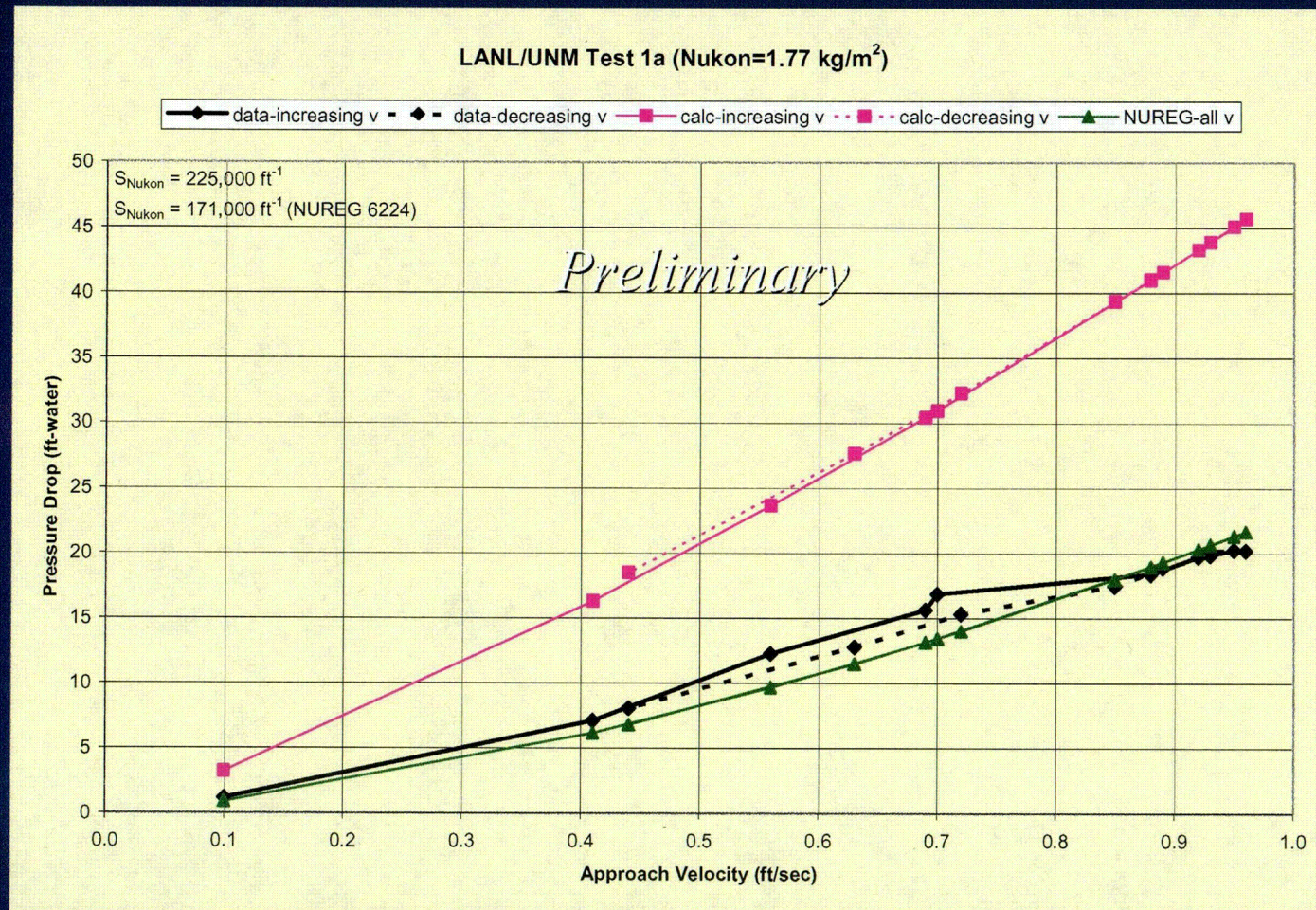
- The following graphs present selected preliminary comparisons for a Nukon debris bed using
 - PNNL Series 1 test data obtained using a metal screen
 - LANL/UNM test data obtained using a metal screen
 - Predictions obtained using the improved one volume head loss model and unoptimized empirical values
 - Predictions using the NUREG/CR-6224 correlation

Head Loss Modeling



- The new unoptimized model predicts pressure drops close to PNNL Series 1 test data.

Head Loss Modeling



- The new unoptimized model predicts pressure drops larger than LANL/UNM test data.

Head Loss Modeling

- Summary of continuing efforts using PNNL test data
 - Use test data to optimize one volume debris bed model.
 - Continue to develop and optimize two control volume debris bed calculational method.
 - Will provide debris concentration and porosity through debris bed.
 - Develop particulate “saturation” condition relation for Nukon/CalSil debris beds.
 - Identify the maximum concentration of CalSil in a specific Nukon bed at which the pressure drop suddenly increases as the bed becomes clogged.